Modeling the “Appeal” of Northeast Lakes

Bryan Milstead
Henry Walker
Jeff Hollister &
Neil Kamman

milstead.bryan@epa.gov
(401)782-3015
Spatial Context:

We are managing a landscape mosaic for multiple Ecosystem Services.
Research Question:
How do nitrogen inputs affect perceived lake quality & cultural ecosystem services at a regional scale?
Pollution Control
- Nutrients
- Contaminants
- Sediment
- Temperature

Other
- Food & Fiber
- Flood Control
- Transportation
- Supporting Services
- Regulating Services

Water Provisioning
- Domestic
- Agriculture
- Industry
- Power Generation

Other
- Food & Fiber
- Flood Control
- Transportation
- Supporting Services
- Regulating Services

Cultural Use
- Recreation
- Housing Amenity
- Ceremonial Use

Existence Value
- Wild Life / Wilderness
- Preservation of Options
- Deep Ecology
How are lakes perceived?

- Aesthetic Appeal: 1=low; 5=high
- Disturbance: 1= developed; 5 = pristine
- Biotic Integrity: 1=Poor; 4=Excellent
- Recreational Value: 1=Poor; 4=Excellent
- Swimmability: 1=Poor; 3=Good
Principal Components Analysis of NLA Stressors for Biological Condition
Reference Lakes vs. Target Lakes

Subjective Rating (mean ± 2 s.e.)

- Aesthetic Quality
- Recreational Value
- Biotic Integrity

Reference Lakes

Target Lakes
Conditional Probability Analysis

The probability that a lake will be classified as either reference or impacted based on its rating for aesthetic quality.
NHD Plus Region

- HUC 1 - New England
- HUC 2 - Mid-Atlantic

Geographic Scope of the Study: NHD Regions 01 and 02
Data Sources: NLA, NELP, and MRB1 SPARROW

National Lake Assessment

New England Lakes & Ponds Survey (REMAP)

Draft USGS Major River Basin 1 SPARROW Model - In collaboration with Richard Moore
Northeast Lakes Database
Locations of 28,000 lakes linked to:
• National Lake Assessment
• New England Lakes, and Ponds Survey
• USGS MRB1 SPARROW model
• NHDPlus, CMAQ, NLCD, NED
• And More
Oracle Database

Online Queries to:
- Select
- Combine
- Sort
- Filter
- Export

<table>
<thead>
<tr>
<th>Wb_Id</th>
<th>Nla_Id</th>
<th>Nla Lake Name</th>
<th>State</th>
<th>Ntl</th>
<th>Ptl</th>
<th>Chla</th>
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SAS Reports

Select Report:
- Chlorophyll Condition Report
- ANC Condition Report
- Turbidity Condition Report
- Total Nitrogen Condition Report
- Total Phosphorus Condition Report
- Dissolved Oxygen Condition Report

Select State for analysis:
- Northeastern Region
- Maine
- New Hampshire
- Vermont
- Massachusetts
- Rhode Island
- Connecticut
- New Jersey
- Delaware

- Show SAS Log
  Run Analysis

SAS Internet
Generate NLA Reports by
- Region
- State
Displaying monitored, modeled data in interactive maps

GIS in a browser
Nutrient Sources

- Point Source

- Atmospheric deposition of nitrogen (Ollinger 1992)

- National Land Cover Dataset 1992
  - Agriculture
  - Developed
  - Forest

Processes

- Land to water delivery
  - Soil permeability – STATSGO

- In-stream loss
  - Mean annual stream-flow
  - Reservoir detention

Thanks Rich Moore
Comparison of SPARROW predicted N and P concentrations for weighted NLA sample sites (n=100) versus all lakes in MRB1 > 4ha (n=9,421)

NLA MRB1 Total Nitrogen

| TN    | Value
<table>
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<tr>
<td>TN &lt; 750 ug/l</td>
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<tr>
<td>TN &lt; 1400 ug/l</td>
<td></td>
</tr>
<tr>
<td>TN &gt; 1400 ug/l</td>
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NL A Measured Total Nitrogen

SPARROW Estimated Total Nitrogen
How do you predict subjective measures?
Random Forest Modeling
R-Package “party”

- A “forest” of Classification Trees
- Random selection of predictor variables
- Assignment probabilities averaged over all trees to predict “Class”

- Training Data = NLA Lakes
- Prediction Set = MRB1 SPARROW Lakes
- Validation Set = NELP Lakes
Random Forest Variables

Response Variables (Binary)

- Appeal Score
- Pristine Score
- Recreation Score
- Swimming Score
- Biotic Integrity Score
- Secchi Depth Class
- Microcystin Detected
- Cyanobacteria Count Class

Predictor Variables

- [Phosphorus] input Conc.
- [Nitrogen] input Conc.
- Outflow (m3/yr)
- Inflow (m3/yr)
- Shoreline Development
- Hydrologic Load
- Shoreline
- Area
- Elevation
Note: n=weight for frequency data= 0
Random Forest Caveats

- Regional Scale
- Causal Mechanisms Unknown-Interactions Implicit
- Results have not been Validated with field work
- Prediction accuracy high but …
- Need more work on predictor variable selection
Research Question:
How do nitrogen inputs affect perceived lake quality & cultural ecosystem services at a regional scale.
What are the Landscape Level Tradeoffs
Reactive Nitrogen Sources for Northeast Lakes from SPARROW

32% Atmospheric Sources

28% Urban Sources

40% Agricultural Sources
Percent Change in Reactive Nitrogen Inputs 2012-2020

Community Multiscale Air Quality Model
http://www.cmaq-model.org

% Change

+10 %
-10 %
-20 %
-30 %
-40 %
-50 %
-60 %

Mean Change = -31.4%

Thanks Robin Dennis
Aesthetic Appeal

Base Condition – Lakes in Shore Area

Base Condition – Lakes in Highest Appeal Class

Base Condition – Lakes in Highest Appeal Class

Shore Area

<table>
<thead>
<tr>
<th>Region</th>
<th>N</th>
<th>Km</th>
<th>Km²</th>
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<td>1</td>
<td>2525</td>
<td>4422</td>
<td>490</td>
</tr>
<tr>
<td>2</td>
<td>1833</td>
<td>2688</td>
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<tr>
<td>Both</td>
<td>4358</td>
<td>7110</td>
<td>706</td>
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20% Decrease in Air N Input

20% Increase in Air N Input
Aesthetic Appeal

Base Condition – Lakes in Highest Appeal Class

<table>
<thead>
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<th>N</th>
<th>Km1</th>
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20% Decrease in Ag N Input

20% Increase in Ag N Input
Secchi Transparency

Base Condition – Lakes in Highest Secchi Class

Shore Area

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% Lakes-Change in Condition

20% Decrease in Ag N Input

20% Increase in Ag N Input
Microcystin Risk

Base Condition – Lakes in Highest Risk Class

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20% Decrease in Air N Input

20% Increase in Air N Input
Microcystin Risk

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% Lakes-Change in Condition

20% Decrease in Ag N Input

20% Increase in Ag N Input
Scenario Conclusions

- Potential for dramatic improvements in perceivable lake quality from realistic changes in reactive nitrogen inputs
- Reductions in atmospheric sources leads to larger improvements
- Gains or losses are location specific
Scenario Caveats

- Across the board reductions unrealistic
- Loss of SPARROW estimates of attenuation
- Nitrogen / Phosphorus ratios not included
Reactive Nitrogen Complementary Reductions

- Nitrogen delivery to estuaries
- Human Health Risk – pulmonary disease
- Human Health Risk – methemoglobinemia
- Nutrient loads to lakes, rivers, & wetlands
- Acid rain and acidification of inland waters
Scenario Future Plans

- Incorporate CMAQ 2002 and 2020 estimates directly into SPARROW
- Develop a more realistic scenario for changes in agriculture inputs
- Expand and refine indicators of “appeal” and other ecosystem services
- Include estimates of nutrient loads to estuaries
Acknowledgements

- NLA Field Crews, Collaborators, & Analysis Team
- Hilary Snook, Toby Stover & Carol Elliot, EPA, NELP
- Richard Moore, USGS MRB1 SPARROW
- Robin Dennis, EPA, CMAQ Model
- John Kiddon, EPA, Data Development & Analysis
- Jane Copeland, Harry Buffum, Michael Charpentier, Melissa Hughes, David Bender, & Cara Cormier-Raytheon & SRA Contractors
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