EPA / USGS integrated assessment of Narragansett Bay, & preliminary assessments in lakes and reservoirs.

NWQMC Meeting, Portland Oregon
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Presentation Outline

- Brief Background on Ecosystem Services Research Program (ESRP) which could make use of a number of planned NMN components.

- Combining information from NMN (USGS / NAWQA: SPARROW models, & EPA monitoring networks)
  - Narragansett Bay. Nitrogen Load Response Relationships
  - Northeastern Lakes. Trophic Status & Water Clarity

- Future Opportunities for further integration of: NMN & EPA ORD Ecosystem Services Research Program components
  - Northeast: ESRP Nr Case Studies (Lakes, Reservoirs & Estuaries)
  - Southeast: ESRP Place Based Studies (Estuaries)
  - Midwest: ESRP Place Based Study
  - Nationally: Mapping “ecosystem services”
Background: EPA ORD Research Program

ORD Water Quality research:
continues to support of a regulatory perspective (e.g. criteria): “protecting the environment from the activities of people”

ORD Ecological research & new emphasis:
More benefits oriented “protecting the environment for people”.

ESRP will help advance the knowledge base for evaluating ecosystem services & benefits trade-offs, and more effectively provide this information to decision makers.
Yes the ESRP has a website:

Website: [http://epa.gov/ord/esrp/](http://epa.gov/ord/esrp/)
Pollutant Specific Research focuses on Nitrogen

Nitrogen Research


Issue

Reactive nitrogen is a pollutant of national and global significance because its use is widespread and dramatically increasing.

Nitrogen is a particularly intricate pollutant. While it is one of life’s essential nutrient elements, providing a valuable service in the production of food and fiber for human use, it also can degrade ecosystems and the services they provide. As a result, it has the potential to impact human health and wellbeing.

Nitrogen is released during combustion by motor vehicles and industry and by the application of fertilizers. This nitrogen is then taken up and stored in rivers, estuaries and other water bodies by a range of biological processes.

The consequences to ecosystem services from this sequestered nitrogen are not fully understood. A new generation of observation and assessment tools are needed to inform decision makers about the trade-offs between releases of nitrogen, the use of ecosystems to sequester the element, and the effects of nitrogen-containing pollutants on human well-being. The insights gained will provide critical information for use by EPA, states, and partners to meet requirements under the Clean Water and Clean Air Acts.

Science Objective

The Ecosystem Services Research Program (ESRP) in EPA’s Office of Research and Development (ORD) applies the expertise and knowledge of its scientists to study and assess reactive nitrogen. The research will improve understanding of how nitrogen, a regulated pollutant, impacts ecosystem services in both positive and negative ways.

The objectives of this research are to:

- Identify nitrogen-responding ecosystems and services
- Assess ecosystems and services affected by changing nitrogen loads
- Quantify the response of ecosystem services to alternative nitrogen loadings from multiple sources
- Determine loads or exposure to nitrogen that conserve, enhance or restore the delivery of ecosystem services
- Determine the value of changes in ecosystem services affected by changes in nitrogen loads

What are the levels of N, above or below which ecosystem services are enhanced, maintained, and/or degraded and how do we manage to balance these trade-offs?

Research will involve collaboration with other Federal Agencies, States, & NGOs
Collaborate efforts that could involved the components of the National Monitoring Network:

- NOAA (related to coastal ecosystem services)
- USGS NAWQA & regional SPARROW modeling
- States, NGOs, etc.

1st: Big Picture: Global / National / Regional Scales
2nd: State and local scales: stakeholder interactions
Big Picture: phytoplankton, zooplankton, fish.
Monitoring Large Marine Ecosystems of the World:

Primary Productivity in the Ocean

Satellite Oceanography

The Color-enhanced image (provided by Rutgers University) depicts a shaded gradient of primary productivity from a high of 450g/Cm2 in red to <45g/Cm2 in purple.
Spatial and temporal variations in marine phytoplankton can affect ecosystem services.

Documented using satellites, e.g. SeaWiFS Remote Sensing (RS)

- Remote sensing of chlorophyll from space holds great promise for improved monitoring of aquatic primary productivity and plant biomass.
- SeaWiFS satellite currently provides global 1.1 km coverage with two-day return frequency.

From Smith and Madden 2007 ERF presentation
Monitoring Data

Aquatic Landscape

Terrestrial Landscape

Predicted Flux, Concentration and Yield: Origin and Fate

NLCD 1K

SPARROW (SPAtially Referenced Regression on Watershed Attributes)
Higher Spatial resolution. Regional Perspectives:
e.g. Northeast and Southeast SPARROW: MRB1 & 2 using NHD Plus (1:100k)

NAWQA Surface-Water Regions
Zoom in for more local view of Narragansett Bay
Local Perspective: Narragansett Bay and Nitrogen Controls

NMN Monitoring & Modeling Components to Support Local Decision Making

- **Monitoring**
  - Synoptic (Satellite Remote Sensing NOAA/NMFS – *but not in Narr. Bay*)
  - Probabilistic (National Coastal Assessment)
  - Moored Instrumentation (*DO Buoys / presently with NOAA funding*)
  - Targeted Sampling (e.g. past efforts of DO SWAT team)
  - Hyperspectral Remote Sensing from Aircraft (*better RS algorithms*)

- **Nitrogen Mass Balance Modeling**
  - New England SPARROW model for TN loading
  - Estuarine TN mass balance calculations (Dettmann)

Water Quality Monitoring Network components in Narragansett Bay

- probability survey data
- moored instrumentation (another type of remote sensing)
- hyperspectral monitoring from aircraft (*not discussed*)

Used to
- Characterize the problem
- Diagnose Causes
- Diagnostic Interactions
- and Forecast
National Coastal Assessment: Regional Characterization
Probabilistic sampling design / Summer 2000.
Narragansett Bay

Temporal variability in surface and bottom DO studies using automated time-series measurement systems.

Dana Kester et al,
Detailed diagnostic studies at fixed station network

Narragansett & Mt Hope Bay: Automated Instrumentation at 12 sites
sensors 0.5 m below the surface and 1.0 m above the bottom:
T, S, O₂, Chl Fluorescence, & Water level

University of Rhode Island, Graduate School of Oceanography (stations 1 thru 6)
RI DEM
Roger Williams Univ.,
University of Mass (Boston and Dartmouth)
Mass. Coastal Zone Management Office.
Chap. 3 Report Highlight: Highlight on Narragansett Bay

Influence of tidal range variations on stratification in the upper Bay

Region of De-stratification

Full

New

Full

M

M

M

Region of Surface Blooms and Subsurface Hypoxia

1st

3rd

1st

3rd

Qtr

Neap

Qtr

Neap

Date -- 2002

Kester -- URI GSO
Time Series measurements
document events and processes that link physical & biological conditions

Targeted Sampling for low DO on August 6, 5 days after the minimum neap tide on August 1st

Findings
In bottom water:
- Chronic DO Criterion exceeded for 10 days after July 26th
- Acute DO Criterion exceeded for 5 days after Aug 1st neap tide.
Findings:
Exceeded chronic criterion for DO in stratified water south of Cape Cod.
Forecast:
Dissolved Oxygen in Narragansett Bay
Summer of 2003

Events & information triggered local action

H$_2$S Belching out of bay, discoloring houses
Water Quality Monitoring
Network components:
3) Estuarine, and
4) Riverine (SPARROW)
Nutrient Models
The Estuary Nitrogen Model.  

\[ \frac{dN}{dt} = L_{\text{land}} + L_{\text{sea}} - E - \alpha N \]

Assumptions:
Model deals with long-term (e.g. annual or multi-year averages).

Approximate steady state at scale of yearly cycle, i.e.

\[ \frac{dN}{dt} = 0 \]
Summary of Data Requirements of the Estuary Nitrogen Model

Annual Loads of Total Nitrogen to Estuary from:
- Watershed
- Atmosphere
- Point sources

Average Annual Freshwater Residence Time ($\tau$)

Estuary Volume

Background Nitrogen Concentration from Transport Across Seaward Boundary ($[N_{\text{seal}}]$)
Estimated TN Input to Narragansett Bay from Rivers & Streams
(NE SPARROW Model)

Sakonnet River excluded from calculations.
## TN Loading to Narragansett Bay

<table>
<thead>
<tr>
<th>Source</th>
<th>kg N y⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sparrow (30 tributaries)</td>
<td>6,227,261</td>
</tr>
<tr>
<td>Nixon et al. (1995)</td>
<td>6,120,928</td>
</tr>
</tbody>
</table>

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<tr>
<th>Source</th>
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</tr>
</thead>
<tbody>
<tr>
<td>TN loading from SPARROW</td>
<td>6,227,261</td>
</tr>
<tr>
<td>Direct Atmospheric Deposition*</td>
<td>420,201</td>
</tr>
<tr>
<td>Sewage Treatment Plants*</td>
<td>2,563,226</td>
</tr>
<tr>
<td>Total TN Loading</td>
<td>9,210,688</td>
</tr>
</tbody>
</table>

*(Nixon et al., 1995)*

Riverine TN loading to Narragansett Bay from New England SPARROW Model is 68% of total.
Point Sources

About 70% of the TN loadings to the bay were estimated to be from point sources

- 28% directly into the bay
- 42% from upstream point sources
  (SPARROW model data)
Understanding Nitrogen sources and Effects in Narragansett Bay

- Can be related to management goals.

- Monitoring information supports management decisions by the State of Rhode Island, & EPA Region 1 to require use of tertiary treatment to reduce nitrogen loading.

- Approach can be generalized for other estuaries.

- Need to account for varying estuarine sensitivity to nitrogen loading.
Generalized Approach / Presented by Dick Smith at ERF 2007

Chlorophyll: Regression Equation for four classes of estuaries *
River Dominated, Coastal Embayment, Coastal Lagoon, & Fjord

\[ C = \sum_{k=1}^{K} E_k \left[ b_k + b_{kN} \ln\left\{ \frac{(Nt/V)}{(1/(1+at))} \right\} + b_{kT}T \right] + E_Rb_R + \varepsilon \]

Where:
- \( C \) = Chlorophyll-a concentration (mg m\(^{-3}\))
- \( E_k, E_R \) = indicator variables (0/1) for class (4) and region (2)
- \( N \) = total nitrogen loading rate (g d\(^{-1}\))
- \( t \) = freshwater residence time (d)
- \( V \) = estuarine volume
- \( a \) = loss rate due to denitrification and settling ( = 0.001 d\(^{-1}\))
- \( T \) = temperature (C)
- \( b_k, b_{kN}, b_{kT}, b_R \) = regression coefficients for effect of class, class-specific effects of N-loading and temperature, and region.
- \( \varepsilon \) = regression error

*Modification of equation derived in Dettmann, 2001

**Caveat:** \( C \) was estimated using SeaWiffs Ocean Color, but SeaWiffs estimates of [Chlorophyll] are biased on high side.
Presentation Outline

➢ Combining information from monitoring networks
  o Narragansett Bay
  o **Northeastern Lakes**

➢ Larger Context: EPA ORD Ecosystem Service Research Program
  o EPA/ORD: ESRP: Role & Goal
  o Organizational Chart
  o Mapping, Monitoring, Modeling, Nitrogen, Wetlands, Decision Support
  o Place Based & Regional Case Studies (lakes and estuaries)

➢ **Opportunities:**
  o Northeast ESRP Nr Case Studies
  o Southeast ESRP Place Based Studies
  o Midwest ESRP Place Based Study
  o Nationally
Northeast Lakes & Ecosystem Services

NEAEB 2009

➢ EPA OW National Aquatic Resource Survey
(National Lakes Survey 2007)

➢ Using draft Northeast SPARROW model (MRB-1) results
Ecosystem Services Approach is Benefits Based

What can be lost?

http://nhlakes.org/docs/Economic-Study-Phase-IV-Brochure.pdf
What are the present conditions? Nation’s Lakes Assessment (NLA) for unbiased estimates of conditions in lakes and reservoirs (stratified sample, unequal weighting by lake size)
Moving from descriptive TSI statistics, to modeling [Chl-a] based on [TN], [TP], etc.

Bayesian Approach

From:

Separate regression coefficients for inference regarding similarities and differences between each of 14 ecoregions, and between the two water-body types, lakes/ponds and reservoirs.
Using Lamon & Qian (2008) regression equations & NLA data

Statistical Ecology Associates LLC
578 Pecan St., Canyon Lake, TX
78133830-964-3155
eclamon@gmail.com

National SPARROW
Fertilizer
Share of Incremental N Flux

G.E. Schwarz, R.A. Smith, and R.B. Alexander
EPA ORD research on nitrogen attenuation by streams & wetlands

National SPARROW

Fertilizer Share of Incremental Flux

Atmospheric Deposition Share of Incremental Flux

G.E. Schwarz, R.A. Smith, and R.B. Alexander
How ecosystem service benefits in lakes and reservoirs may be change in water quality, water quantity and timing of flow
## Trophic Status Indicators & possible ecological effects

\[
\text{TSI(TP)} = 14.42 \ln(\text{TP}) + 4.15 \quad \text{or} \quad \text{TSI(CHL)} = 9.81 \ln(\text{CHL}) + 30.6
\]

Using Carlson 1977 Trophic Status Index for Northern Temperate Lakes

<table>
<thead>
<tr>
<th>Trophic State</th>
<th>Possible Ecological Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligo-</td>
<td>Clear water; Salmonid fisheries dominate</td>
</tr>
<tr>
<td>Meso-</td>
<td>Anoxia in shallow lakes; Salmonid fisheries in deep lakes only</td>
</tr>
<tr>
<td>Eutrophic</td>
<td>Anoxia; turbidity; taste and odor problems; loss of salmonids</td>
</tr>
<tr>
<td>Hypertrophic</td>
<td>Fish Kills; Dense algae</td>
</tr>
<tr>
<td></td>
<td>Transparency loss; blue-green algae; algal scum; macrophytes; odor</td>
</tr>
<tr>
<td></td>
<td>Anoxia; macrophyte problems; loss of Salmonids.</td>
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A quick descriptive look at trophic status variations by ecoregion.
Trophic Status Indices for Chlorophyll and Phosphorous (National Lakes Survey)

Reference Lines: Green - Oligotrophy, Red - Eutrophy, Purple - Hypereutrophy. Dashed = 1:1 Line

```r
> xyplot(TSI_Chl ~ TSI_TP | WSA_9_NM, groups = TURB_CAT50)
```

TURB < 50 NTU  🟠
TURB > 50 NTU  🟡
Probabilistic Snap Shot vs Nutrient Flux Based Perspectives

Chl-a, [TN], [TP].

Preliminary comparison with draft Northeast SPARROW model results

Lakes & Reservoirs represented as polygons ("areas" with "hydraulic loads")

Not Represented:
- Average lake depth
- Residence Time
NLA data vs draft Northeast Sparrow Model results

NLA TN vs. Sparrow CN

Sparrow Observed Log Nitrogen Load Concentration
\[ r^2 = 0.4092 \]

NLA TP vs. Sparrow CP_out

Sparrow Observed Log Phosphorus Outflow Concentration
\[ r^2 = 0.3547 \]
Preliminary regressions by Bryan Milstead using NLA & SPARROW (MRB-1)
Legend

MRB1_WBIDLakes

Est_TP

- TP < 10 ug / l
- TP < 25 ug / l
- TP < 50 ug / l
- TP > 50 ug / l

Preliminary regressions by Bryan Milstead using NLA & SPARROW (MRB-1)
Legend

MRB1_WBIDLakes
Est_CHLA

- ChlA < 2 ug / l
- ChlA < 7 ug / l
- ChlA < 30 ug / l
- ChlA > 30 ug / l

Preliminary regressions by Bryan Milstead using NLA & SPARROW (MRB-1)

Est_CHlA=10**(1.0241163*Est_logTP)+(.0031017*Est_NPRatio)-.4976196
Observed Total Nitrogen (NLA) vs. SPARROW MRB-1 estimated Total Nitrogen (“Tuned”)

Sparrow Model Alone

Modified Vollenwieder Eq.

\[
\log_{10}(CN)/(1+(0.2 \times \text{HRT}^{0.21}))
\]
Observed Total Phosphorus (NLS 2007) vs. SPARROW MRB-1 estimated Total Phosphorus

Sparrow Model Alone

Modified Vollenwieder Eq.

Sparrow Observed Log Phosphorus Outflow Concentration r-squared = 0.3547

Sparrow Predicted Log Total Phosphorus r-squared = 0.5131
Next steps: Moving from descriptive statistics to modeling Chl-a and ecosystem services.

Refine predictions of variations in:

- Chlorophyll-a / Trophic Status, based on TN & TP, e.g. by nutrient regions.
- Water Clarity

Ecosystem Service Trade-Off implications

- Related to lake and reservoir Trophic Status
- Related to Water Clarity
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  which could make use of a number of planned NMN components.

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  - Northeastern Lakes. Trophic Status & Water Clarity

- Future Opportunities for Integration: NMN & EPA ORD

  - Ecosystem Services Research Program components
  - Northeast ESRP Nr Case Studies (Lakes & Estuaries)
  - Southeast ESRP Place Based Studies (Estuaries)
  - Midwest ESRP Place Based Study (Lakes)
  - Nationally
Regional Nutrient SPARROW models now being developed for 2002 conditions

Major River Basin study areas 1 through 5, and 7 underway
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  o Northeast ESRP Nr Case Studies (Lakes & Estuaries)
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  o Nationally National Mapping of Ecosystem Services
EPA / USGS integrated assessment of Narragansett Bay, & preliminary assessments in lakes and reservoirs.

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