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/

Pollutant Specific Research focuses on Nitrogen

U.S. ENVIRONMENTAL PROTECTION AGENCY

Ecosystem Services Research Program

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  - Pesticides/Toxics
  - Water Quality

Nitrogen Research

US EPA: Research Focuses On Nitrogen And Its Impact On Ecosystem Services (2 pp, 681KB, About PDF)

Topics
- Community Research Projects
- Coastal Carolinas Research
- Coral Reef Research
- Midwest Research
- Nitrogen Research
- Southwest Research
- Tampa Bay Research
- Wetlands Research
- Willamette River Valley 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.

itrogen 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

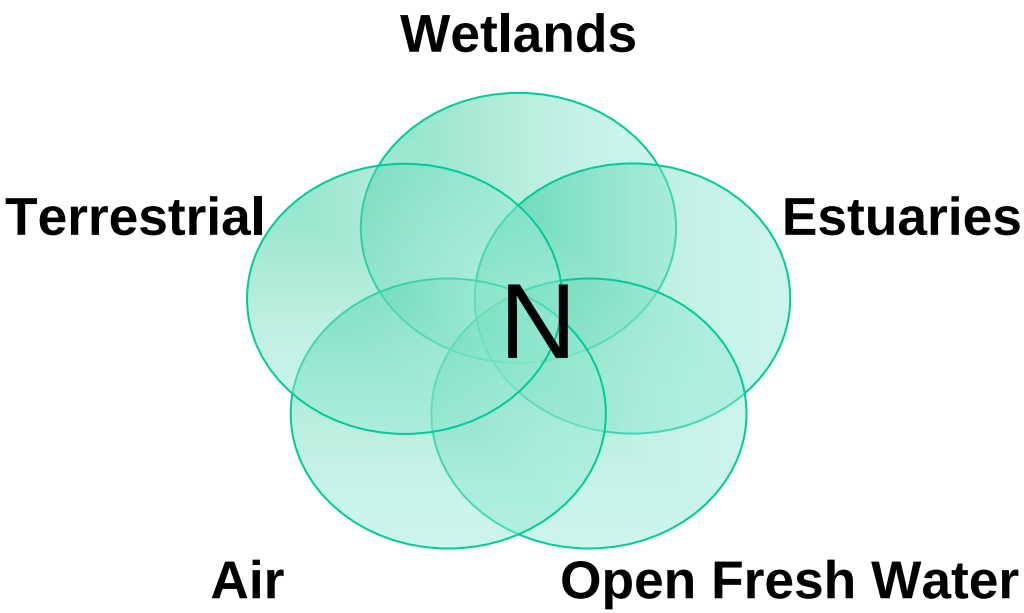
The Ecosystem Services Research Program (ESRP) in EPA's Office of Research and Development (ORD) applies the expertise and knowledge of its scientists to study and assess reactive nitrogen. The research will improve understanding of how nitrogen, a regulated pollutant, impacts ecosystem services in both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

http://epa.gov/ord/esrp/quick-finder/nitrogen-research.htm

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.

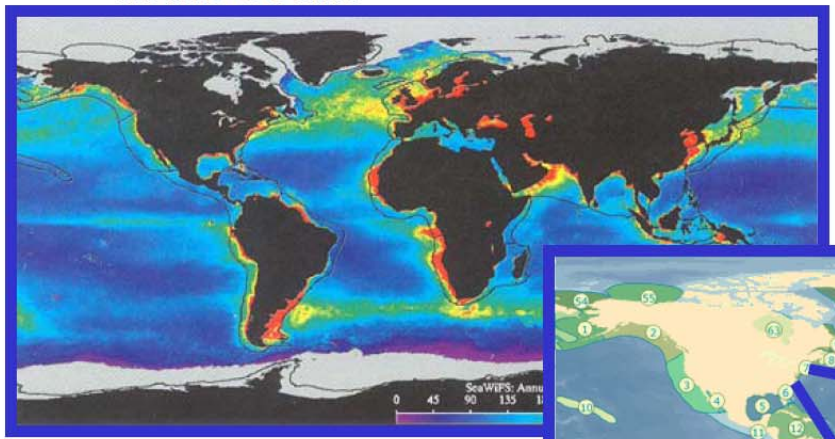
1st: Big Picture: Global / National / Regional Scales

2nd: State and local scales: stakeholder interactions

Big Picture: phytoplankton, zooplankton, fish. Monitoring Large Marine Ecosystems of the World:

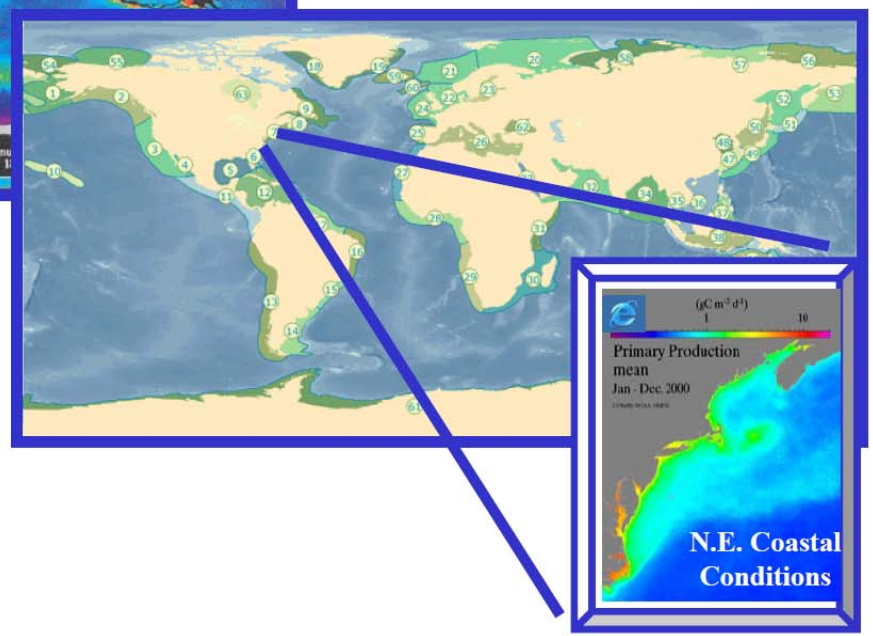
Satellite Oceanography

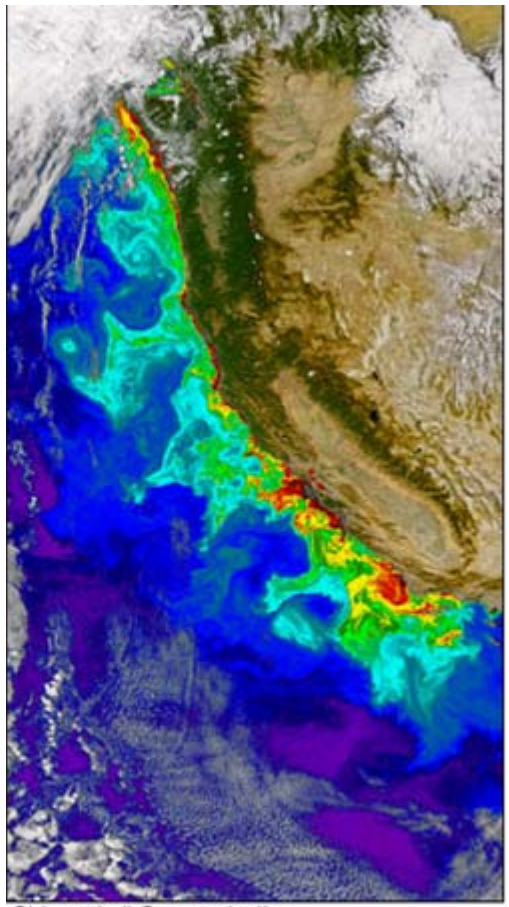
Primary Productivity in the Ocean



The Color-inhanced 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.

UN Atlas of the Ocean: Interactive Map





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.

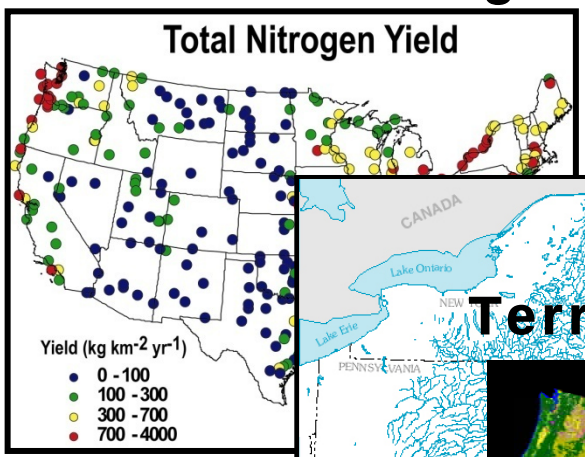
From Smith and Madden 2007 ERF presentation

National SPARROW models

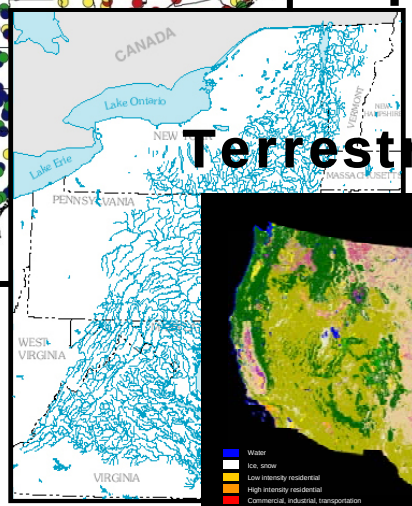
SPARROW (SPAtially Referenced Regression on Watershed Attributes)

National Perspectives from Smith et al., *Water Resour. Res.*, 1997.

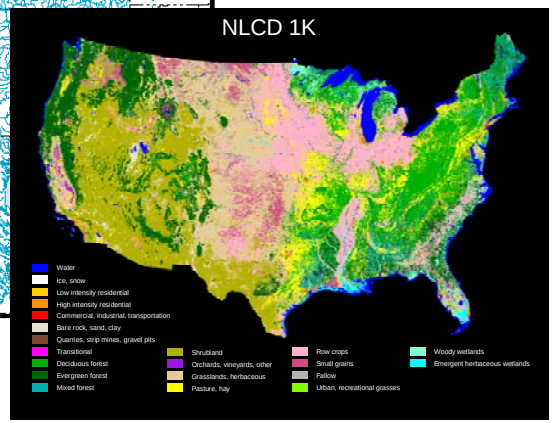
Monitoring Data



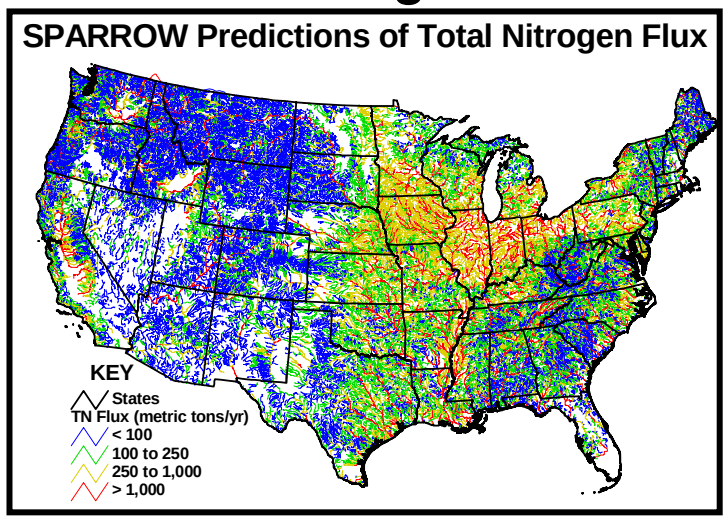
Aquatic Landscape



Terrestrial Landscape



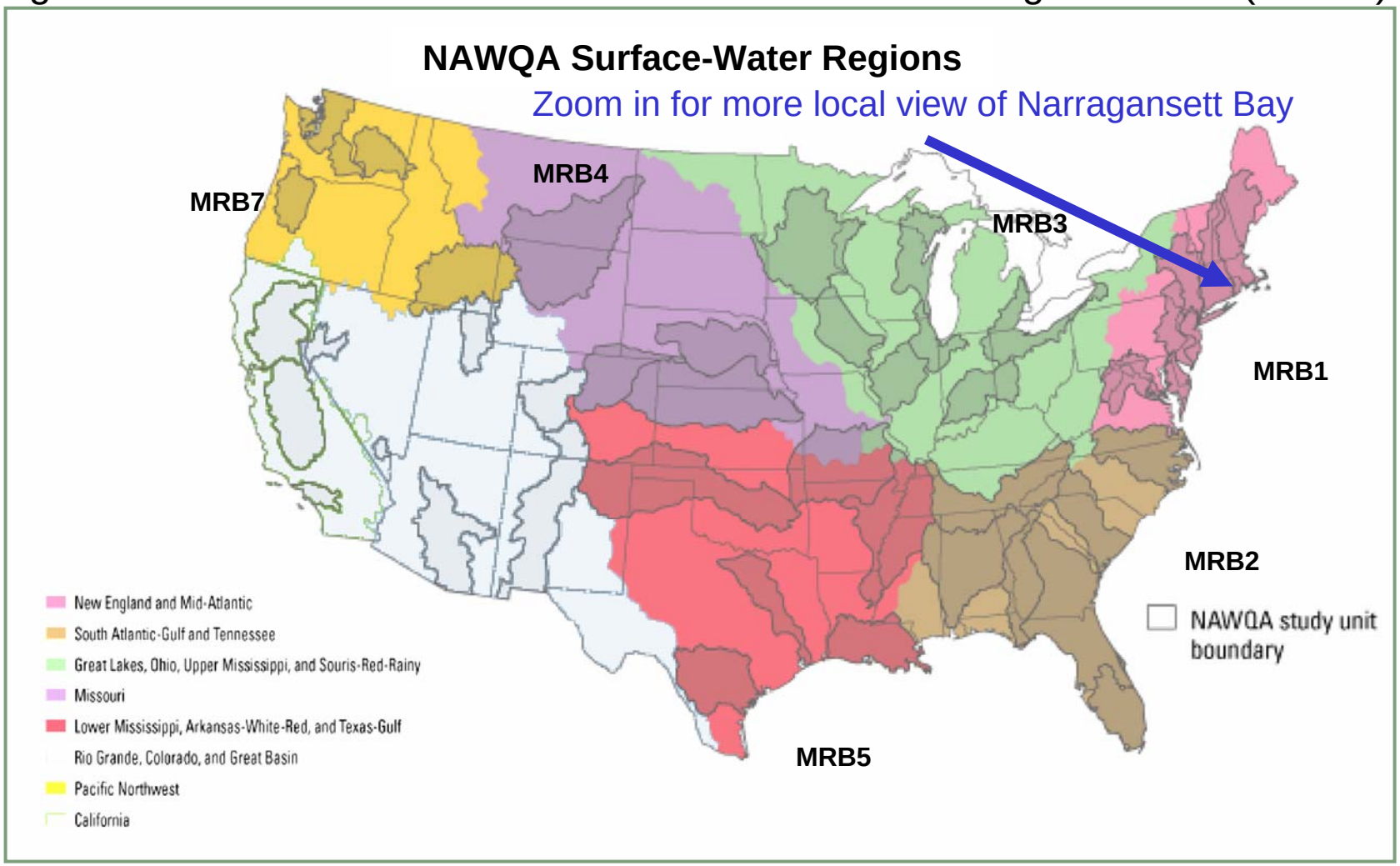
Predicted Flux, Concentration and Yield: Origin and Fate



Regional SPARROW models for Major River Basins

Higher Spatial resolution. Regional Perspectives:

e.g. Northeast and Southeast SPARROW: MRB1 & 2 using NHD Plus (1:100k)



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)

http://www.epa.gov/emap2/html/pubs/docs/groupdocs/symposia/symp2007/abstracts/Moore.pdf

Water Quality Monitoring Network components in Narragansett Bay

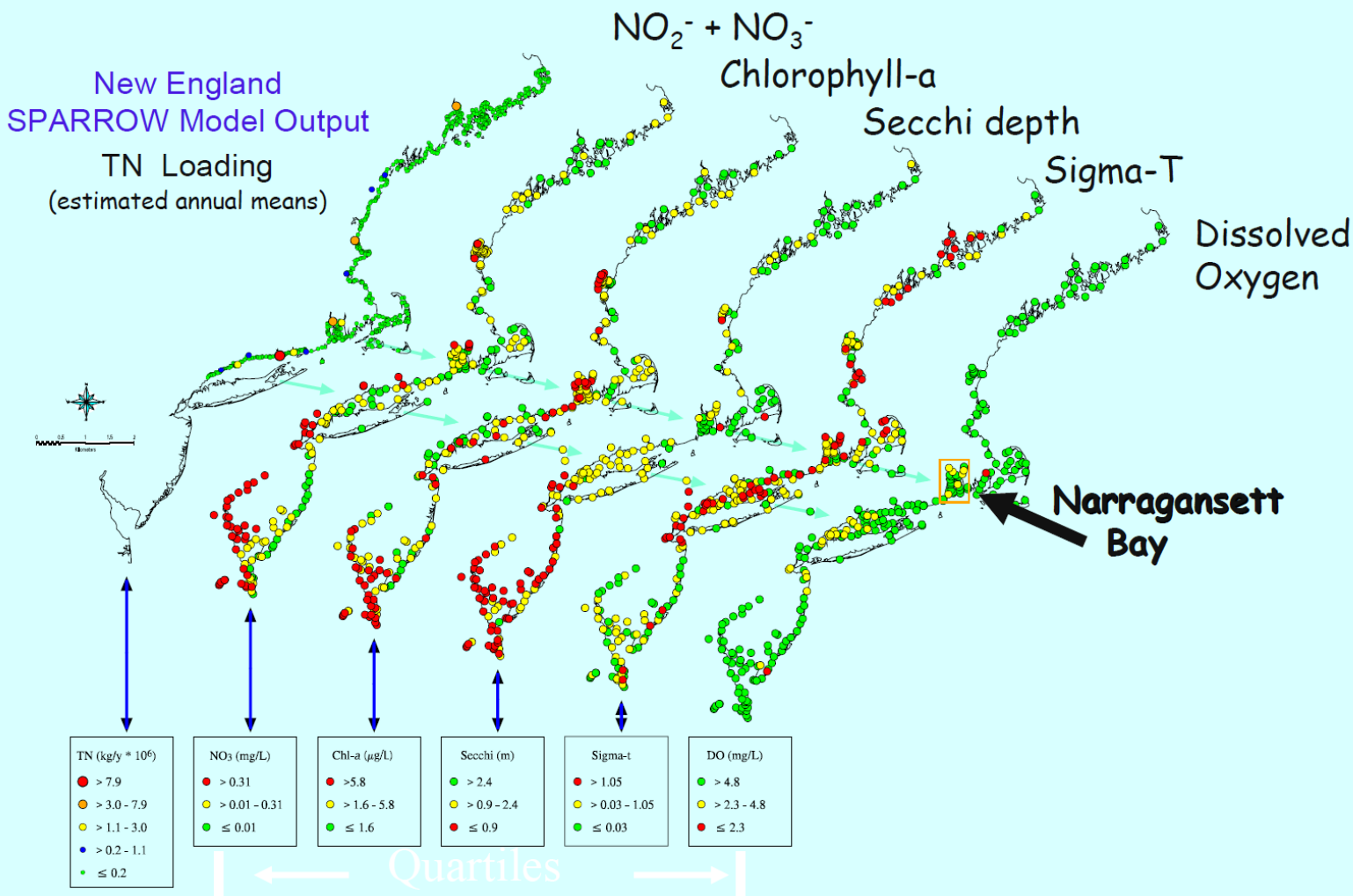
- probability survey data
- moored instrumentation (another type of remote sensing)
- hyperspectral monitoring from aircraft *(not discussed)*

Used to

- ➢ Characterize the problem
- ➢ Diagnose Causes
- ➢ Diagnostic Interactions
- ➢ and Forecast

National Coastal Assessment: Regional Characterization

Probabilistic sampling design / Summer 2000.

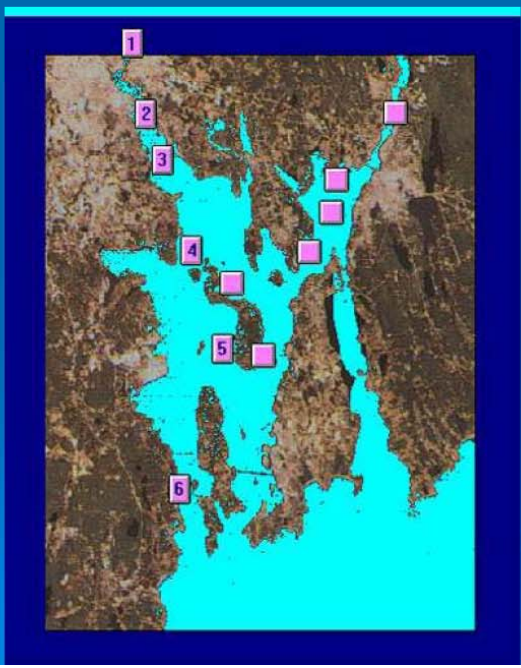


Narragansett Bay

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, O_2 , Chl Fluorescence, & Water level



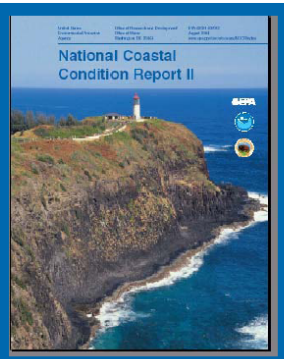
University of Rhode Island, Graduate School of Oceanography (stations 1 thru 6)

RI DEM

Roger Williams Univ.,

University of Mass
(Boston and Dartmouth)

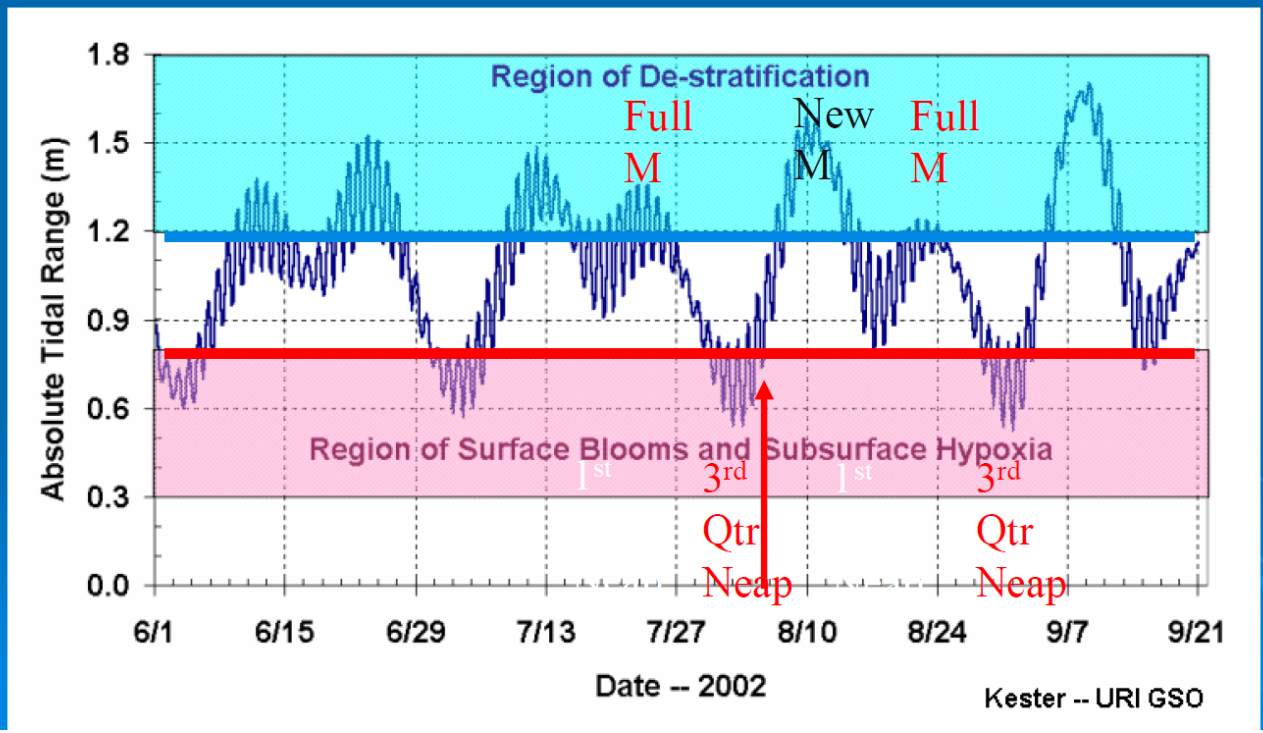
Mass. Coastal Zone Management Office.



2004

Chap. 3 Report Highlight:
Highlight on Narragansett Bay

Influence of tidal range variations on stratification in the upper Bay

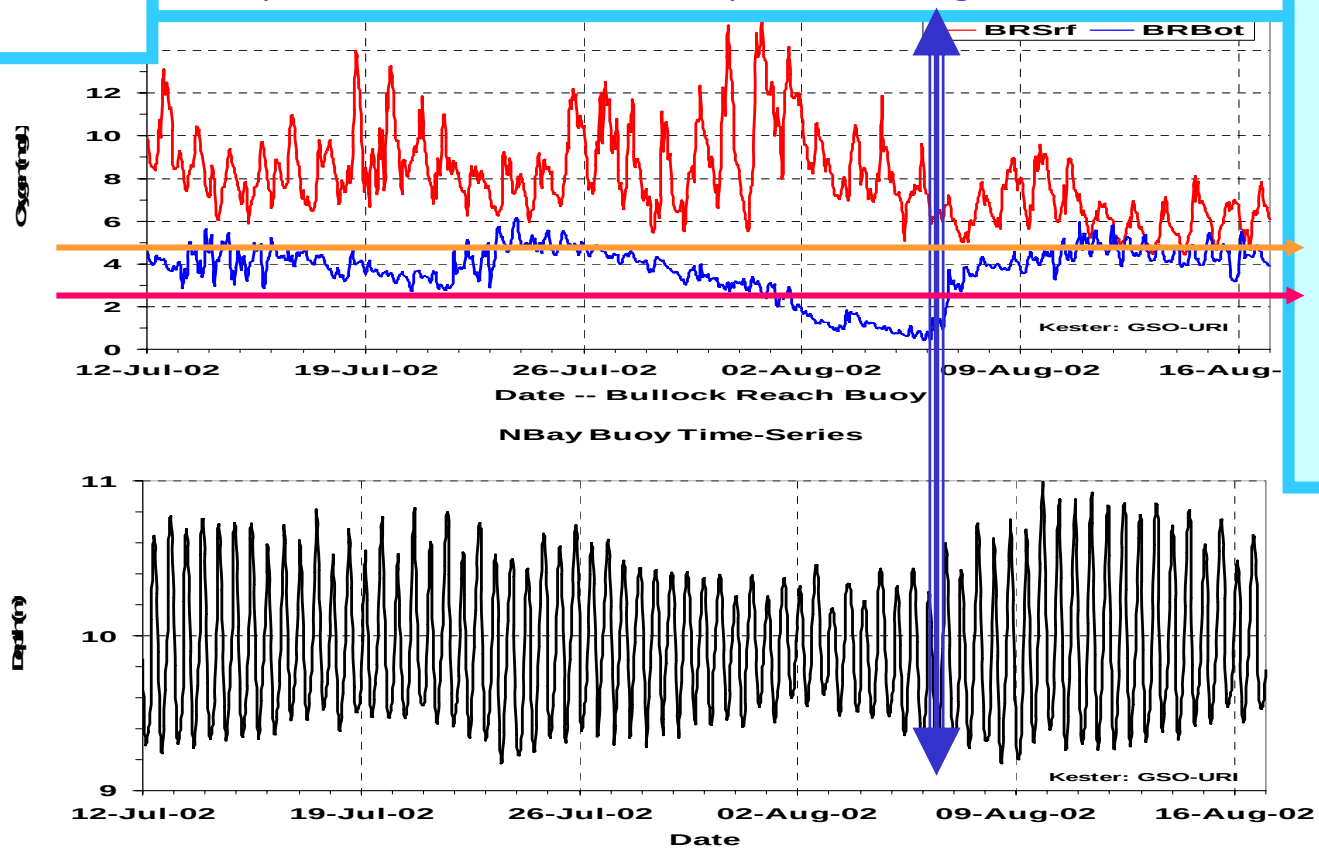


Time Series measurements

document events and processesthat link physical & biological conditions

Data from moored buoys

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



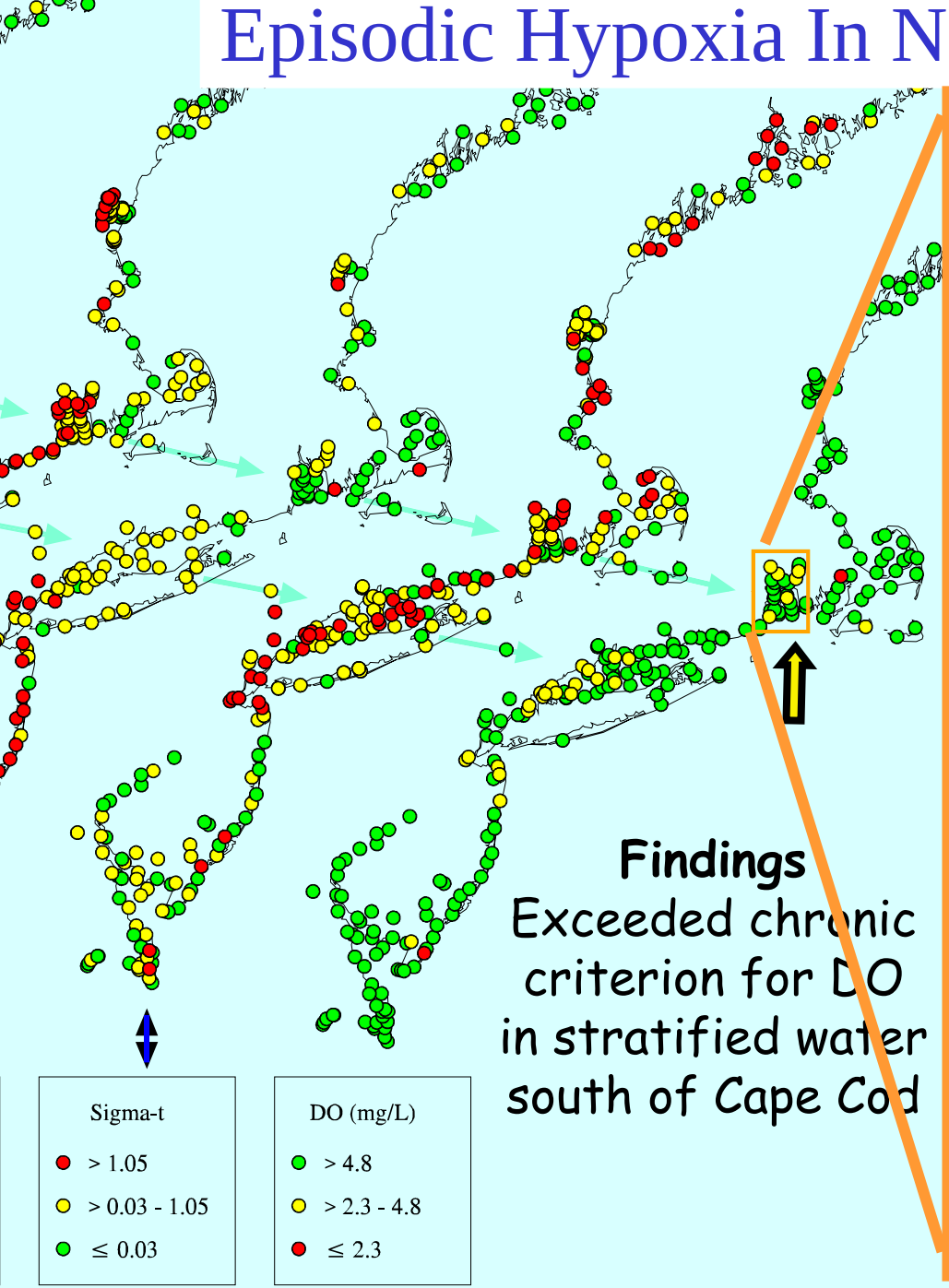
Findings

In bottom water:

Chronic DO Criterion exceeded for 10 days after July 26th

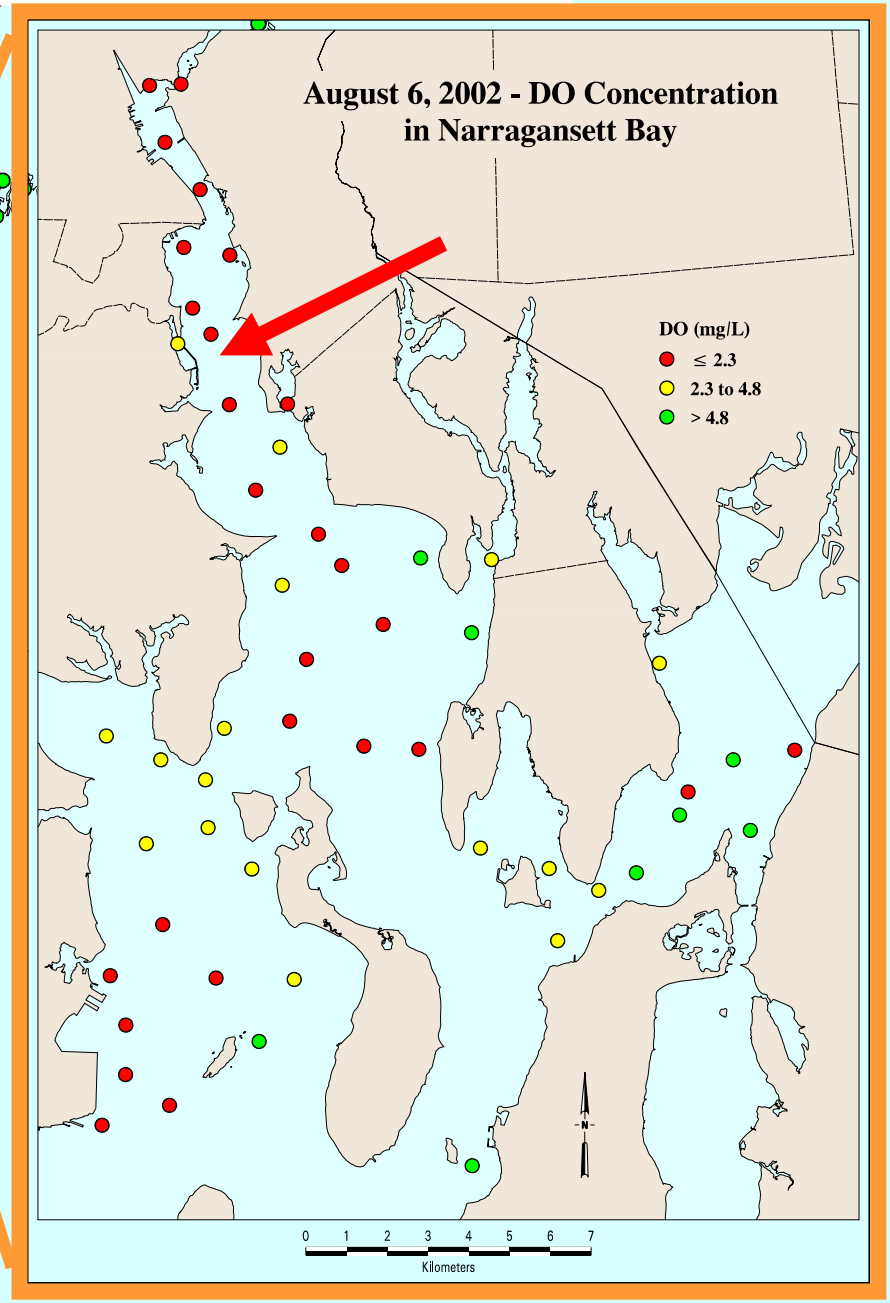
Acute DO Criterion exceeded for 5 days after Aug 1st neap tide.

Episodic Hypoxia In Narragansett Bay



Findings

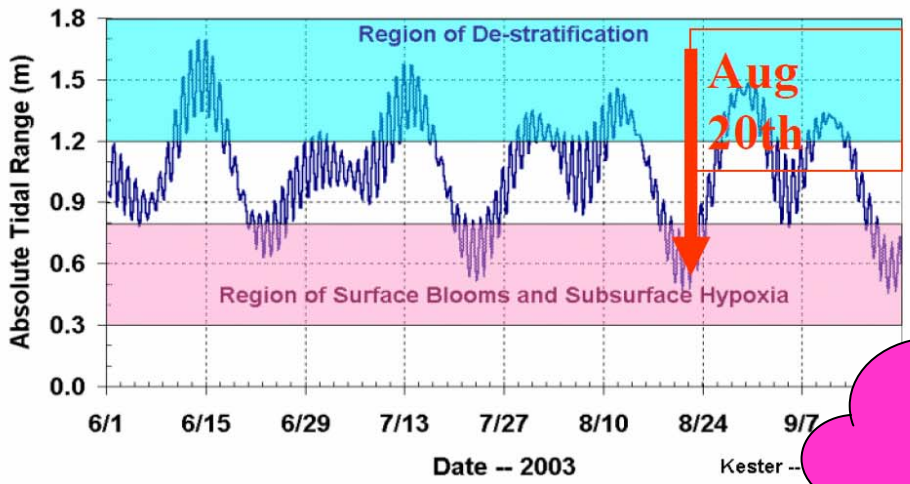
Exceeded chronic criterion for DO in stratified water south of Cape Cod



➢Forecast:

Dissolved Oxygen in Narragansett Bay

Summer of 2003



H_2S Belching out of bay, discoloring houses

Events & information triggered local action

Water Quality Monitoring Network components:

3) Estuarine, and
4) Riverine (SPARROW)

Nutrient Models

The Estuary Nitrogen Model.

Dettmann (2001)

N Loading

$$\frac{dN}{dt} = L_{land} + L_{sea} - E - \alpha N$$

Export Internal Losses

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

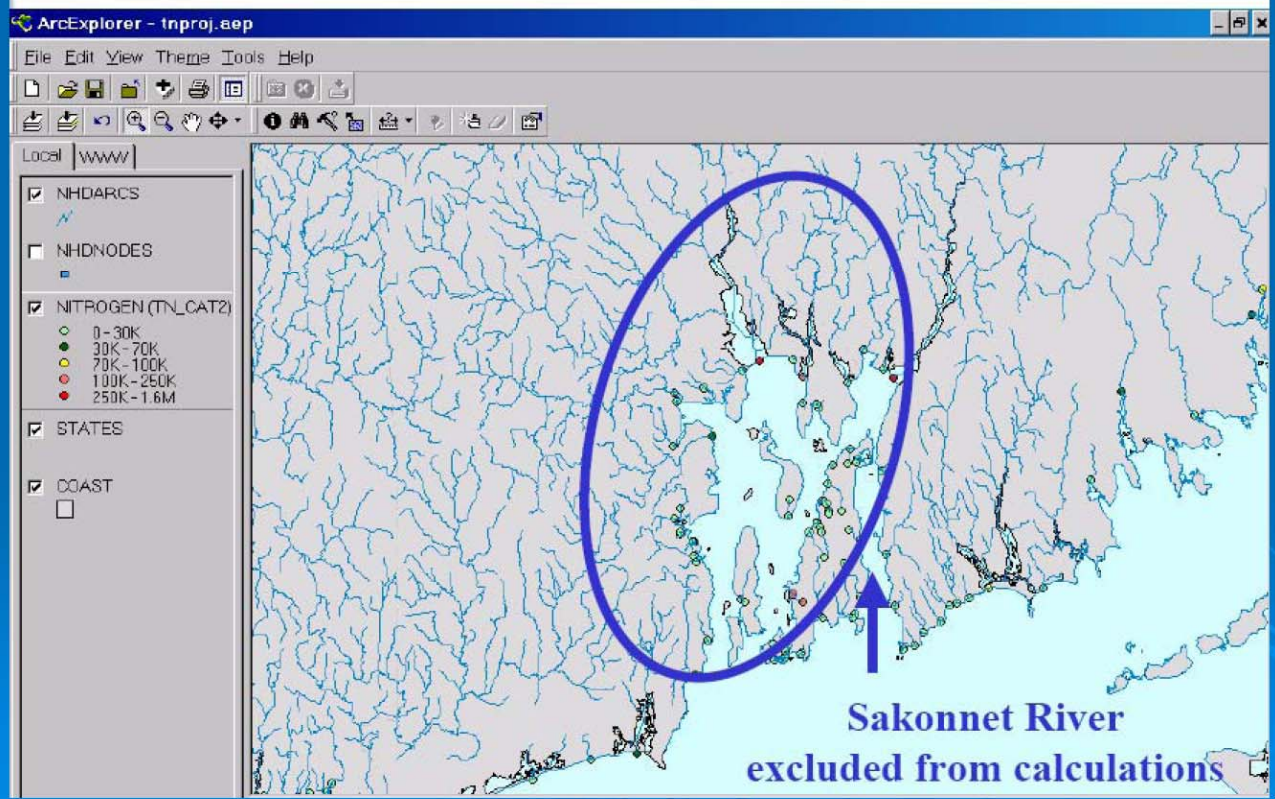
Average Annual Freshwater Residence Time (τ)

Estuary Volume

Background Nitrogen Concentration from Transport Across Seaward Boundary ($[N_{sea}]$)

Estimated TN Input to Narragansett Bay from Rivers & Streams

(NE SPARROW Model)



TN Loading to Narragansett Bay

	kg N y^{-1}
Sparrow (30 tributaries)	6,227,261
Nixon et al. (1995)	6,120,928

TN loading from SPARROW	6,227,261
Direct Atmospheric Deposition*	420,201
Sewage Treatment Plants*	2,563,226
Total TN Loading	9,210,688

*(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

$$C = \sum_{k=1 \text{ to } K} E_k \left[b_k + b_{kN} \ln\{[(Nt/V)][1/(1+at)]\} + b_{kT} T \right] + E_R b_R + \varepsilon$$

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.

ε = 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
  - Narragansett Bay
  - **Northeastern Lakes**

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

- Opportunities:
  - Northeast — ESRP Nr Case Studies
  - Southeast — ESRP Place Based Studies
  - Midwest — ESRP Place Based Study
  - Nationally

Northeast Lakes & Ecosystem Services

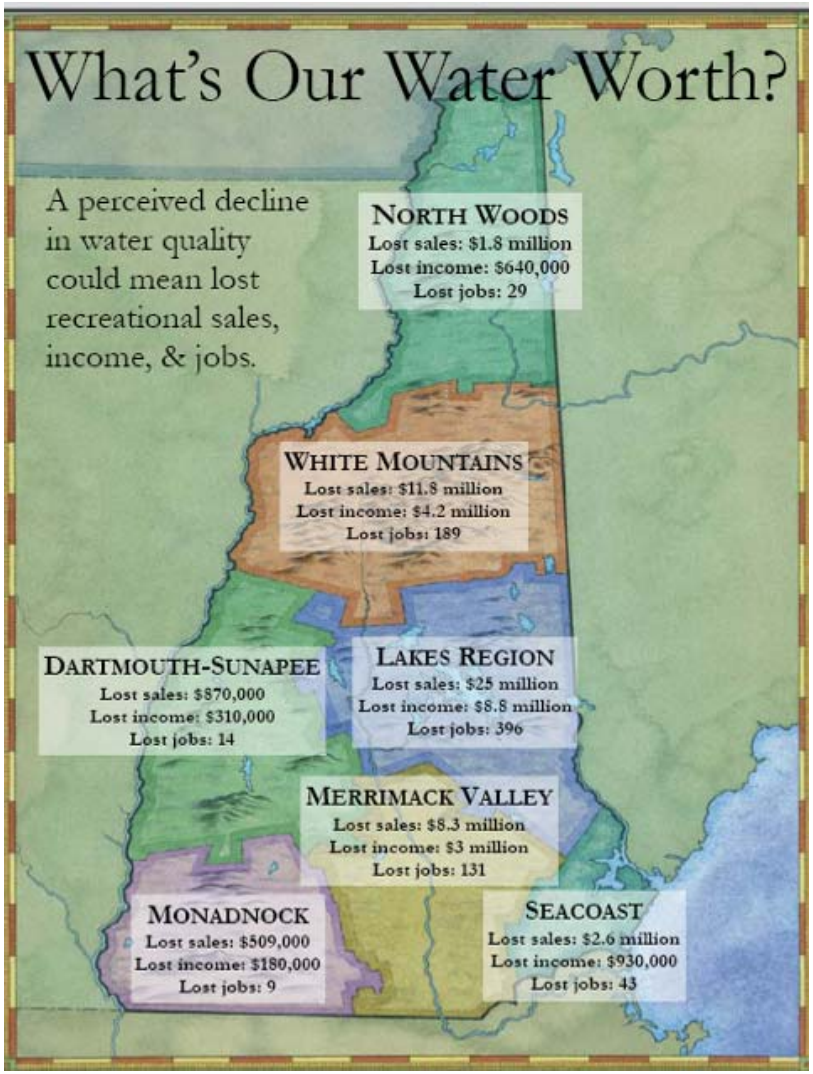
- The Benefits of Protecting and Restoring Northeastern Lakes: an Ecosystem Services Perspective. Brian Milstead.

  NEAEB 2009

  http://www.epa.gov/region1/neaeb2009/pdfs/20_4_Milstead_NEAEB_20090319.pdf
  http://www.epa.gov/region1/neaeb2009/pdfs/21_4_NEAEB2009_Walker.pdf

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

- Using draft Northeast SPARROW model (MRB-1) results



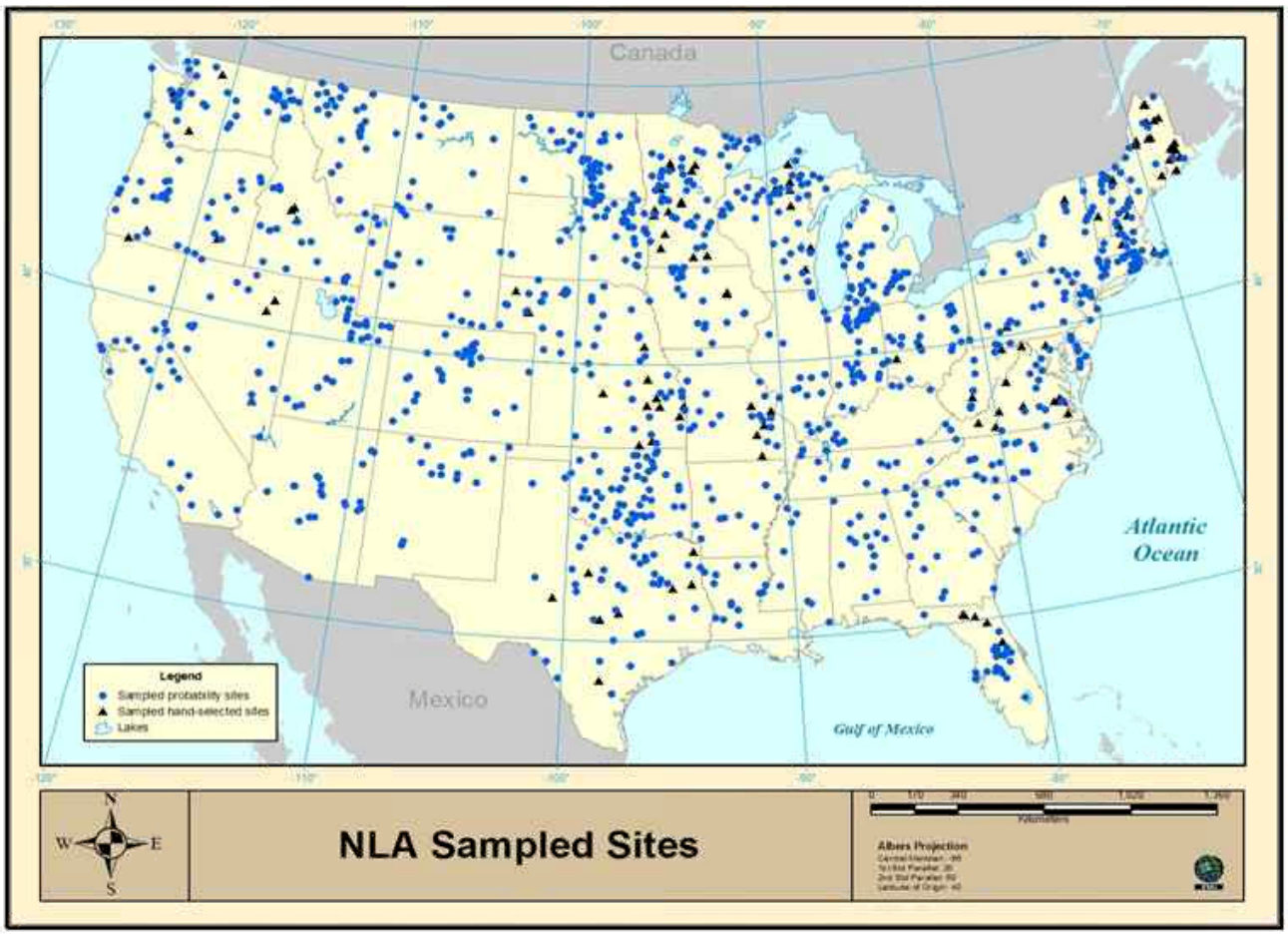
Ecosystem Services Approach is Benefits Based

What can be lost?

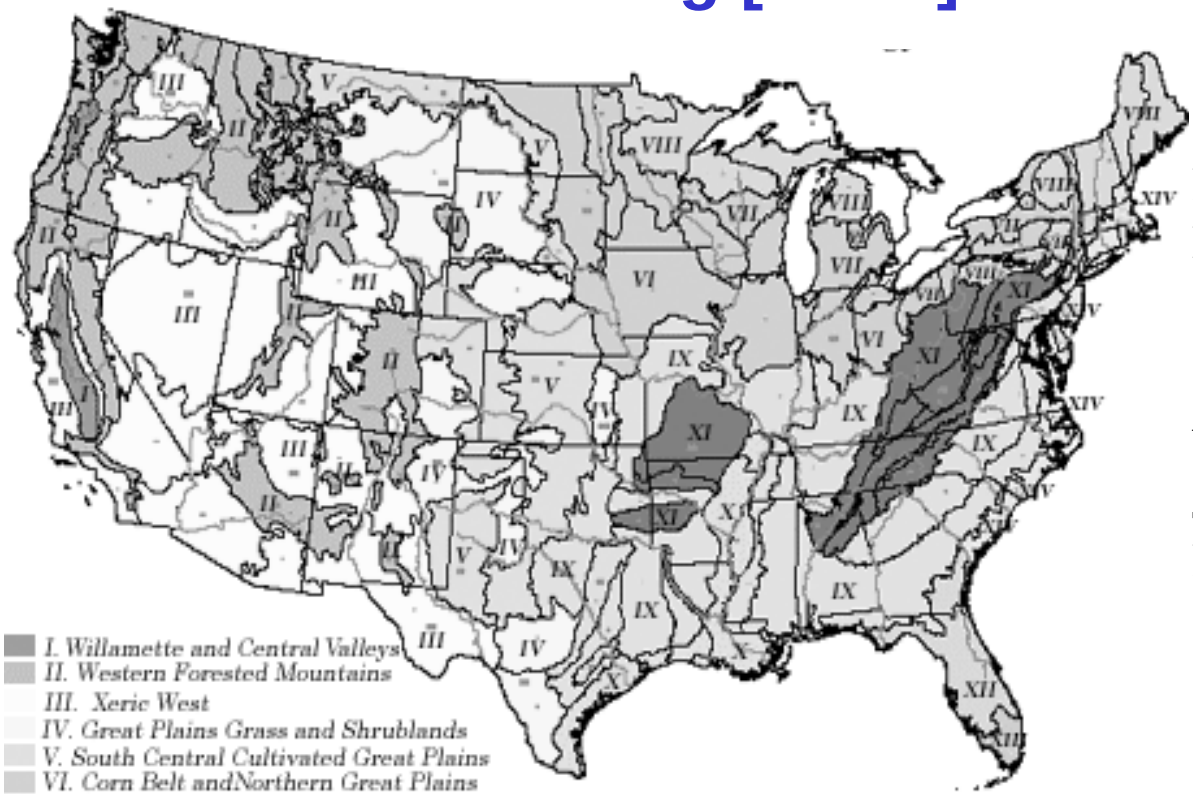
http://nhlakes.org/docs/Economic-Study-Phase-IV-Brochure.pdf

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

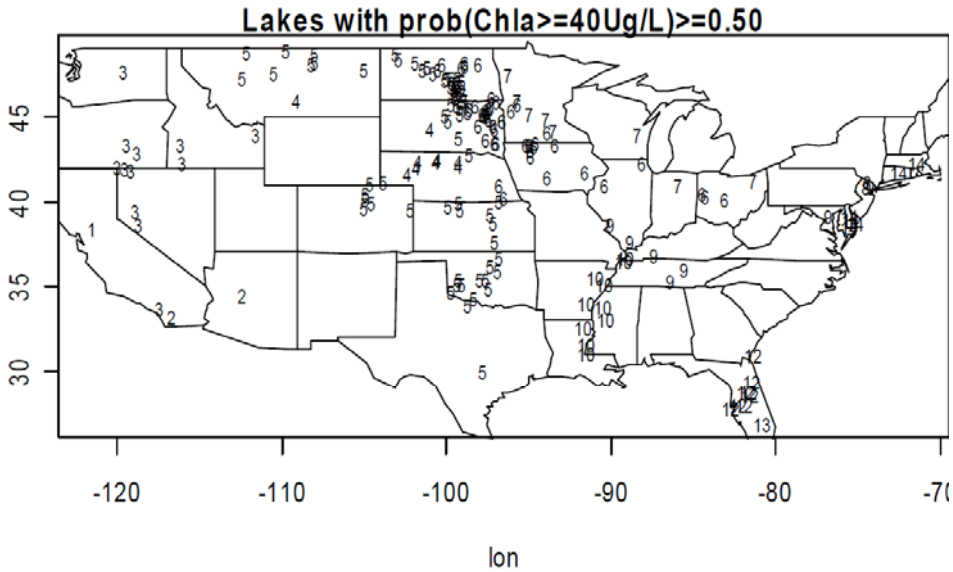
From:
Lamon III, E. Conrad and Song S. Qian, 2008. Regional Scale Stressor-Response Models in Aquatic Ecosystems.

Journal of the American Water Resources Association (JAWRA) 44(3):771-781.

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.

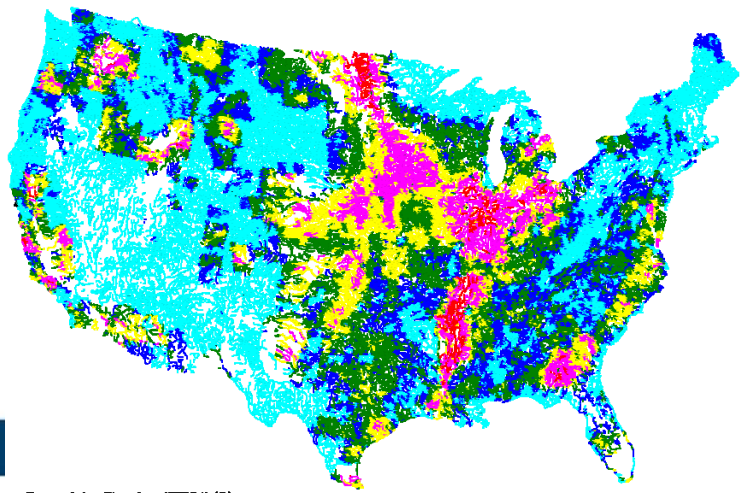
Using Lamon & Qian (2008) regression equations & NLA data

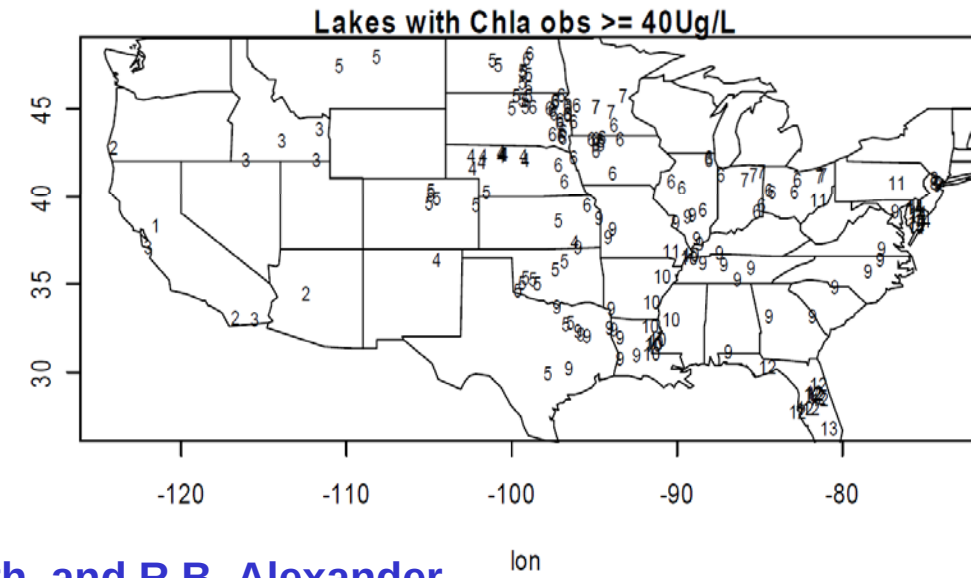
Statistical Ecology Associates LLC578
Pecan St., Canyon Lake, TX
78133830-964-3155
eclamon@gmail.com



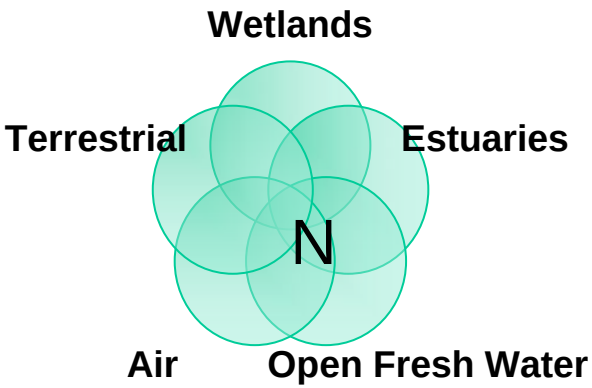
National SPARROW

Fertilizer
Share of Incremental N Flux





G.E. Schwarz, R.A. Smith, and R.B. Alexander

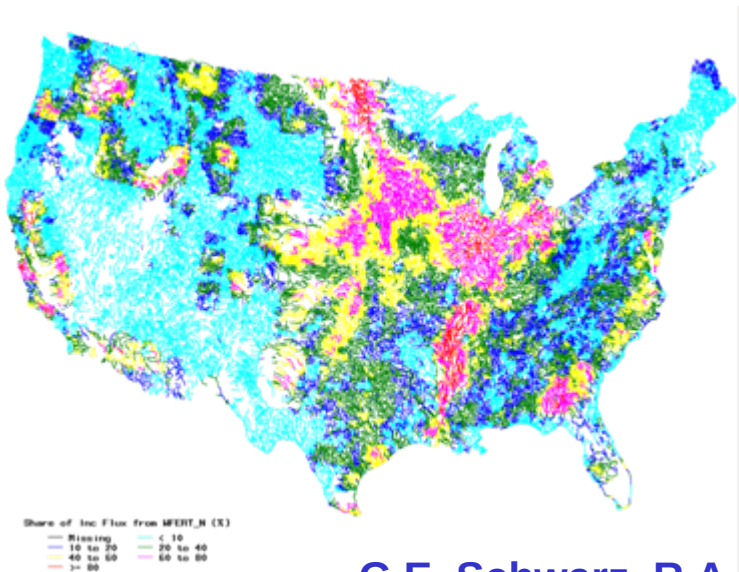


EPA ORD research on nitrogen attenuation by streams & wetlands

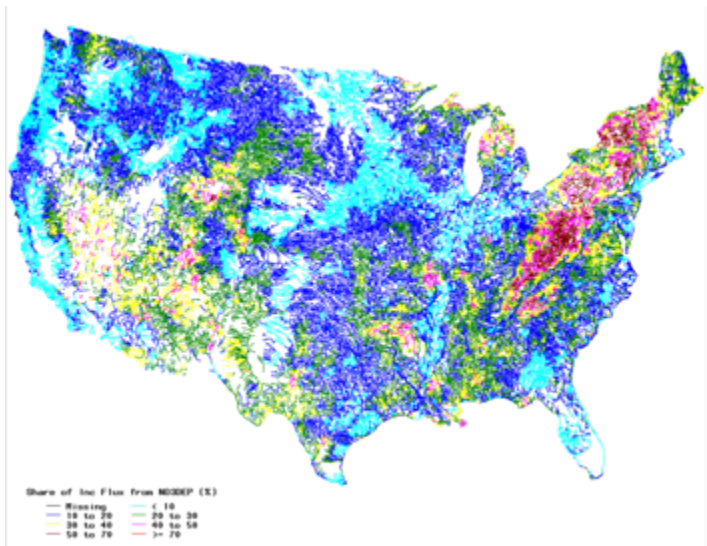
USGS science for a changing world

National SPARROW

Fertilizer
Share of Incremental Flux

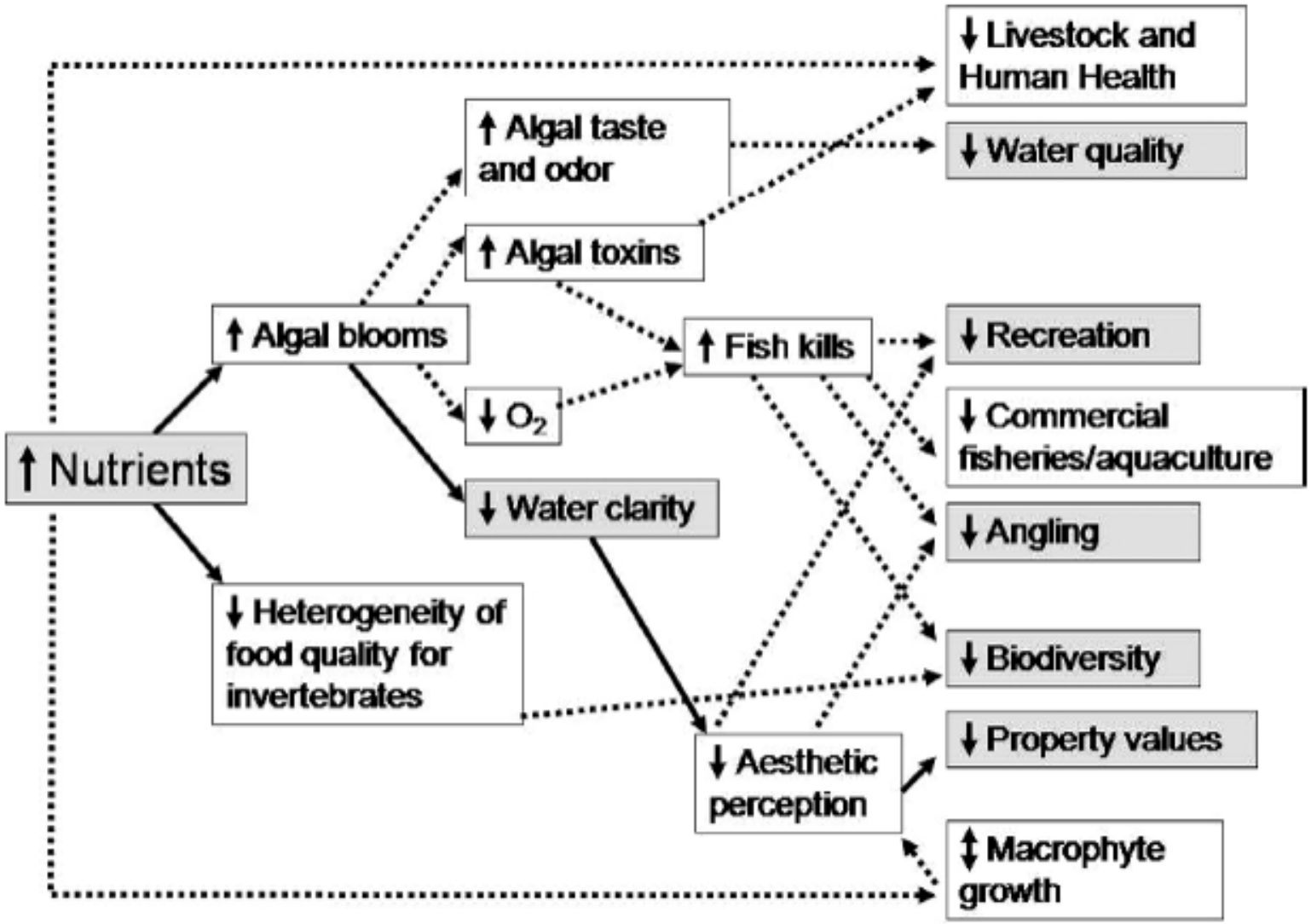


Atmospheric Deposition
Share of Incremental Flux



G.E. Schwarz, R.A. Smith, and R.B. Alexander

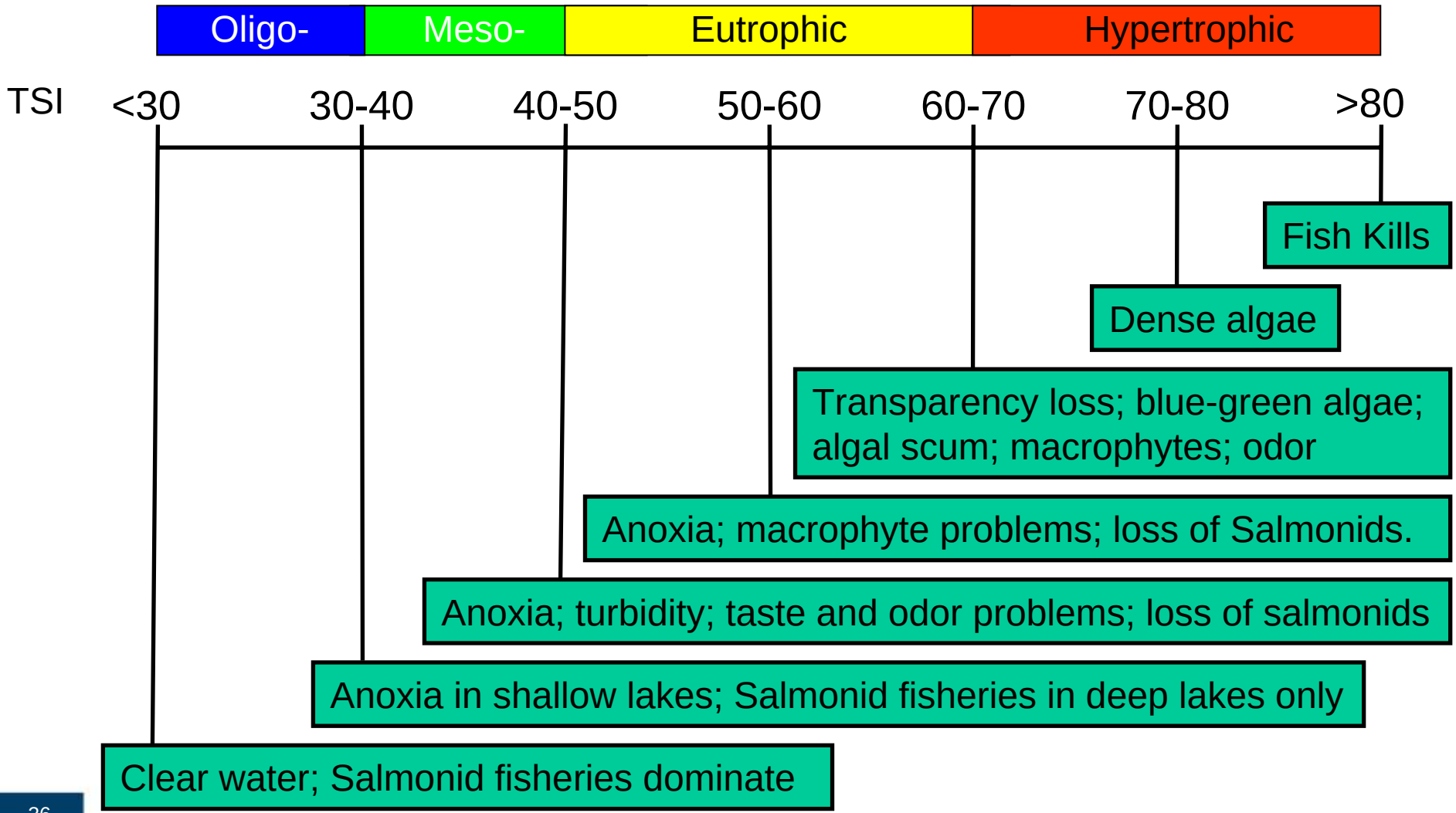
How ecosystem service benefits in lakes and reservoirs may be change in water quality, water quantity and timing of flow



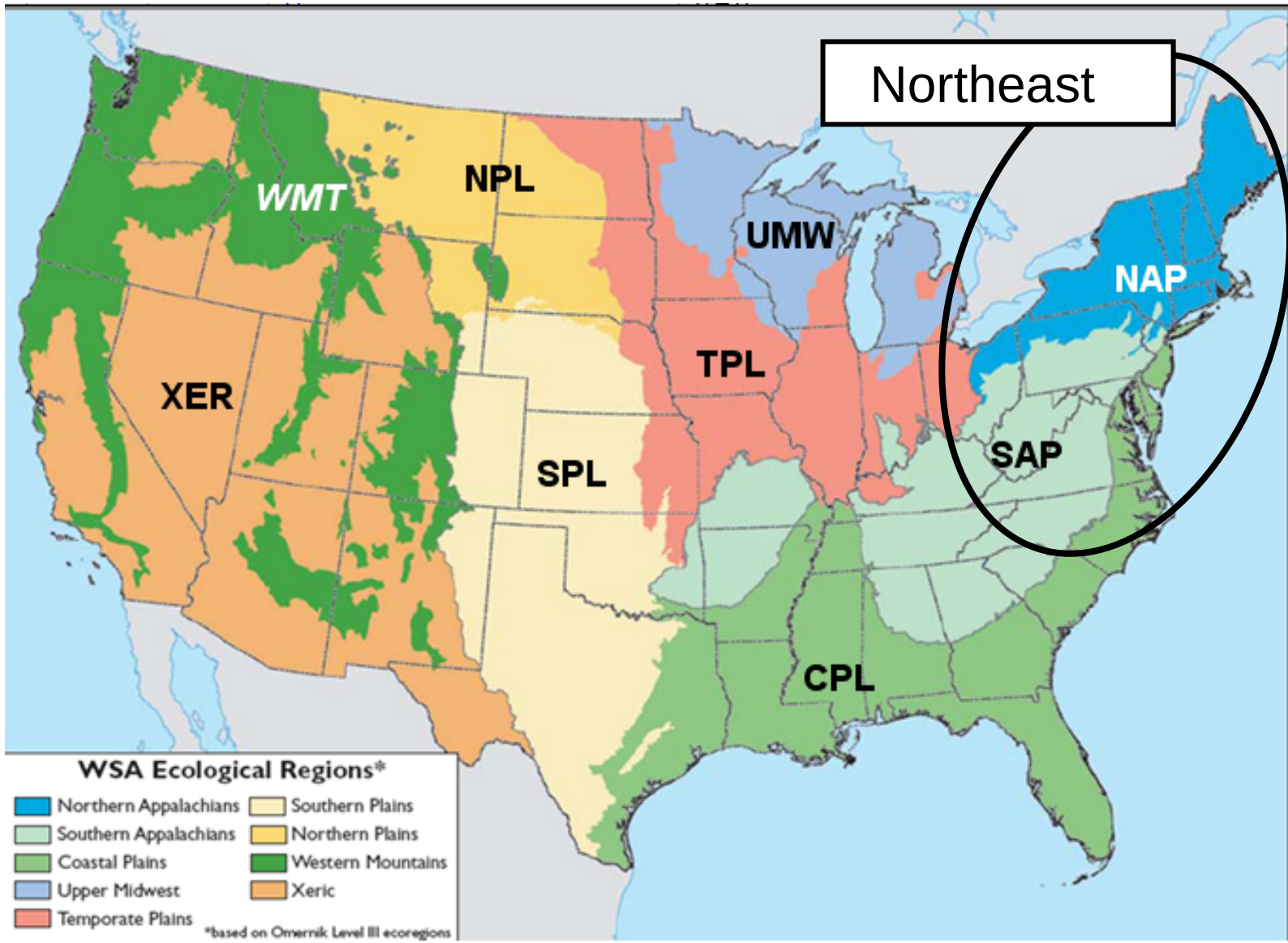
Trophic Status Indicators & possible ecological effects

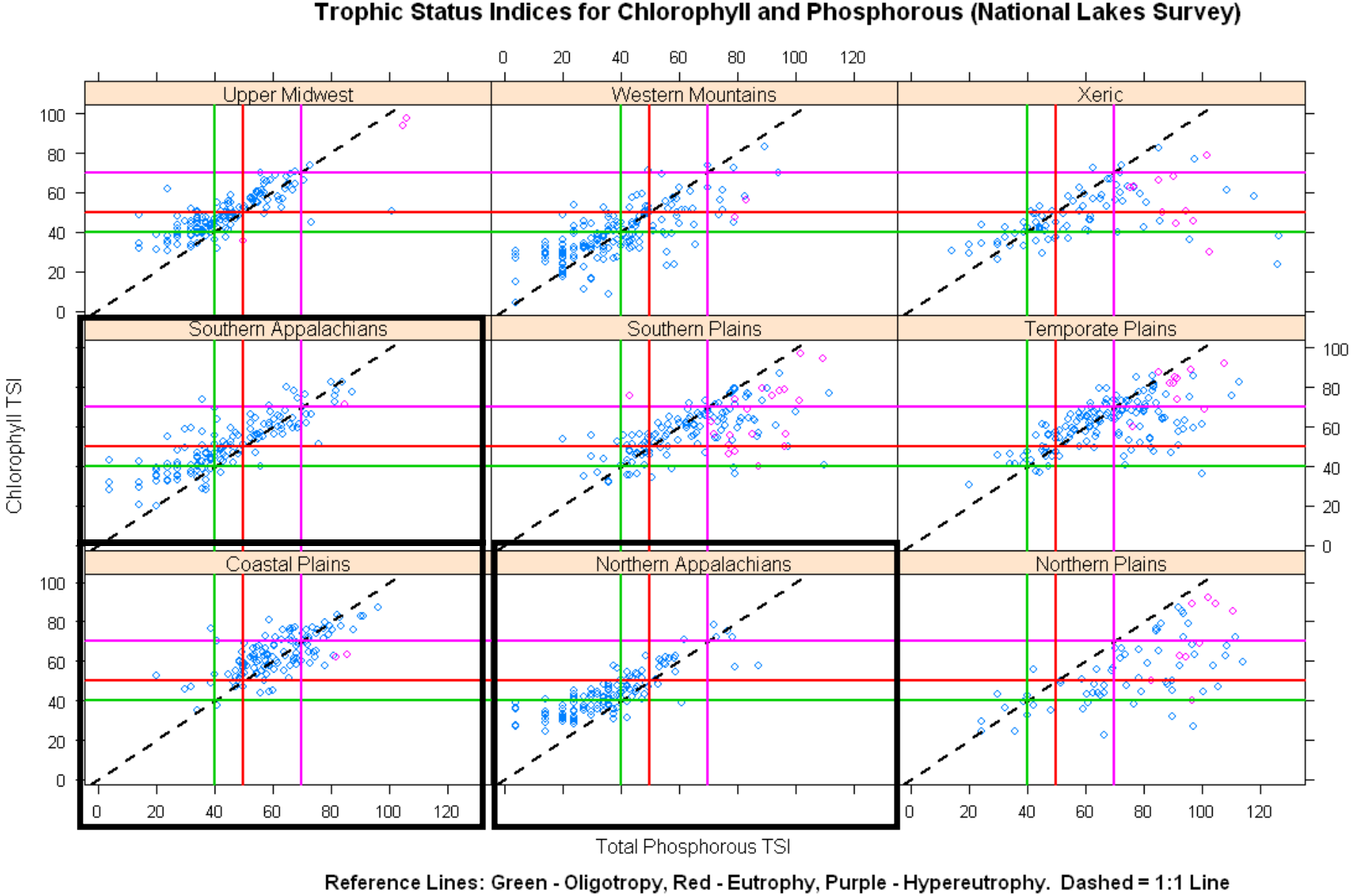
TSI(TP) = 14.42 ln(TP) + 4.15 or TSI(CHL) = 9.81 ln(CHL) + 30.6

Using Carlson 1977 Trophic Status Index for Northern Temperate Lakes



A quick descriptive look at trophic status variations by ecoregion.



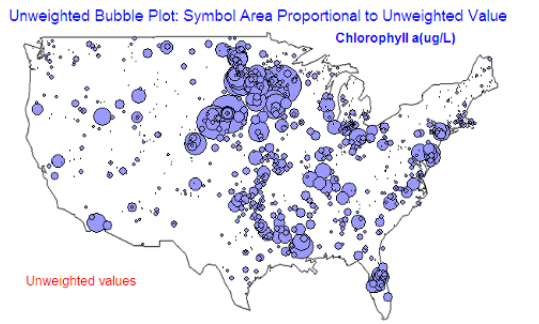


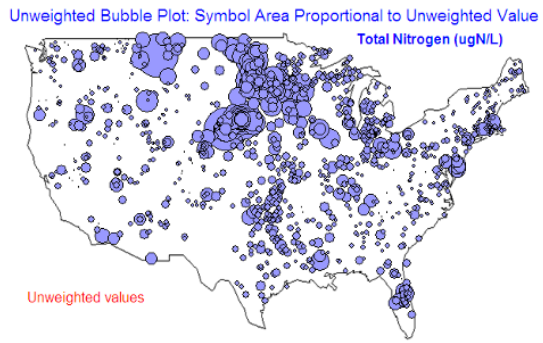
> xyplot(TSI_Chl ~ TSI_TP | WSA_9_NM, groups = TURB_CAT50)

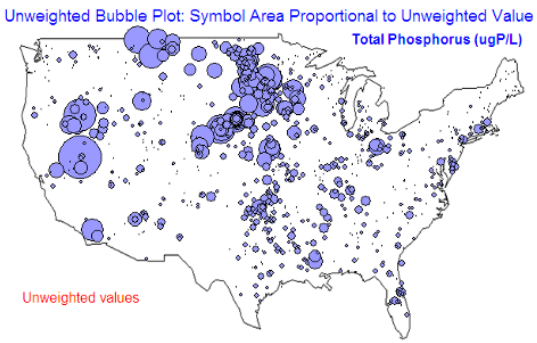
TURB < 50 NTU
TURB > 50 NTU

Probabilistic Snap Shot vs Nutrient Flux Based Perspectives

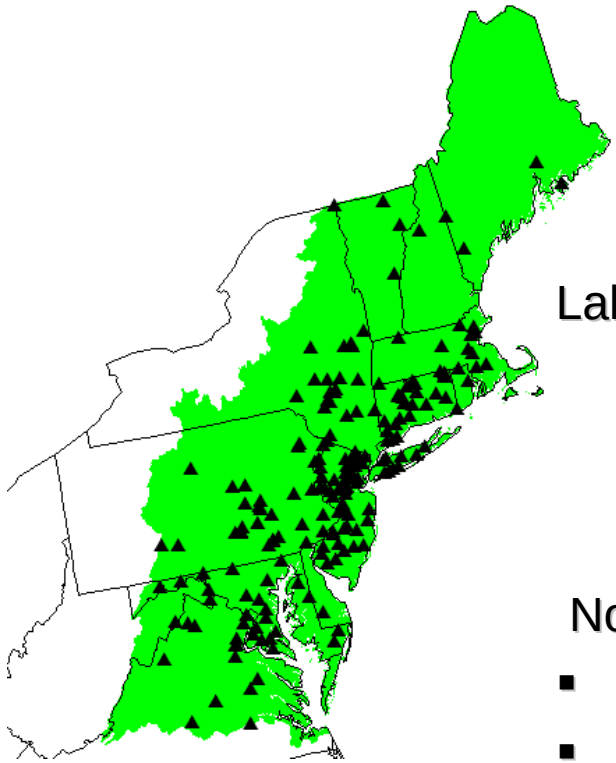
[Chl-*a*], [TN], [TP].







Preliminary comparison with draft Northeast SPARROW model results

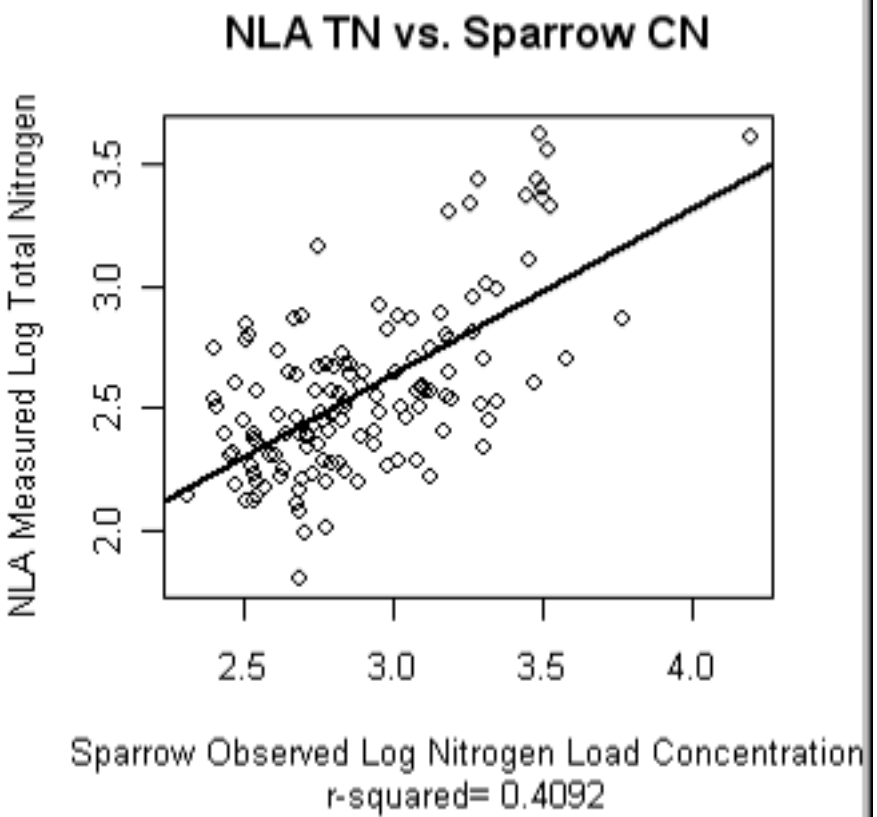


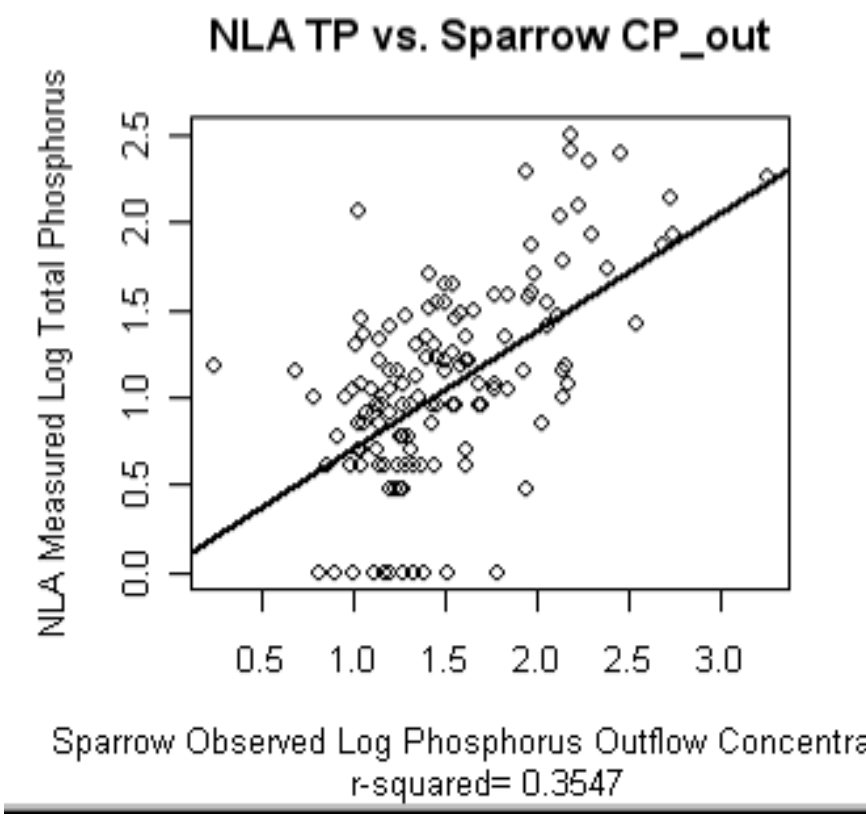
Lakes & Reservoirs represented as polygons (“areas” with “hydraulic loads”)

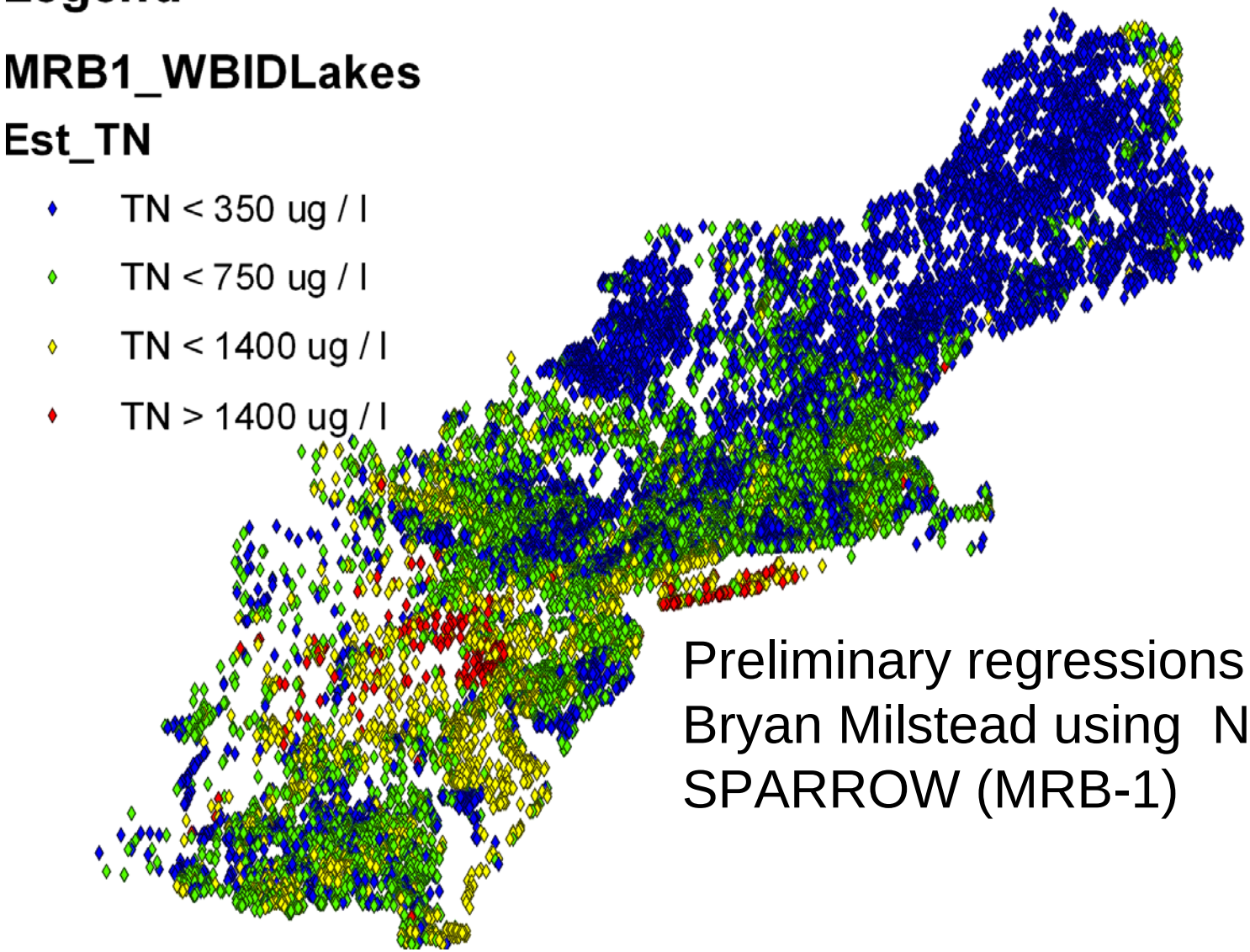
Not Represented:

- Average lake depth
- Residence Time

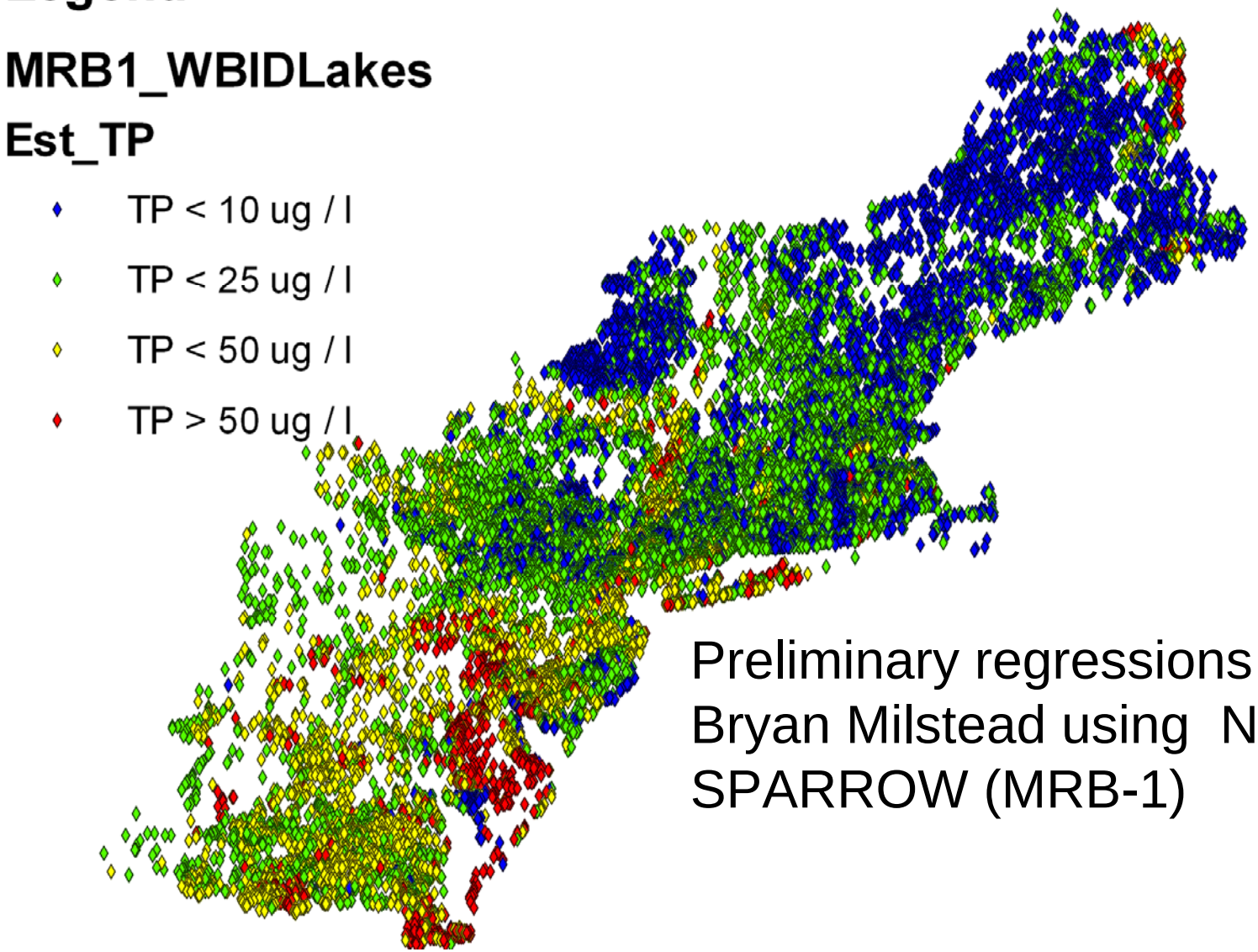
NLA data vs draft Northeast Sparrow Model results







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



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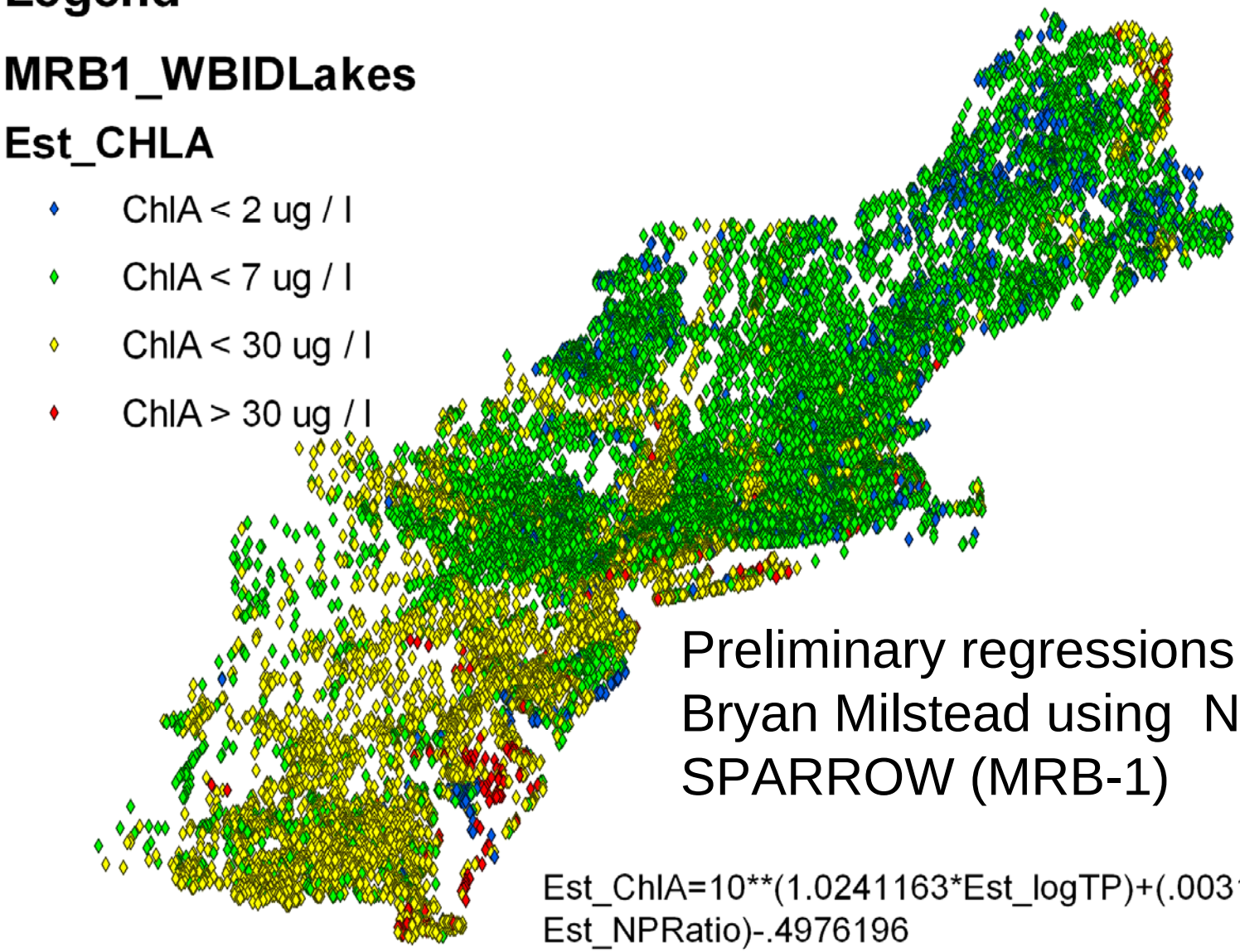
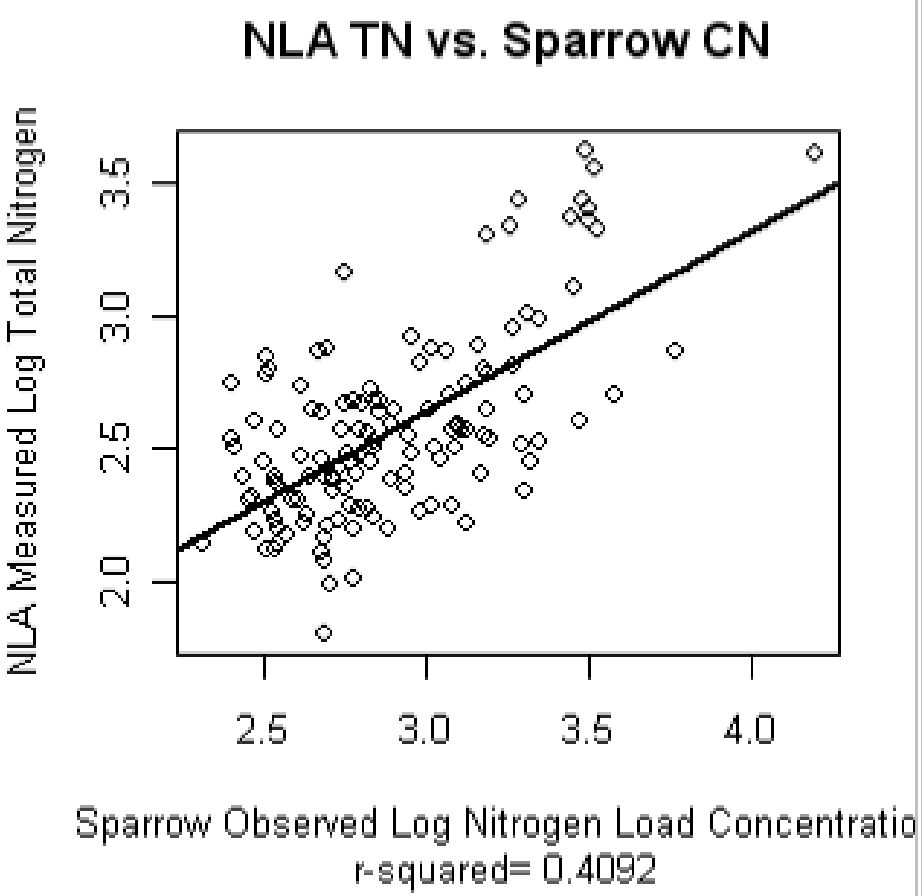


Preliminary regressions by Bryan Milstead using NLA & SPARROW (MRB-1)

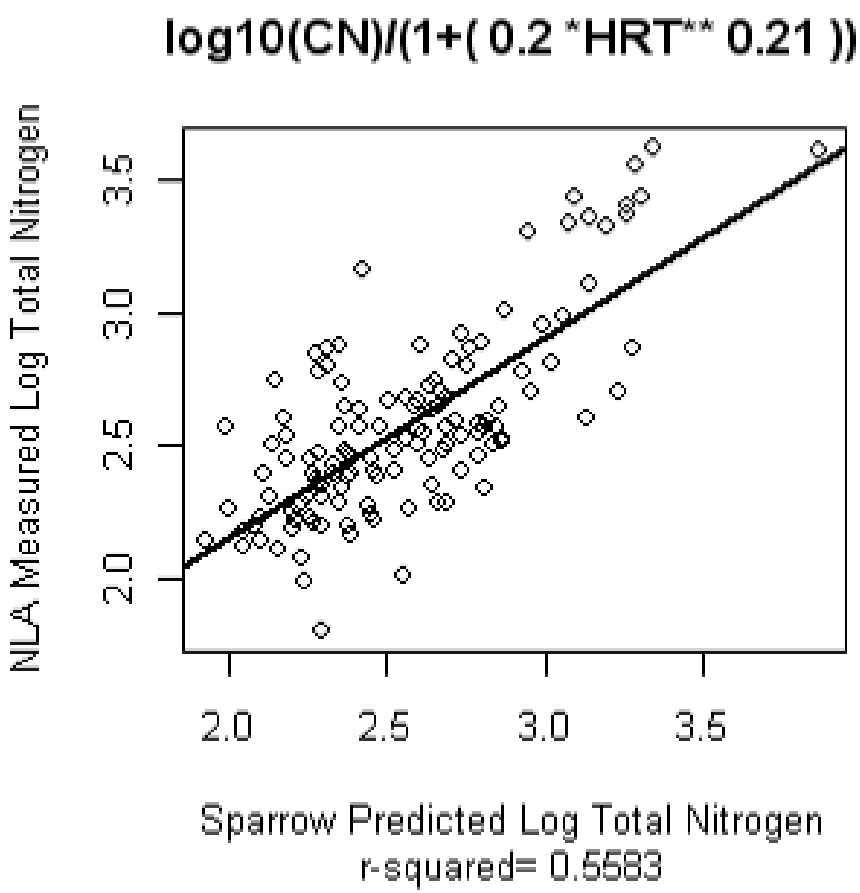
Est_ChlA=10**(1.0241163*Est_logTP)+(.0031017* Est_NPRatio)-.4976196

Observed Total Nitrogen (NLA) vs. SPARROW MRB-1 estimated Total Nitrogen ("Tuned")

Sparrow Model Alone

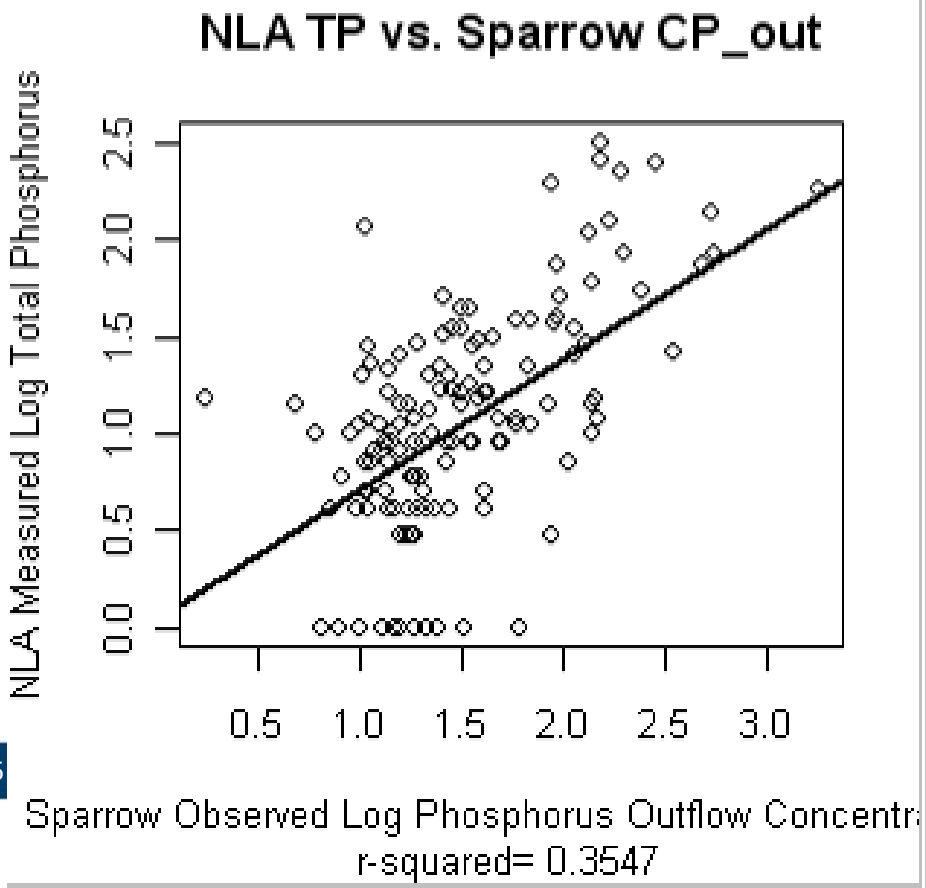


Modified Vollenwieder Eq.

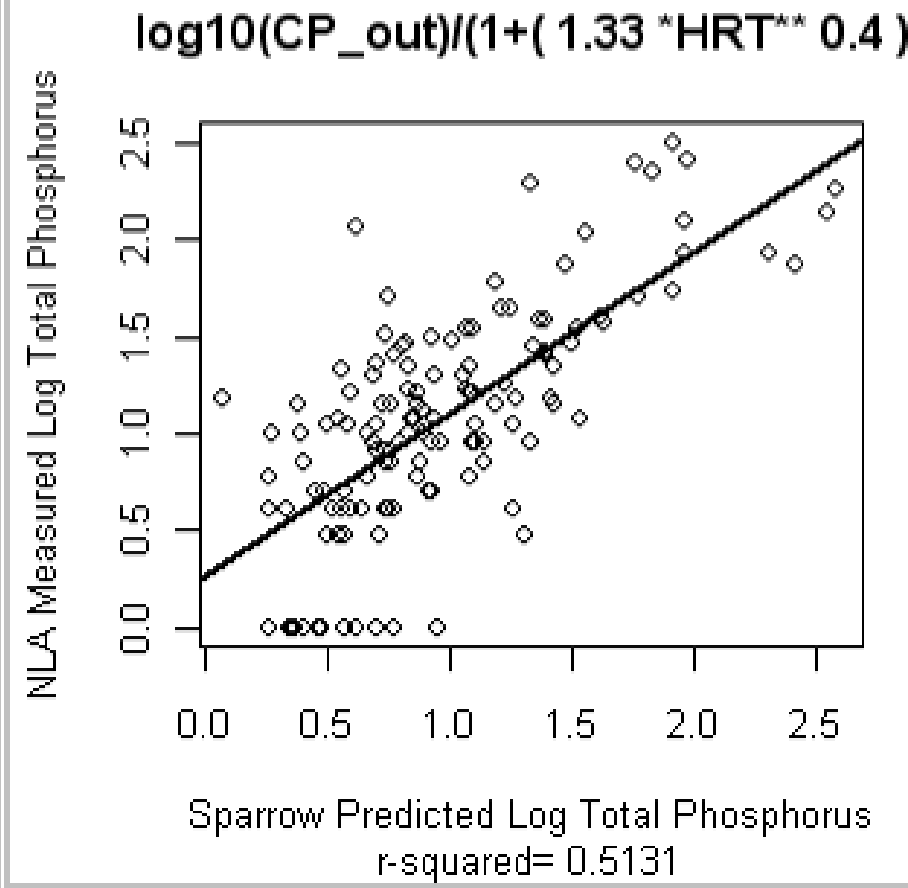


Observed Total Phosphorus (NLS 2007) vs. SPARROW MRB-1 estimated Total Phosphorus

Sparrow Model Alone



Modified Vollenwieder Eq.



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

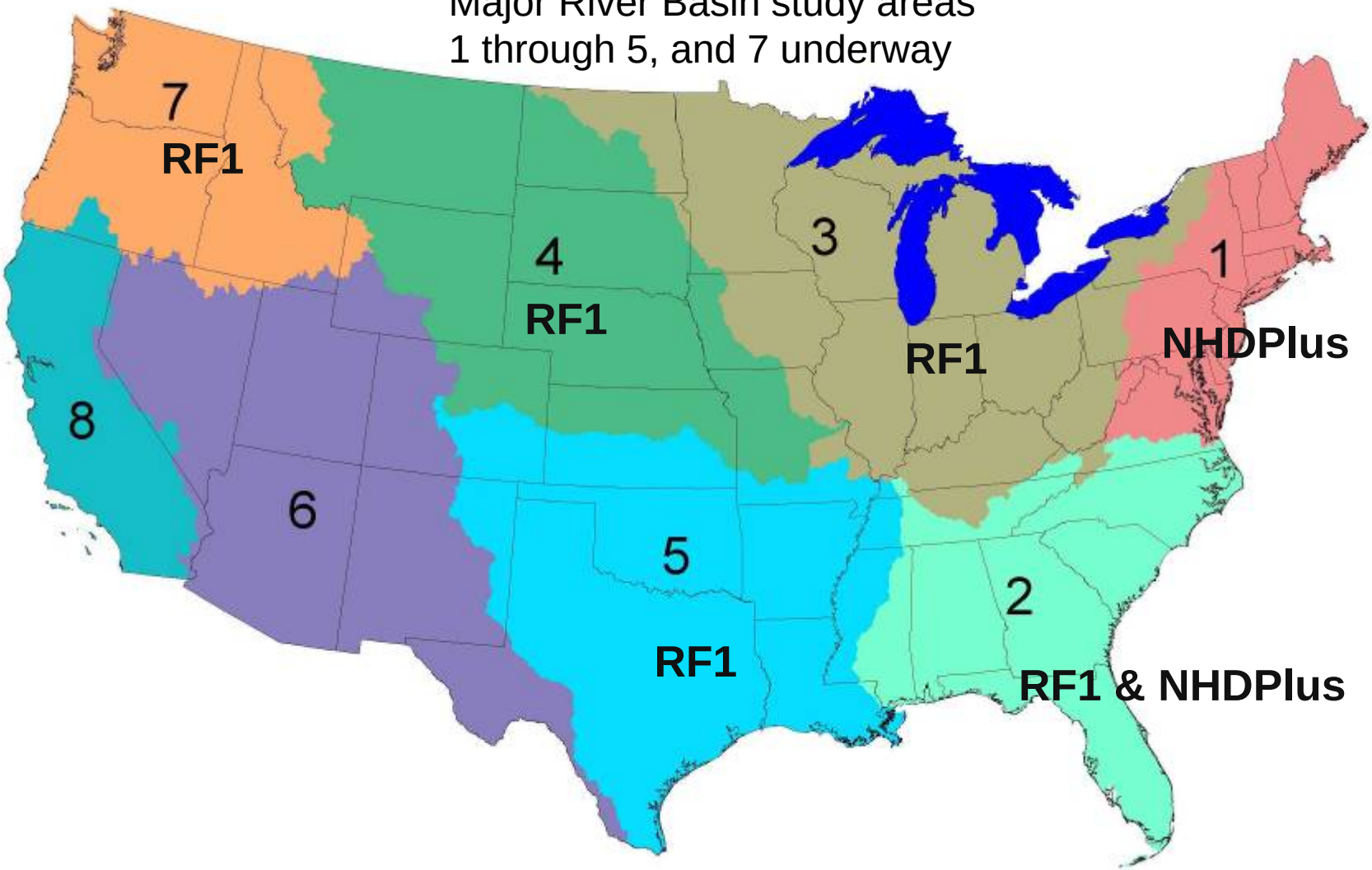
Presentation Outline

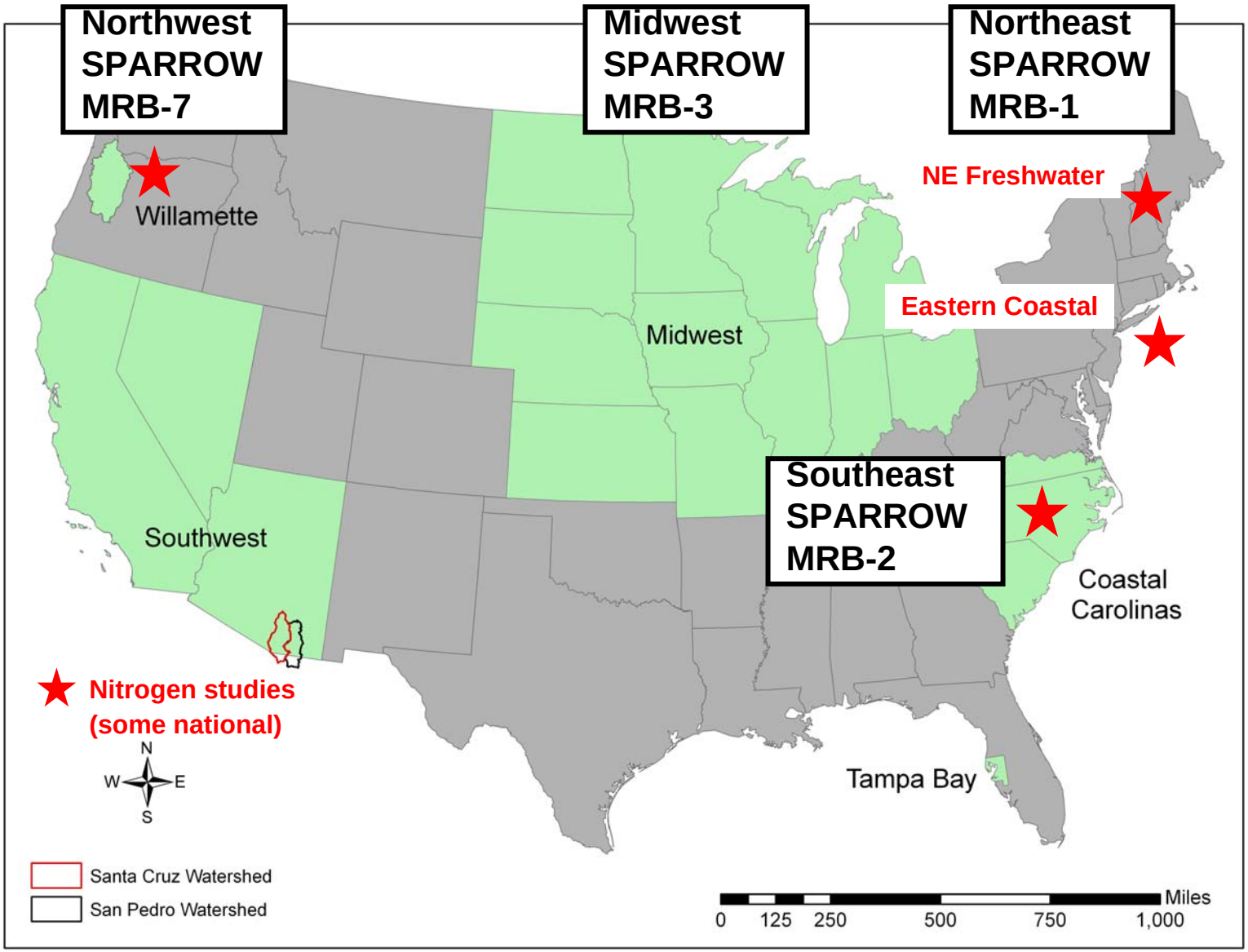
- Background on Ecosystem Services Research Program
  which could make use of a number of planned NMN components.

- Combining information from NMN (monitoring networks)
  - Narragansett Bay. Nitrogen Load Response Relationships
  - 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




Northwest SPARROW MRB-7
Midwest SPARROW MRB-3
Northeast SPARROW MRB-1
Willamette
NE Freshwater
Eastern Coastal
Midwest
Southeast SPARROW MRB-2
Southwest
Coastal Carolinas
Nitrogen studies (some national)
N
W
E
S
Tampa Bay
Santa Cruz Watershed
San Pedro Watershed
Miles
0 125 250 500 750 1,000

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  - Nationally — National Mapping of Ecosystem Services

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

NWQMC Meeting, Portland Oregon

July 21-24, 2009

Hal Walker, Bryan Milstead, Edward Dettmann
EPA ORD NHEERL Atlantic Ecology Division

Richard Moore
USGS NH / VT Water Science Center