EPA

www.epa.gov/ecology

Protecting America's Waters

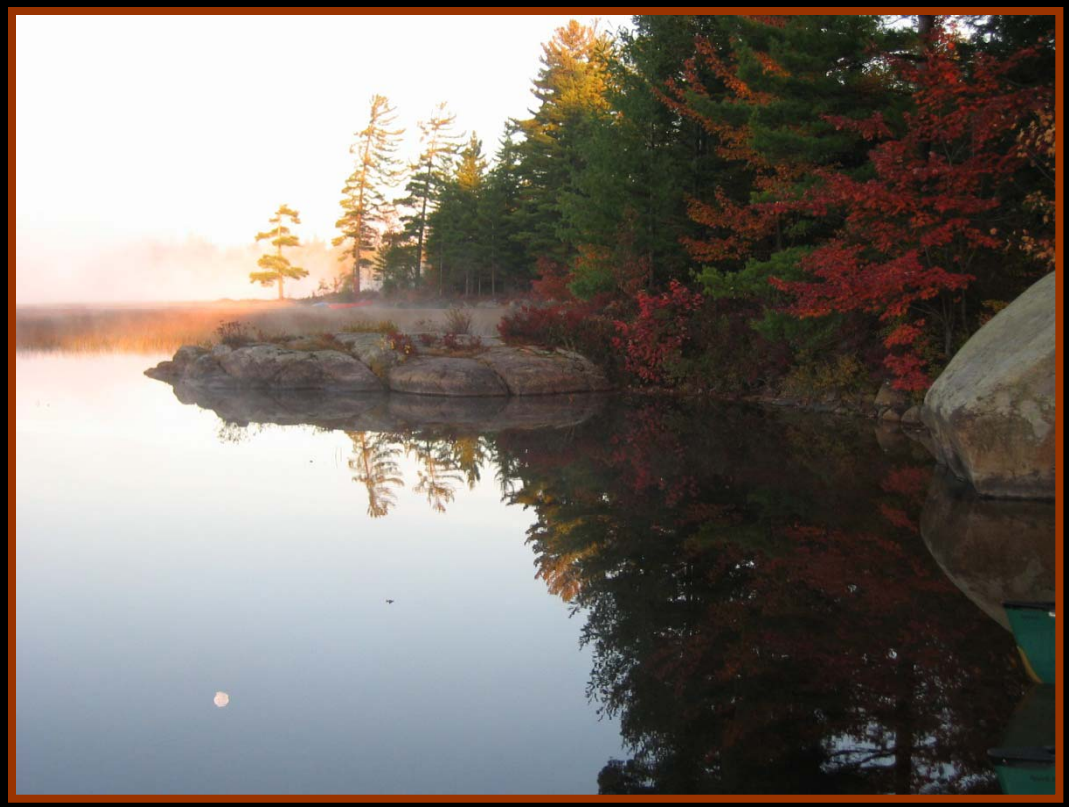
ECOSYSTEM SERVICES RESEARCH PROGRAM

BUILDING A SCIENTIFIC FOUNDATION FOR SOUND ENVIRONMENTAL DECISIONS

Modeling the "Appeal" of Northeast Lakes

Bryan Milstead
Henry Walker
Jeff Hollister &
Neil Kamman

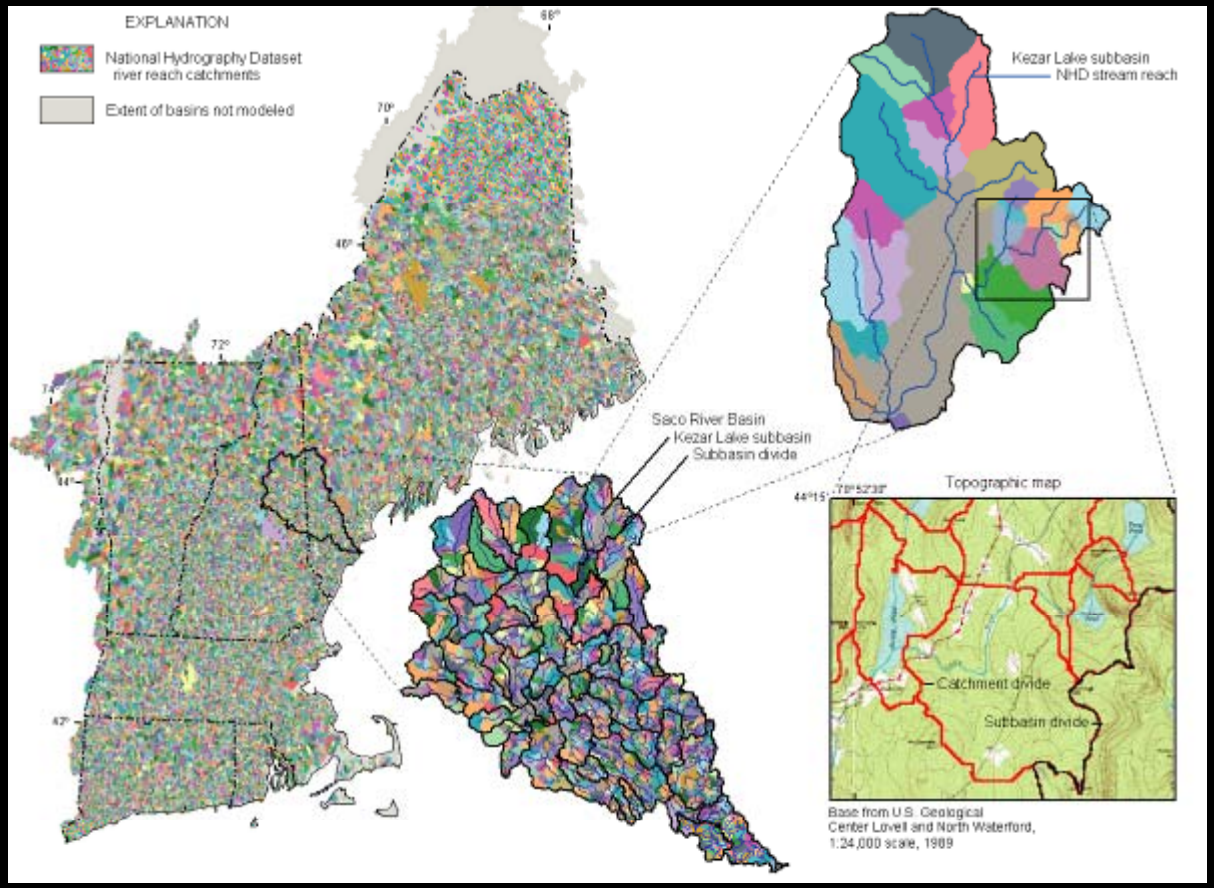
milstead.bryan@epa.gov
(401)782-3015



U.S. Environmental Protection Agency
Office of Research and Development

Spatial Context:

We are managing a landscape mosaic for multiple Ecosystem Services



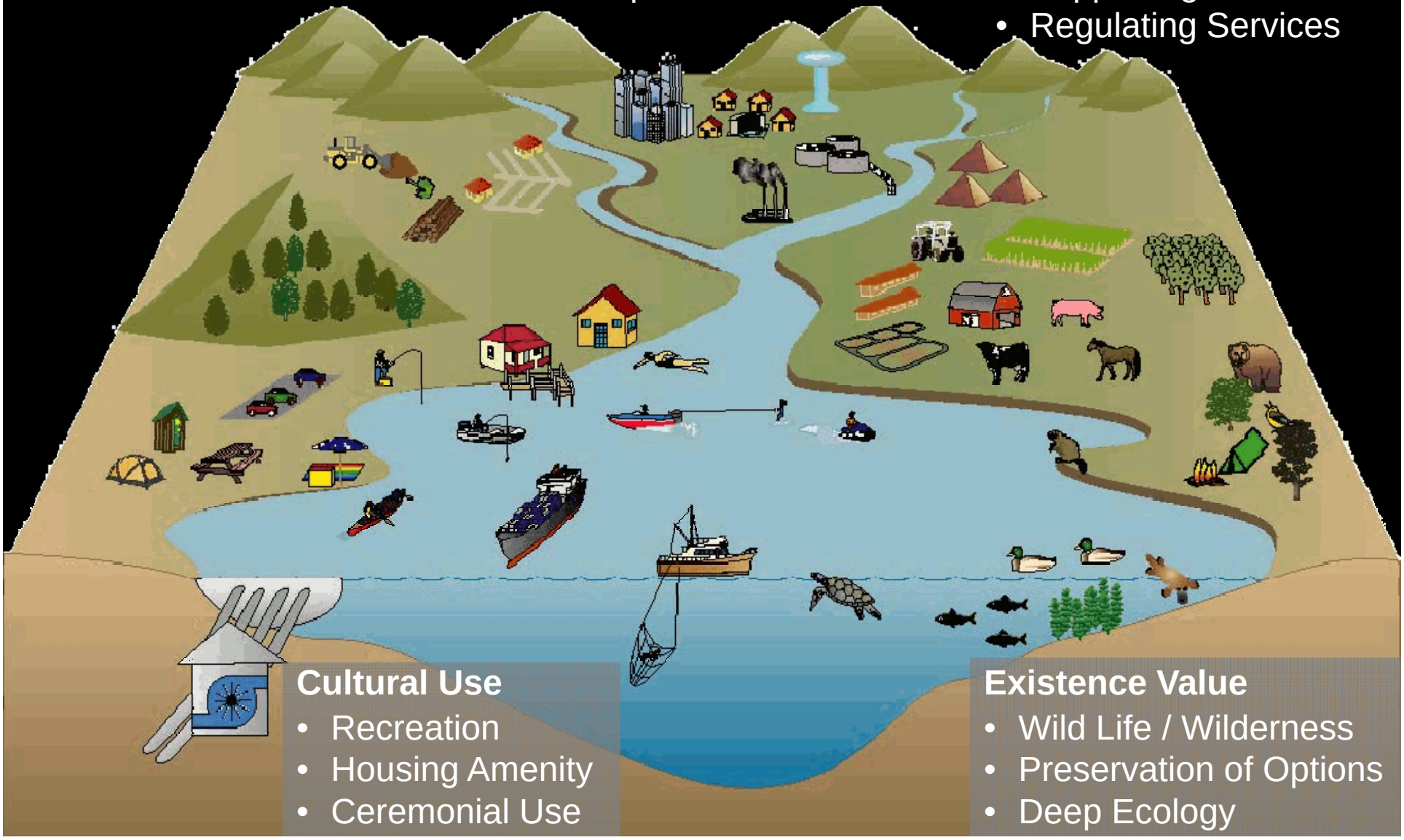
Research Question:

How do nitrogen inputs affect perceived lake quality & cultural ecosystem services at a regional scale?

Water Provisioning
- Domestic
- Agriculture
- Industry
- Power Generation

Pollution Control
- Nutrients
- Contaminants
- Sediment
- Temperature

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

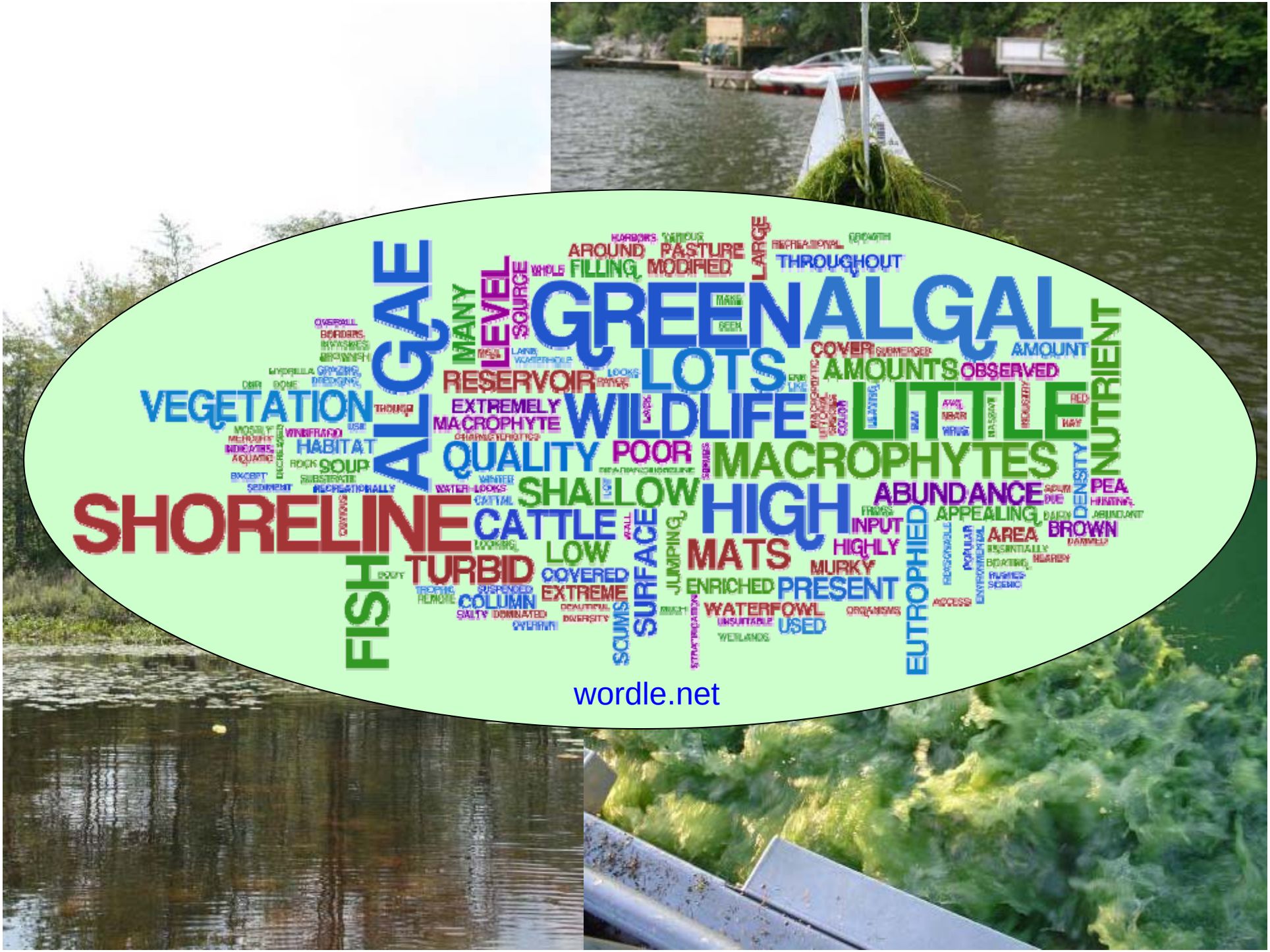
How are lakes perceived?

- 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

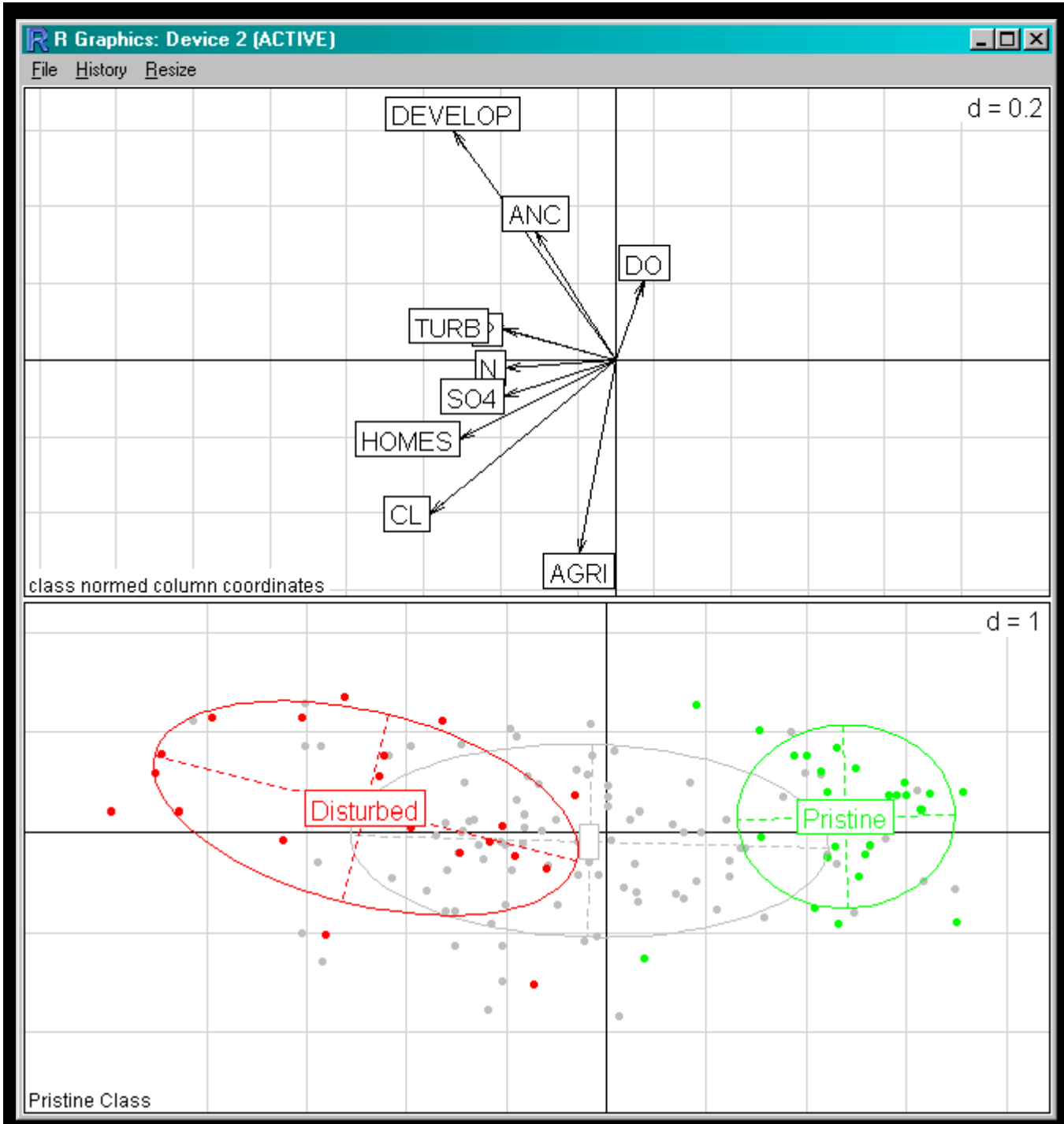

Photo by Jeff Hollister


CLEAR
NICE
BEAUTIFUL
SHORELINE
RESERVOIR
MACROPHYTES
LOW
ALGAE
FISH
WATERSHED
DEEP
IMPACT
HIGH
AREA
OBSERVED
WILDERNESS
QUALITY
PRISTINE
UNDISTURBED
DEVELOPMENT
SCENIC
FOREST
GREAT
LITTLE
GOOD
EXCELLENT
LOTS
SURROUNDED
LARGE
NATURAL
CLEAN
FISHING
SHALLOW
BOTTOM
MANAGED
wordle.net

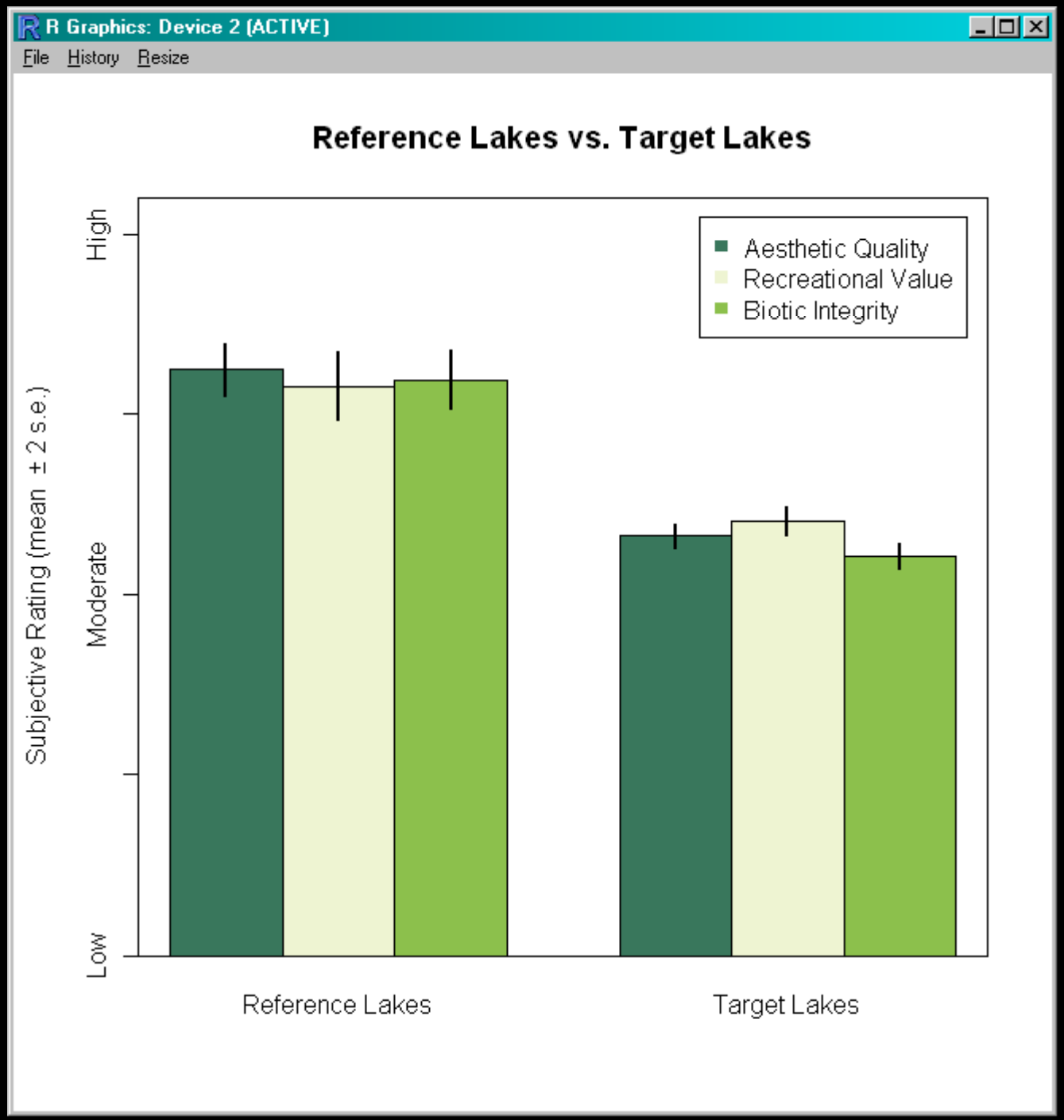
Photos From Toby Stover


GREEN
ALGAL
ALGAE
LOTS
LITTLE
WILDLIFE
MACROPHYTES
VEGETATION
SHORELINE
HIGH
QUALITY
POOR
SHALLOW
CATTLE
TURBID
FISH
MATS
PRESENT
ABUNDANCE
EUTROPHIED
NUTRIENT
RESERVOIR
AMOUNTS
OBSERVED
THROUGHOUT
AROUND
PASTURE
MODIFIED
FILLING
LEVEL
MANY
HABITAT
SOUP
MACROPHYTE
EXTREMELY
LOW
COVERED
EXTREME
COLUMN
SURFACE
SCUMS
JUMPING
ENRICHED
WATERFOWL
USED
MURKY
HIGHLY
INPUT
APPEALING
AREA
BROWN
DENSITY
PEA
COVER
AMOUNT

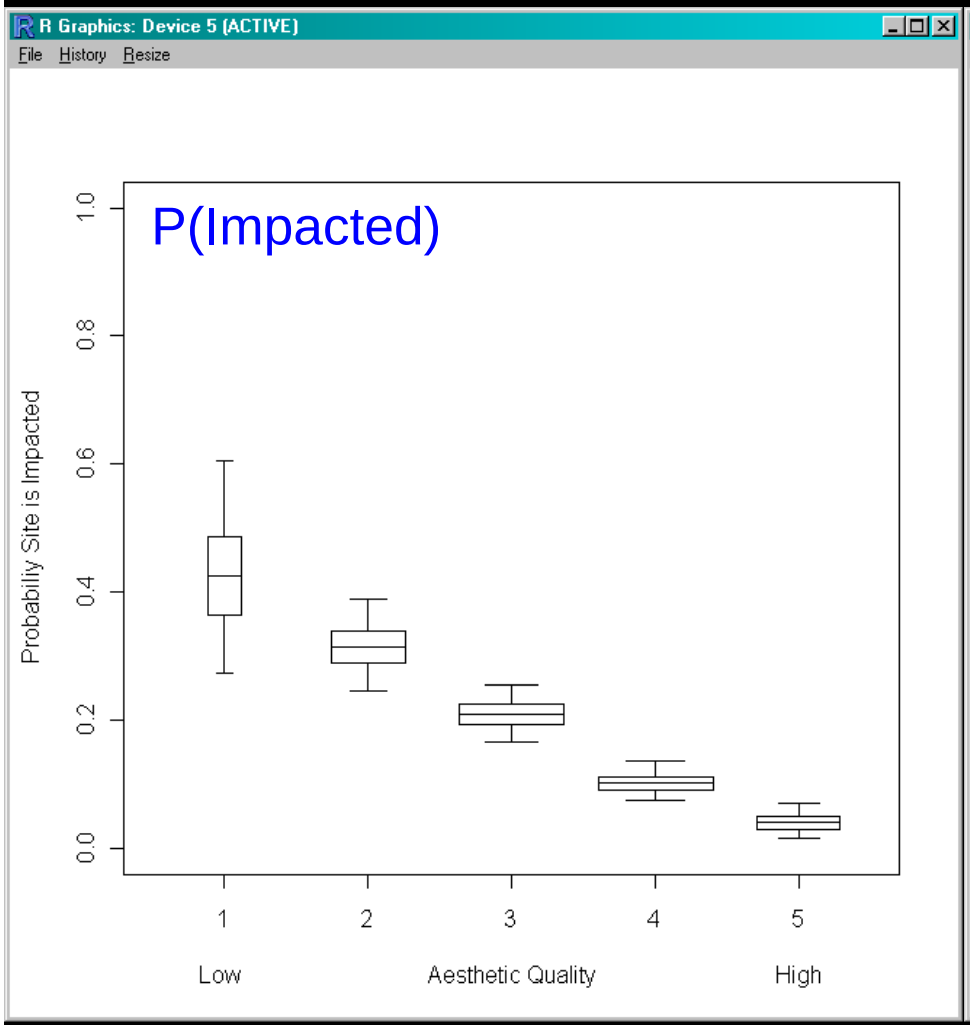
wordle.net

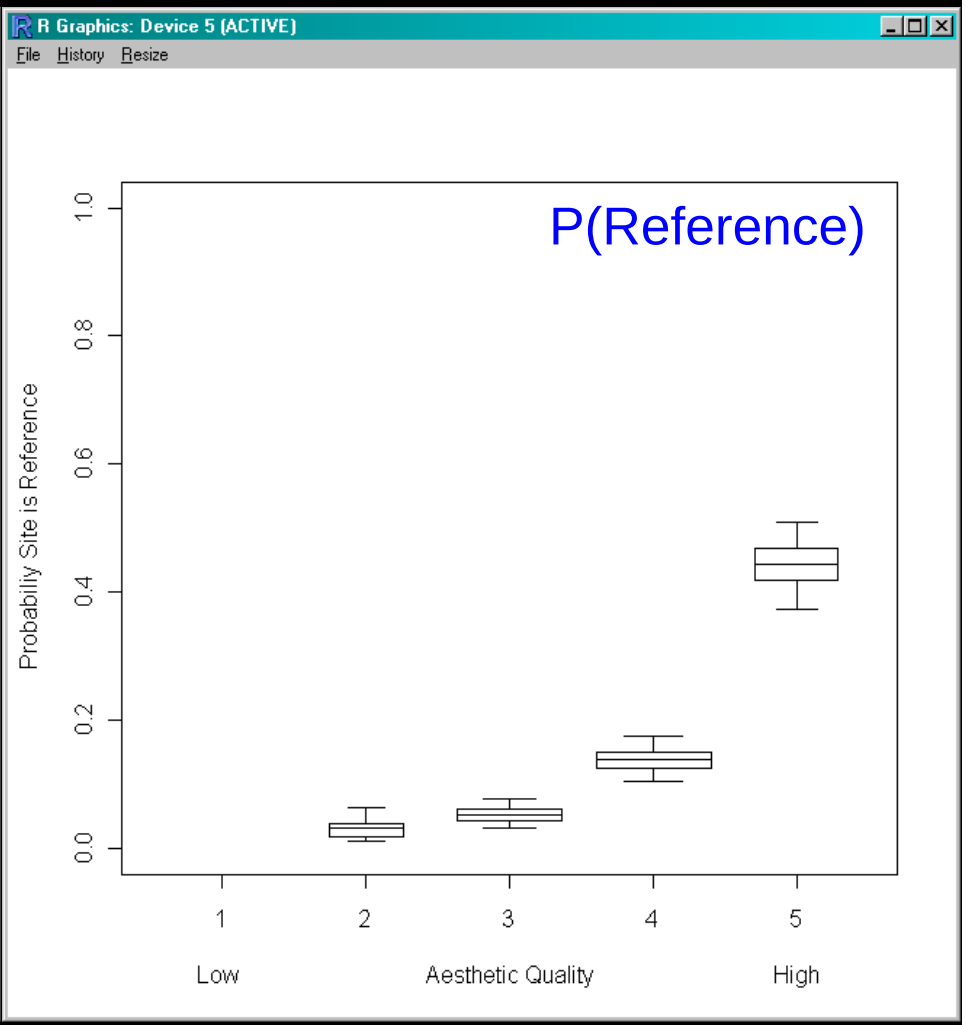


Principal Components Analysis of NLA Stressors for Biological Condition

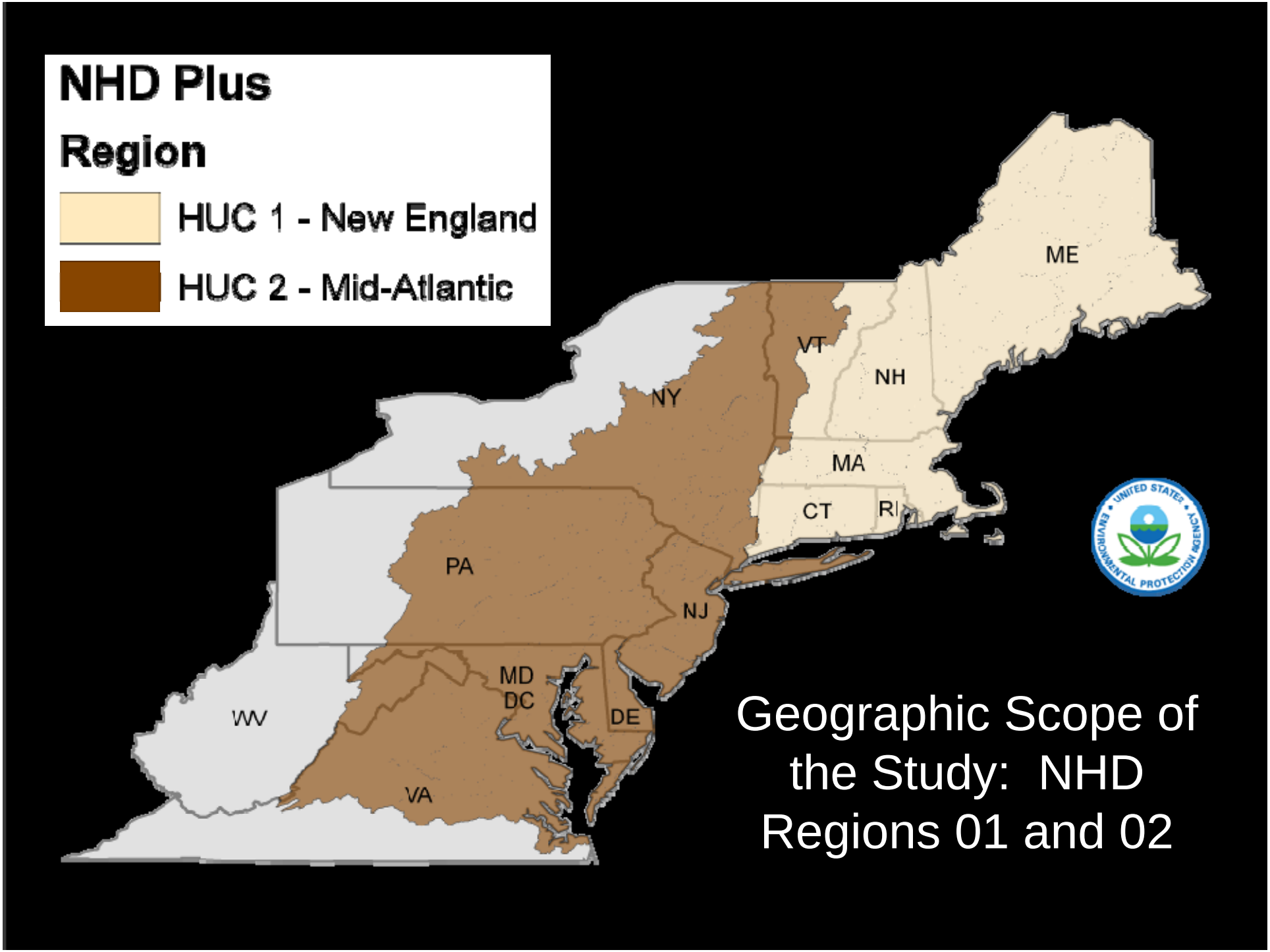

R Graphics: Device 2 (ACTIVE)
File History Resize
Reference Lakes vs. Target Lakes
Aesthetic Quality
Recreational Value
Biotic Integrity
Subjective Rating (mean ± 2 s.e.)
High
Moderate
Low
Reference Lakes
Target Lakes

Conditional Probability Analysis

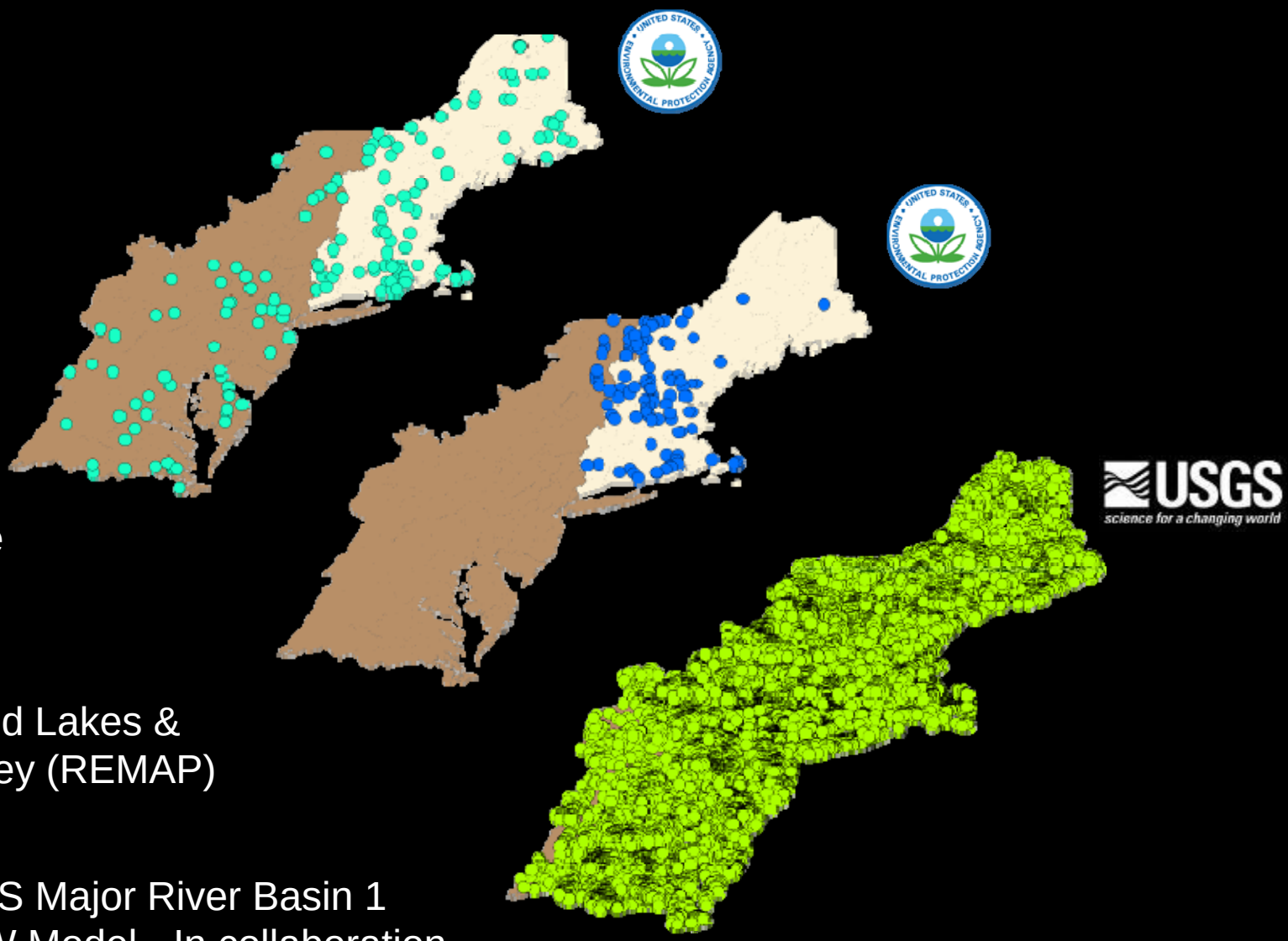




The probability that a lake will be classified as either reference or impacted based on its rating for aesthetic quality.


NHD Plus
Region
HUC 1 - New England
HUC 2 - Mid-Atlantic
ME
VT
NH
NY
MA
CT
RI
PA
NJ
MD
DC
DE
WV
VA
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

ESRP Pilot | US EPA

http://naraxp.nar.epa.gov/esrp/

EPA US Environmental Protection Agency

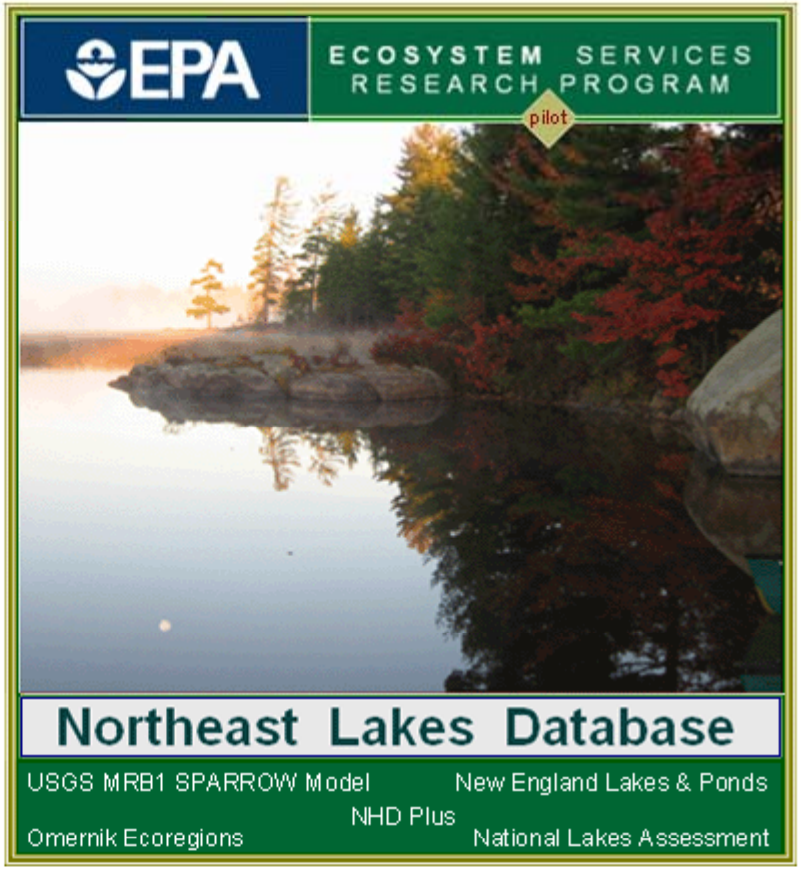
ESRP Pilot

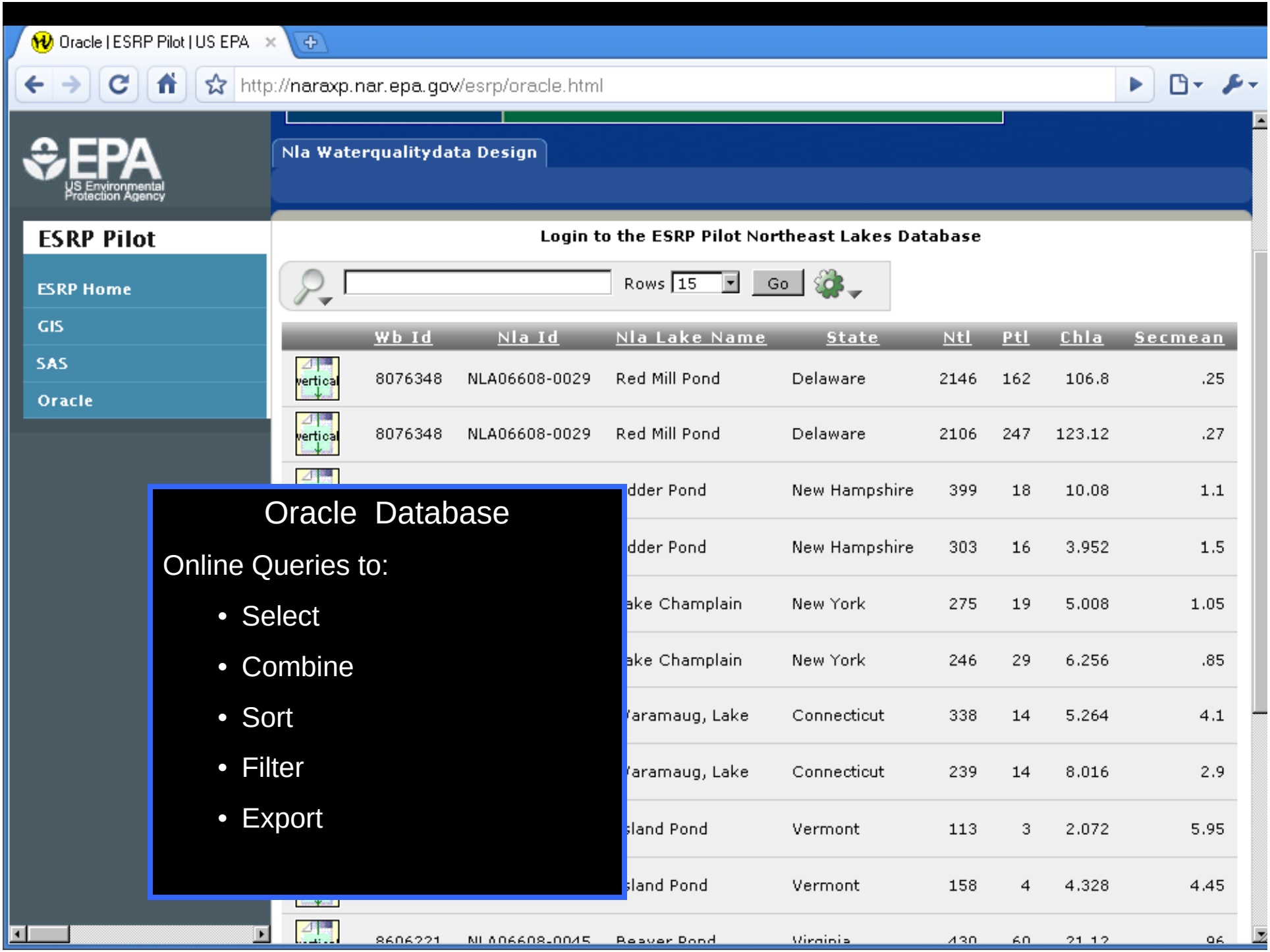
- ESRP Home
- GIS
- SAS
- Oracle

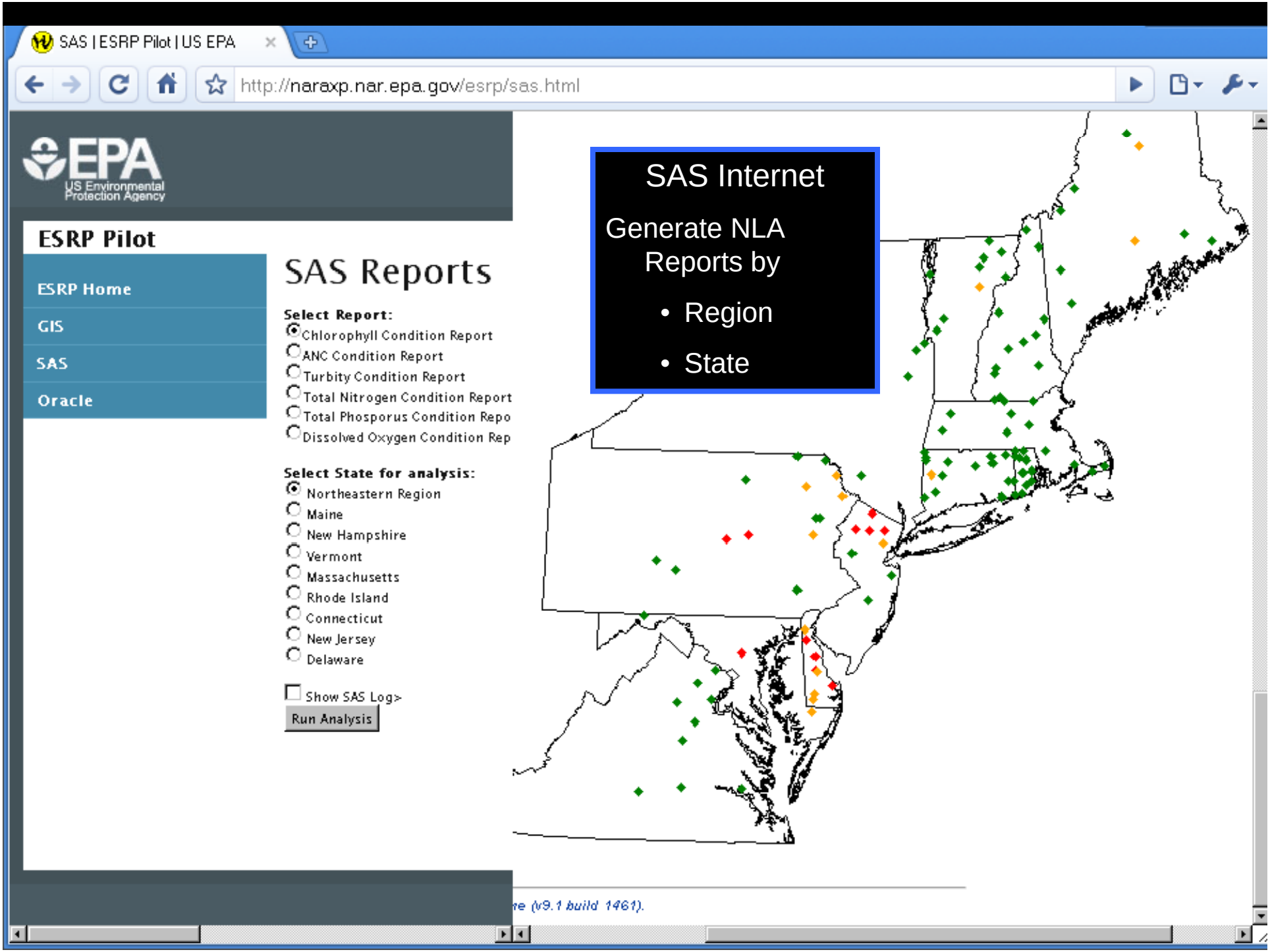
Northeast Lakes Database

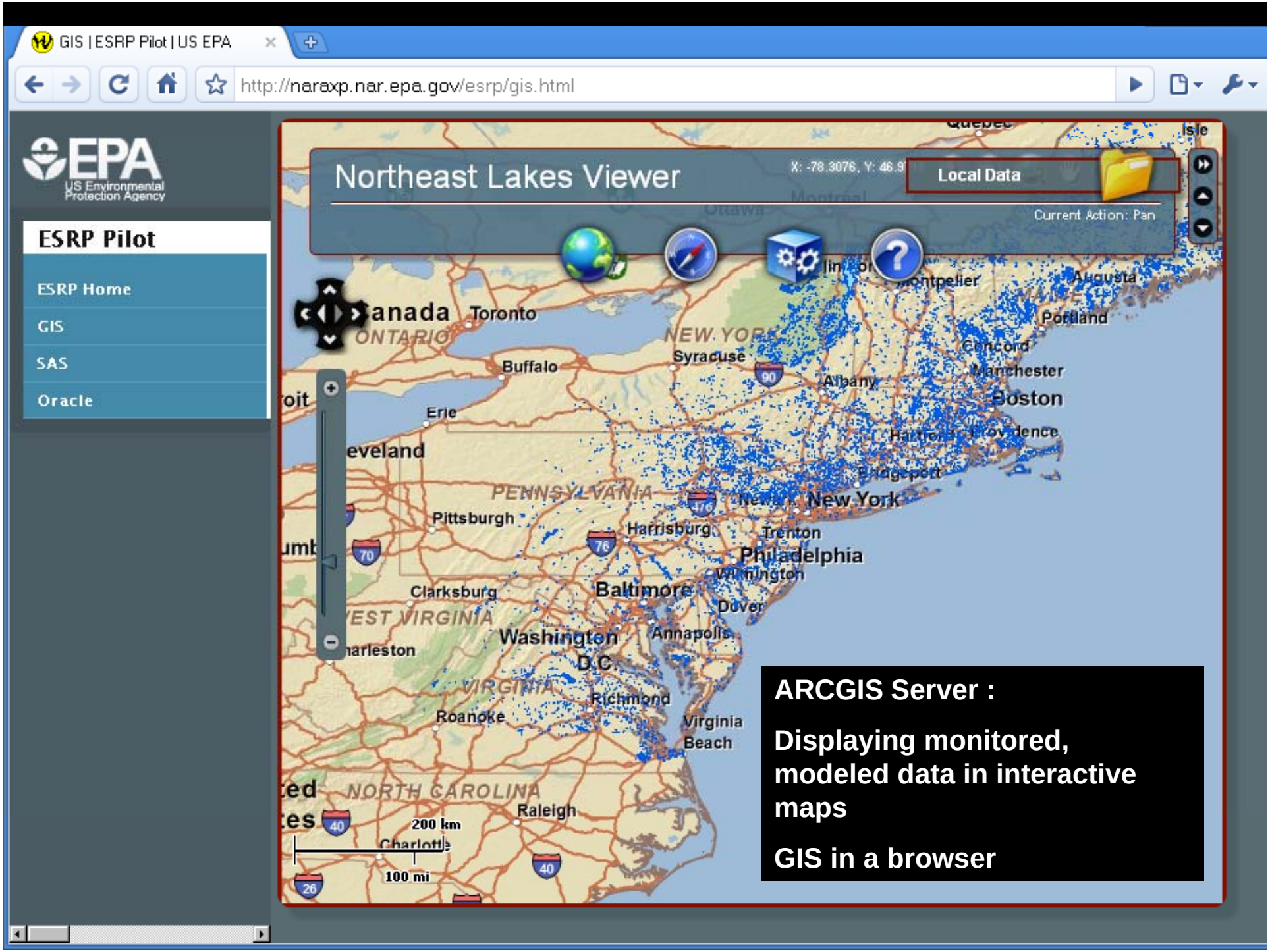
Locations of 28,000 lakes linked to:

- National Lake Assessment
- New England Lakes, and Ponds Survey
- USGS MRB1 SPARROW model
- NHDPlus, CMAQ, NLCD, NED
- And More

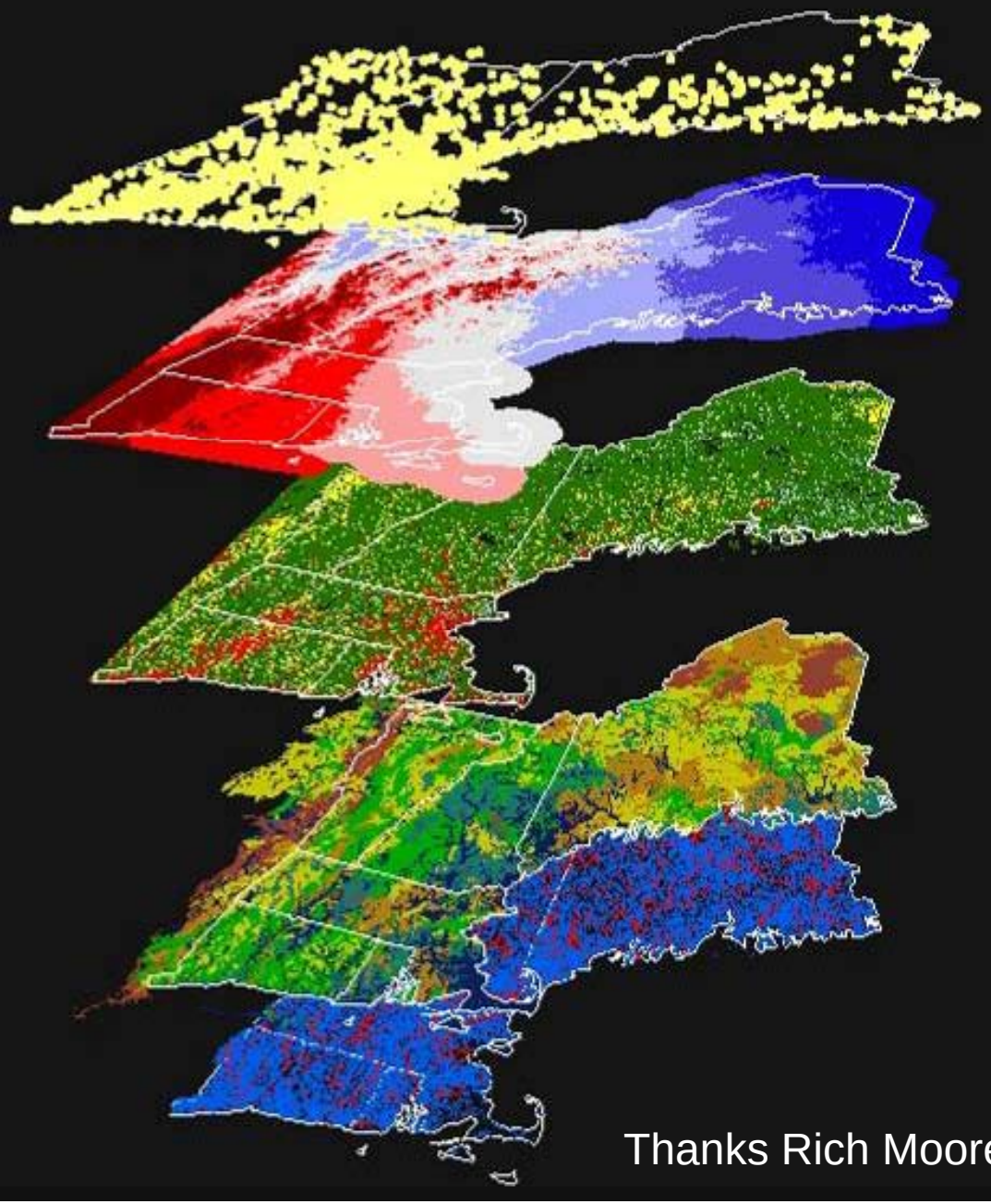



Oracle | ESRP Pilot | US EPA
http://naraxp.nar.epa.gov/esrp/oracle.html
EPA
US Environmental Protection Agency
Nla Waterqualitydata Design
ESRP Pilot
ESRP Home
GIS
SAS
Oracle
Login to the ESRP Pilot Northeast Lakes Database
Rows 15
Go
Wb Id | Nla Id | Nla Lake Name | State | Ntl | Ptl | Chla | Secmean
8076348 | NLA06608-0029 | Red Mill Pond | Delaware | 2146 | 162 | 106.8 | .25
8076348 | NLA06608-0029 | Red Mill Pond | Delaware | 2106 | 247 | 123.12 | .27
dder Pond | New Hampshire | 399 | 18 | 10.08 | 1.1
dder Pond | New Hampshire | 303 | 16 | 3.952 | 1.5
ake Champlain | New York | 275 | 19 | 5.008 | 1.05
ake Champlain | New York | 246 | 29 | 6.256 | .85
aramaug, Lake | Connecticut | 338 | 14 | 5.264 | 4.1
aramaug, Lake | Connecticut | 239 | 14 | 8.016 | 2.9
sland Pond | Vermont | 113 | 3 | 2.072 | 5.95
sland Pond | Vermont | 158 | 4 | 4.328 | 4.45
Oracle Database
Online Queries to:
• Select
• Combine
• Sort
• Filter
• Export


SAS | ESRP Pilot | US EPA
http://naraxp.nar.epa.gov/esrp/sas.html
EPA
US Environmental Protection Agency
ESRP Pilot
ESRP Home
GIS
SAS
Oracle
SAS Reports
Select Report:
Chlorophyll Condition Report
ANC Condition Report
Turbity Condition Report
Total Nitrogen Condition Report
Total Phosporus Condition Repo
Dissolved Oxygen Condition Rep
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
ne (v9.1 build 1461).


GIS | ESRP Pilot | US EPA
http://naraxp.nar.epa.gov/esrp/gis.html
EPA
US Environmental Protection Agency
ESRP Pilot
ESRP Home
GIS
SAS
Oracle
Northeast Lakes Viewer
Local Data
Current Action: Pan
Toronto
ONTARIO
Buffalo
Syracuse
Albany
Boston
Portland
Concord
Manchester
Erie
Pittsburgh
Harrisburg
Trenton
Philadelphia
New York
Baltimore
Washington D.C.
Annapolis
Dover
Clarksburg
Roanoke
Richmond
Virginia Beach
Raleigh
NORTH CAROLINA
200 km
100 mi
ARCGIS Server :
Displaying monitored, modeled data in interactive maps
GIS in a browser

NE SPARROW Model Input



Thanks Rich Moore

Nutrient Sources

Point Source

Atmospheric deposition of nitrogen (Ollinger 1992)

National Land Cover Dataset 1992

- Agriculture
- Developed
- Forest

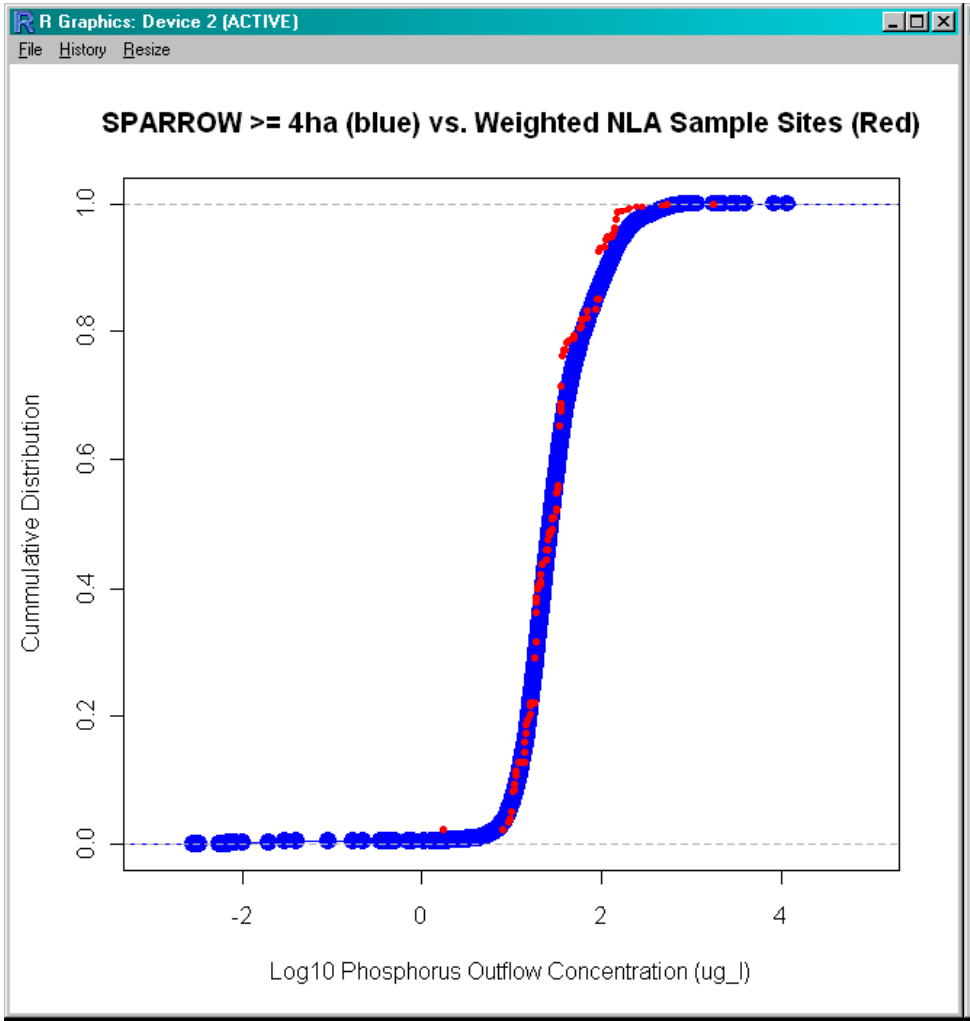
Processes

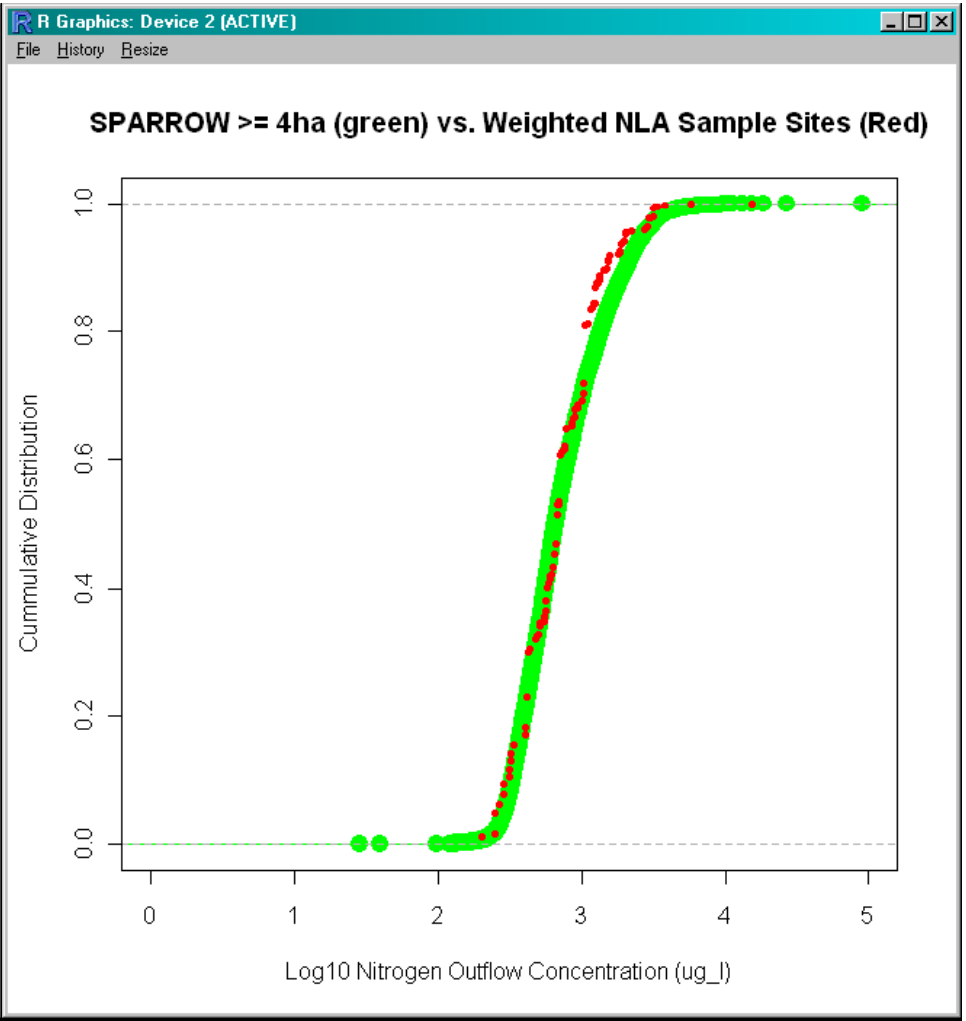
Land to water delivery

Soil permeability – STATSGO

In-stream loss

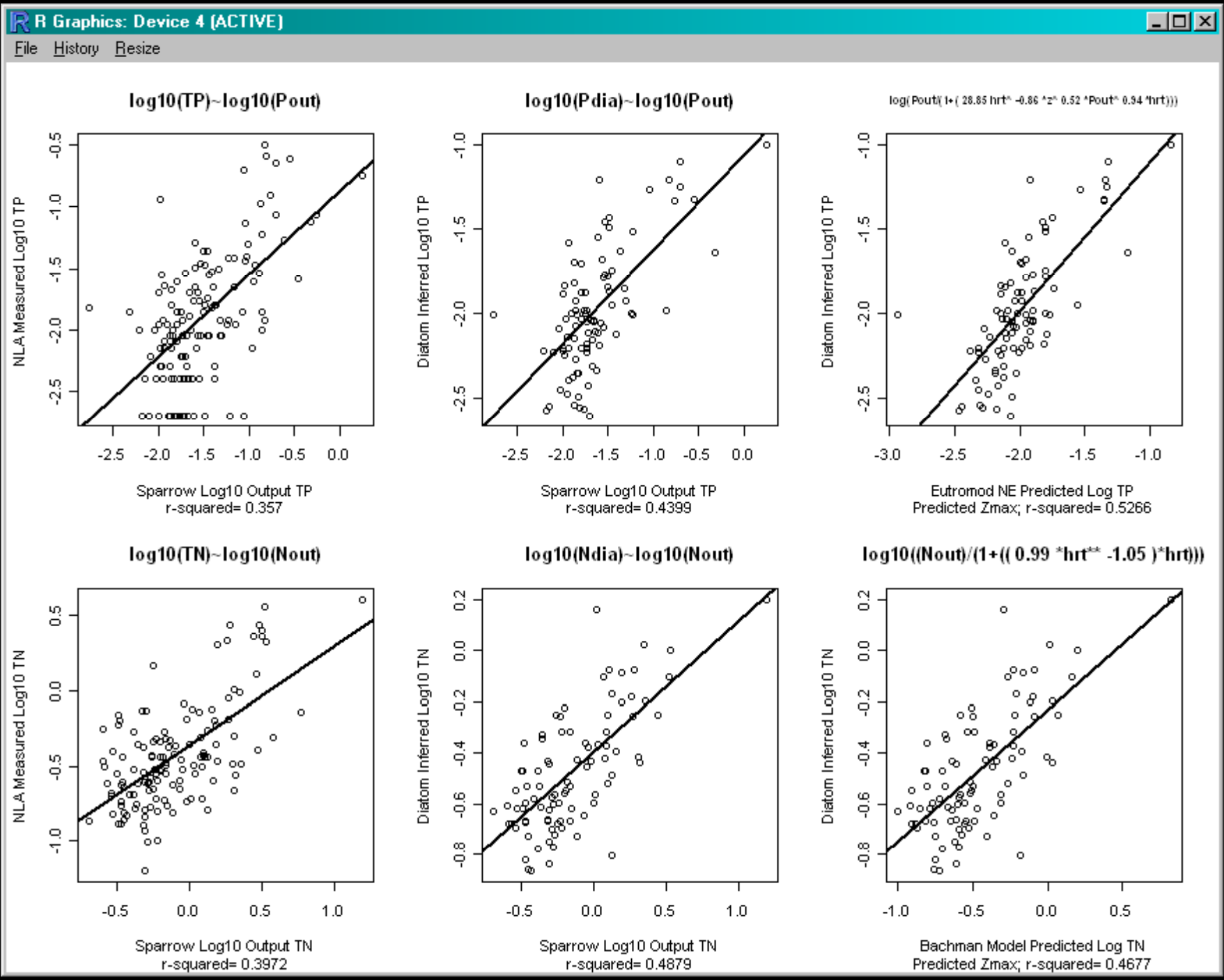
Mean annual stream-flow
Reservoir detention

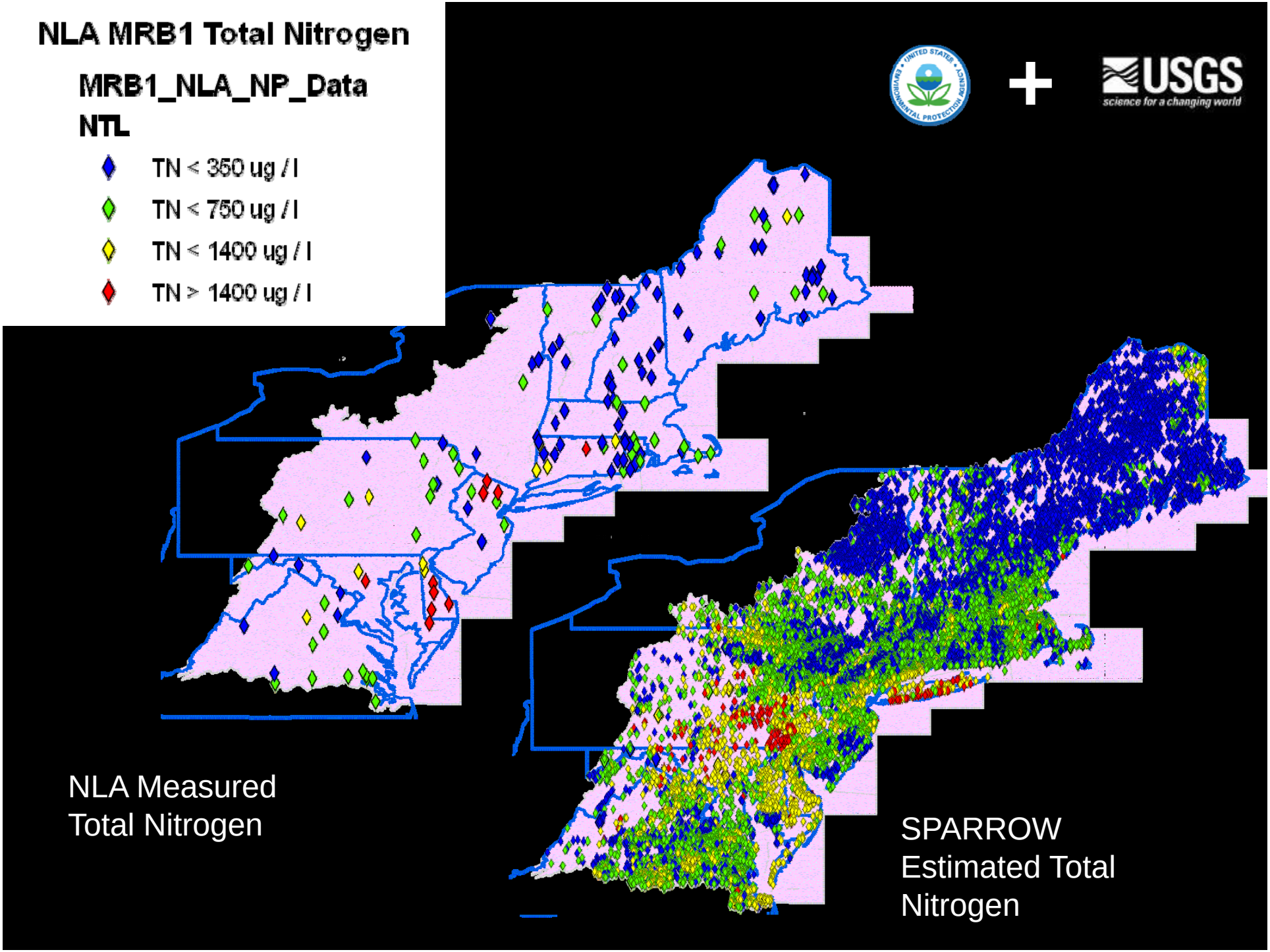


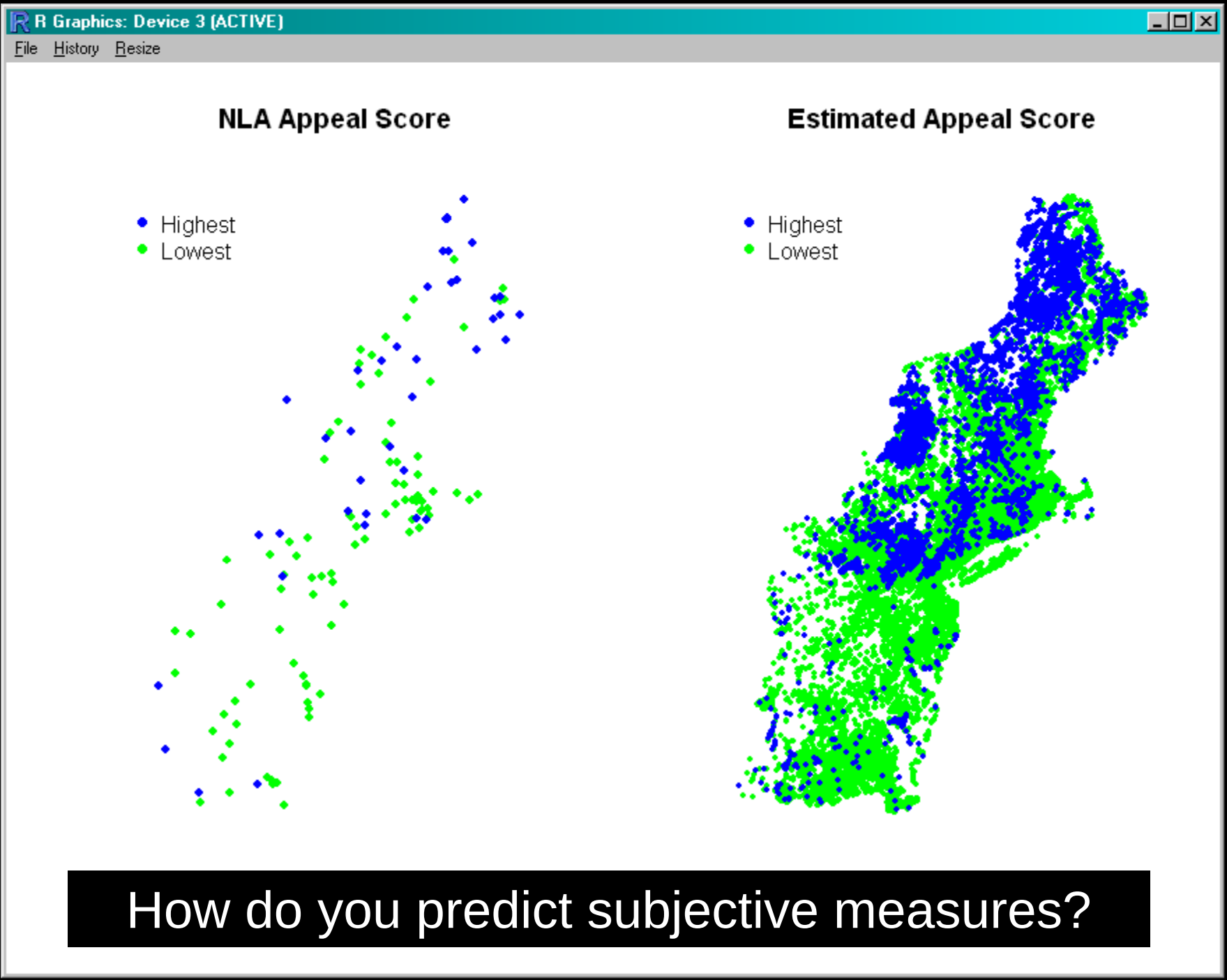


Comparison of SPARROW predicted N and P concentrations for weighted NLA sample sites (n=100) versus all lakes in MRB1 > 4ha (n=9,421)

Moore, R. B., C. M. Johnston, R. A. Smith, and B. Milstead. *in prep* (2010). Source and Delivery of Nutrients to Receiving Waters in the Northeastern and Mid-Atlantic Regions of the United States.


R Graphics: Device 4 (ACTIVE)
File History Resize
log10(TP)~log10(Pout)
NLA Measured Log10 TP
Sparrow Log10 Output TP
r-squared= 0.357
log10(Pdia)~log10(Pout)
Diatom Inferred Log10 TP
Sparrow Log10 Output TP
r-squared= 0.4399
log(Pout)(1+(28.85 hrt^ -0.86 *z^ 0.52 *Pout^ 0.94 *hrt)))
Diatom Inferred Log10 TP
Eutromod NE Predicted Log TP
Predicted Zmax; r-squared= 0.5266
log10(TN)~log10(Nout)
NLA Measured Log10 TN
Sparrow Log10 Output TN
r-squared= 0.3972
log10(Ndia)~log10(Nout)
Diatom Inferred Log10 TN
Sparrow Log10 Output TN
r-squared= 0.4879
log10((Nout)/(1+((0.99 *hrt** -1.05)*hrt)))
Diatom Inferred Log10 TN
Bachman Model Predicted Log TN
Predicted Zmax; r-squared= 0.4677


NLA MRB1 Total Nitrogen
MRB1_NLA_NP_Data
NTL
TN < 350 ug / l
TN < 750 ug / l
TN < 1400 ug / l
TN > 1400 ug / l
USGS
science for a changing world
NLA 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

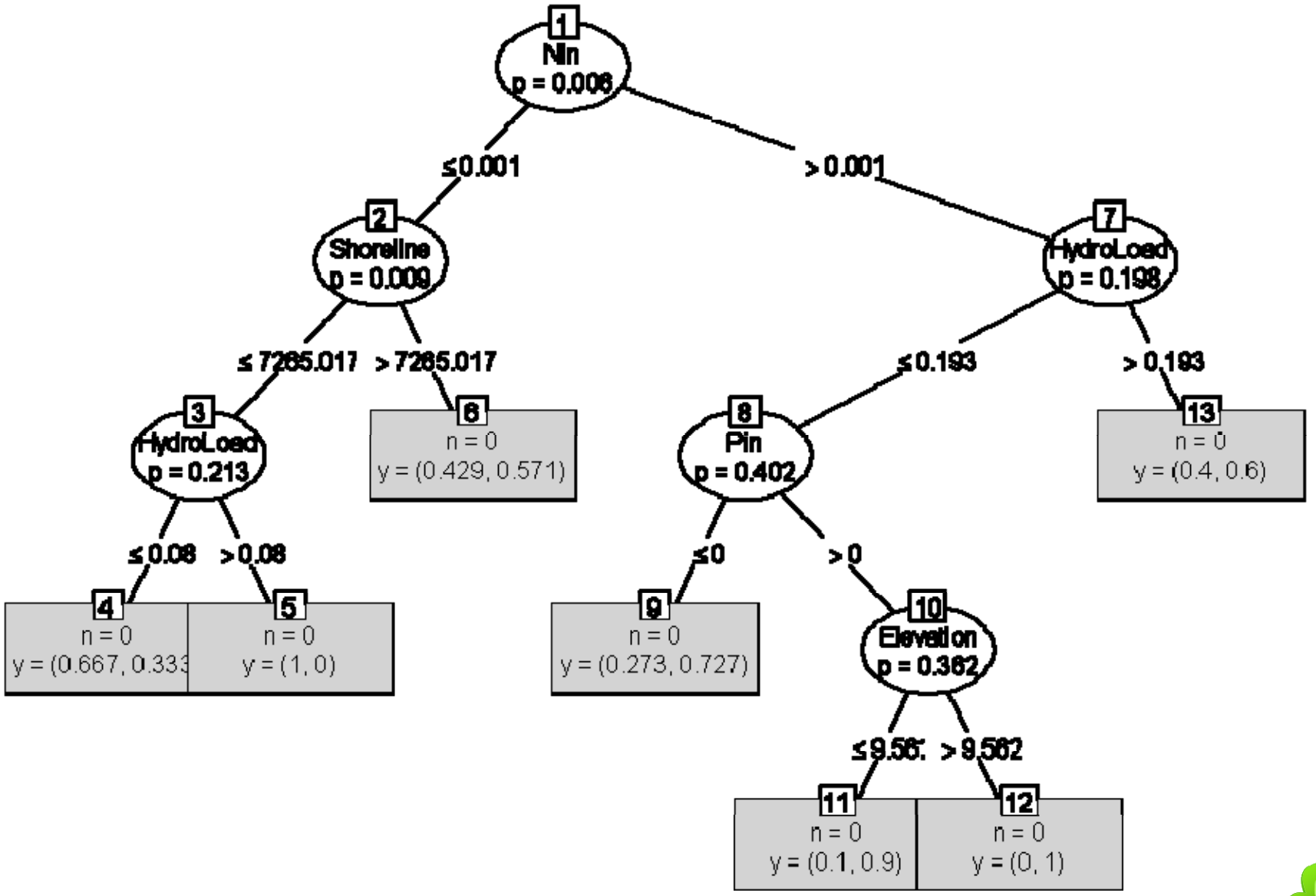
Random Forest Variables

Response Variables (Binary)

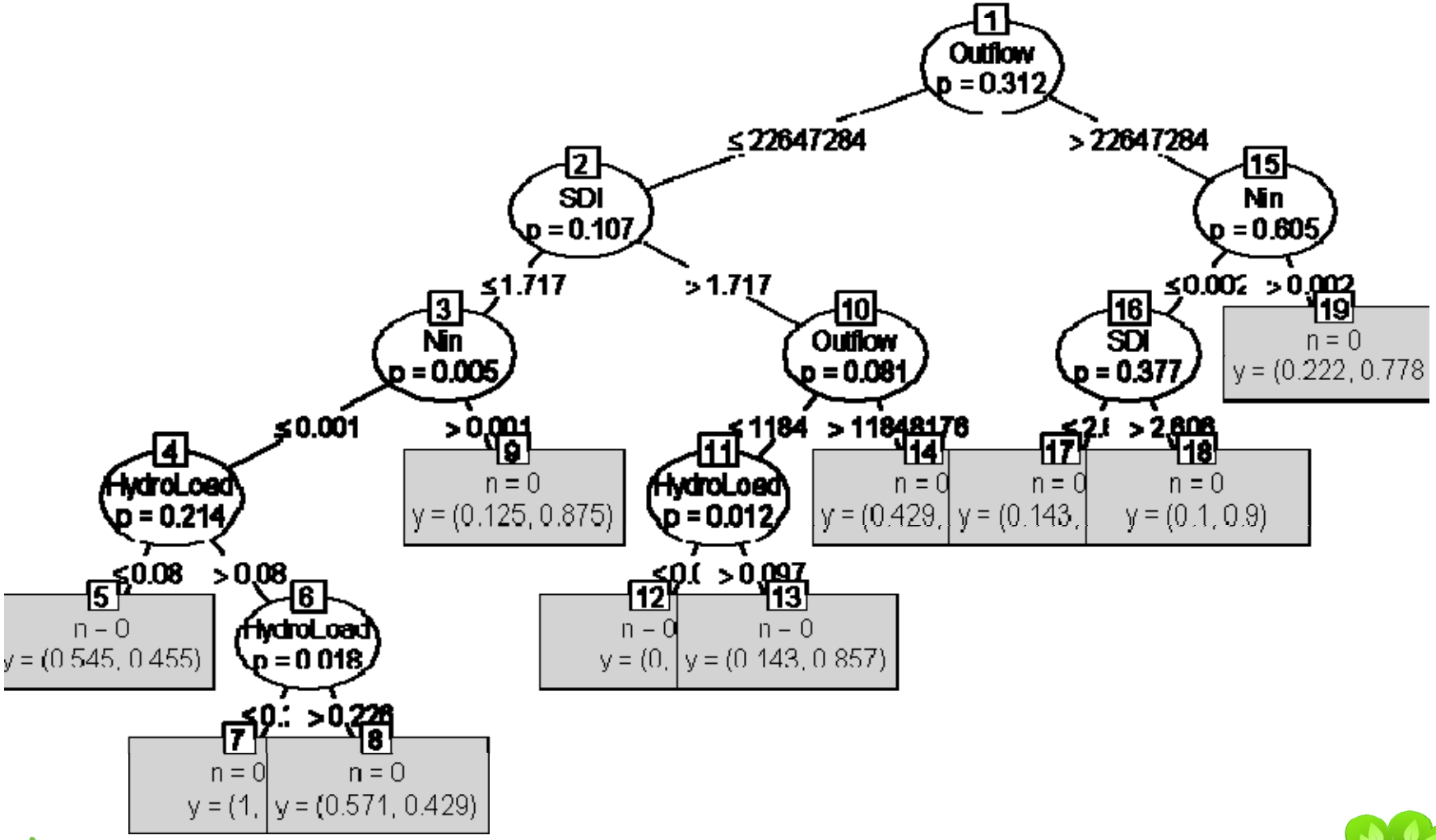
- Appeal Score
- Pristine Score
- Recreation Score
- Swimming Score
- Biotic Integrity Score
- Secchi Depth Class
- Microcystin Detected
- Cyanobacteria Count Class

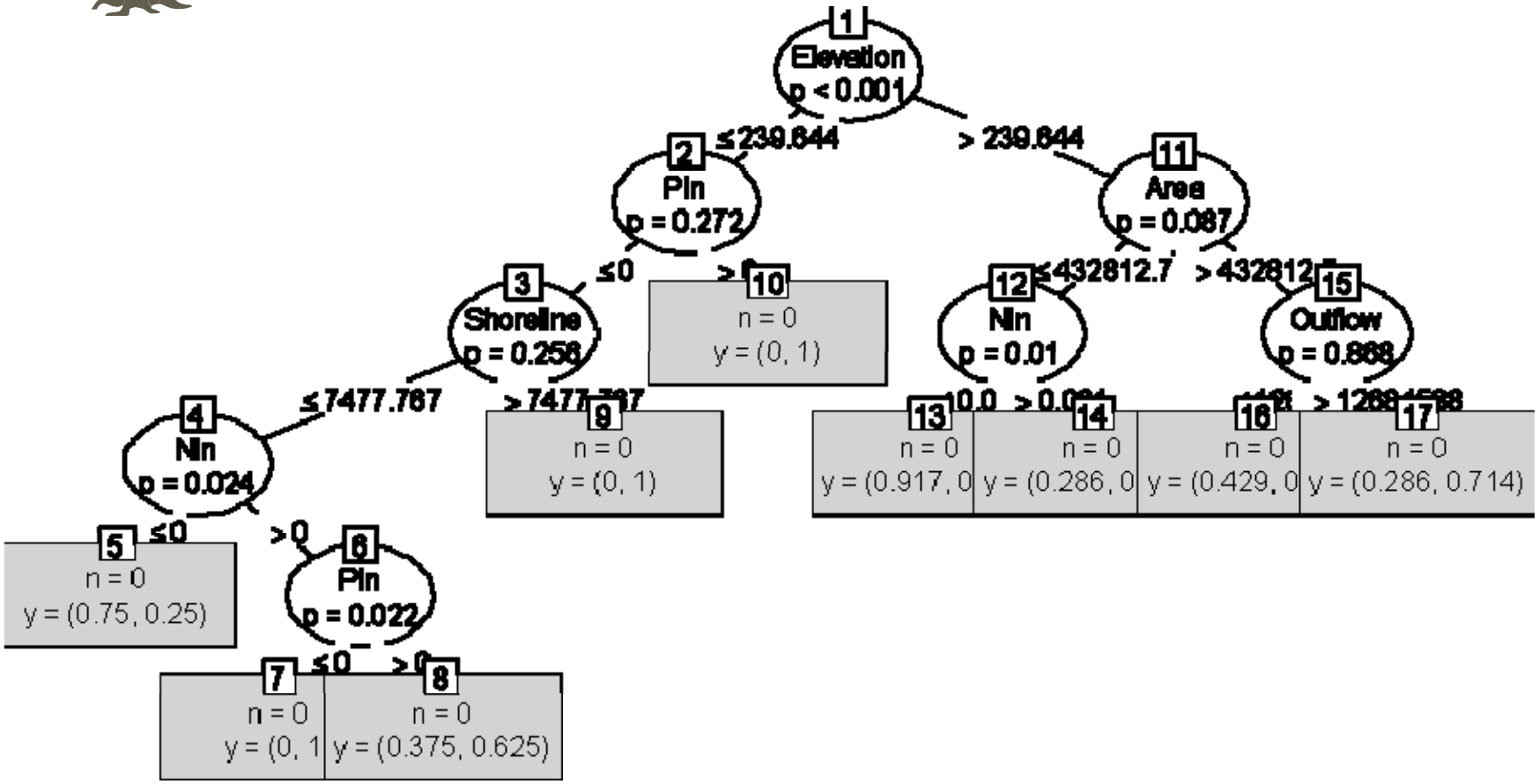
Predictor Variables

- [Phosphorus] input Conc.
- [Nitrogen] input Conc.
- Outflow (m3/yr)
- Inflow (m3/yr)
- Shoreline Development
- Hydrologic Load
- Shoreline
- Area
- Elevation

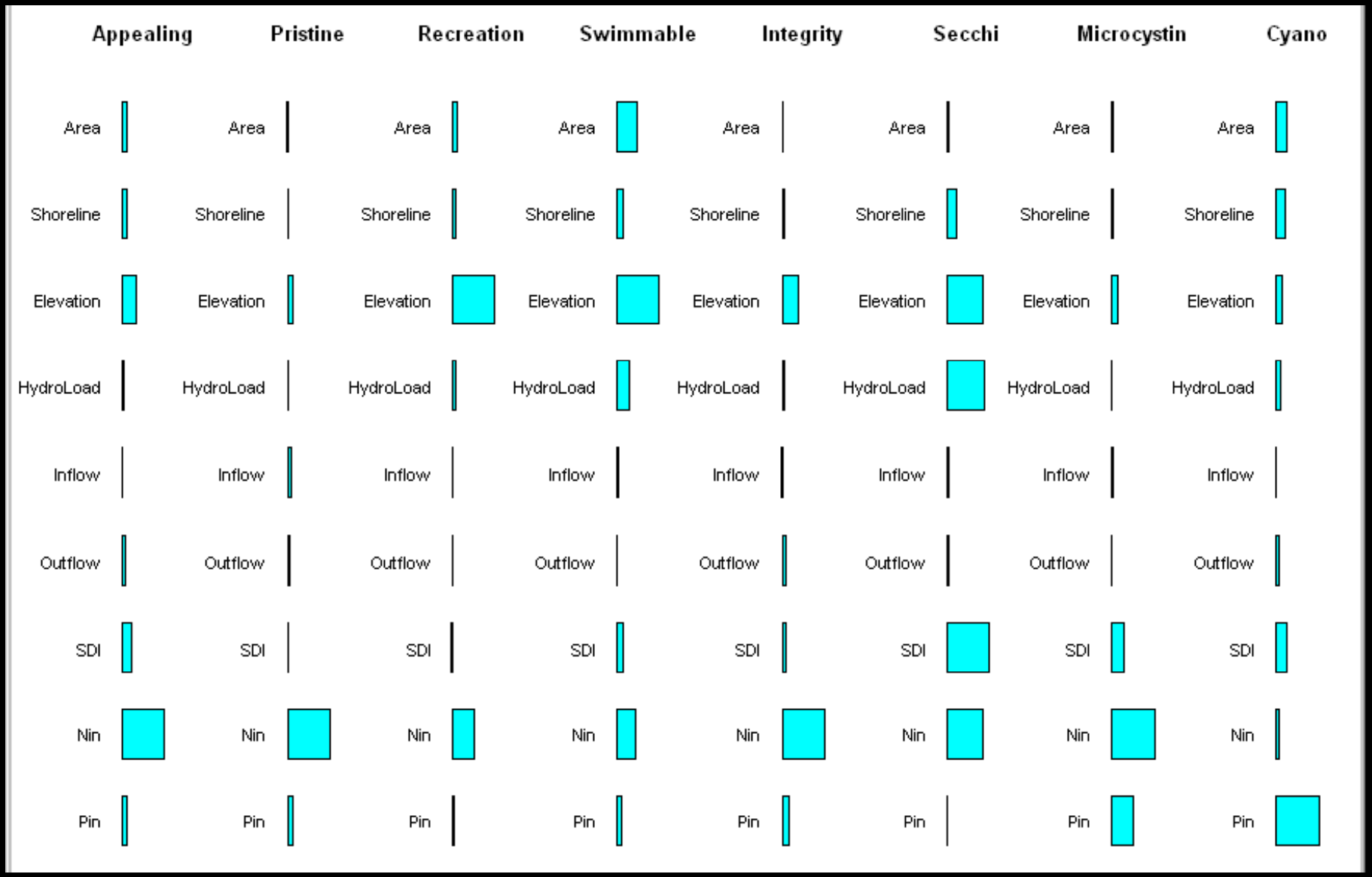


Note: n=weight for frequency data= 0


1
Outflow
p = 0.312
≤ 22647284
> 22647284
2
SDI
p = 0.107
15
Nin
p = 0.605
≤1.717
>1.717
3
Nin
p = 0.005
10
Outflow
p = 0.081
16
SDI
p = 0.377
19
n = 0
y = (0.222, 0.778
≤0.001
> 0.001
4
HydroLoad
p = 0.214
9
n = 0
y = (0.125, 0.875)
11
HydroLoad
p = 0.012
14
n = 0
17
n = 0
18
n = 0
y = (0.1, 0.9)
≤0.08
> 0.08
5
n = 0
y = (0.545, 0.455)
6
HydroLoad
p = 0.018
12
n = 0
13
n = 0
y = (0.143, 0.857)
7
n = 0
8
n = 0
y = (0.571, 0.429)

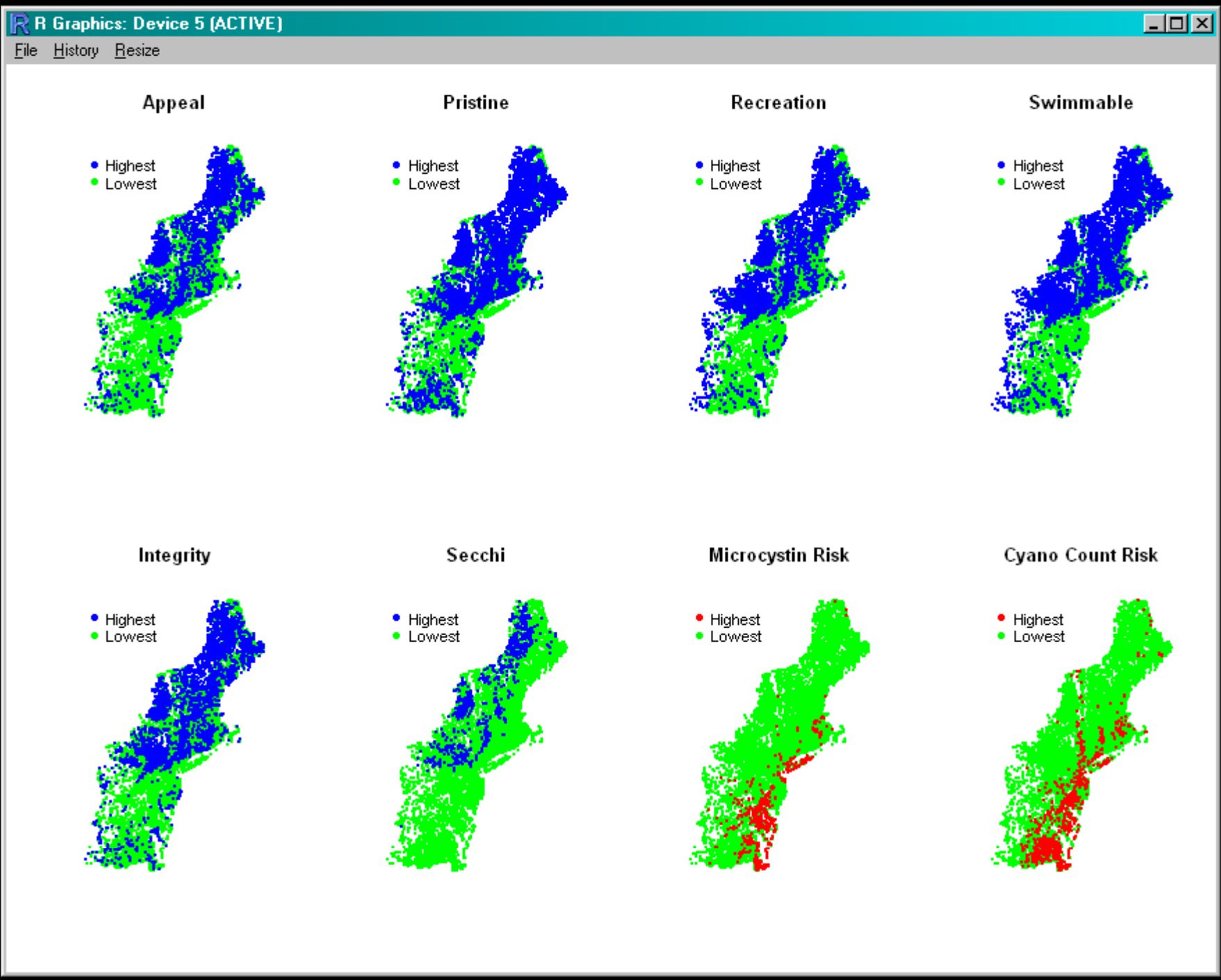

1
Elevation
p < 0.001
≤ 239.644
> 239.644
2
Pin
p = 0.272
11
Area
p = 0.087
≤ 0
> 0
3
Shoreline
p = 0.256
10
n = 0
y = (0, 1)
≤ 432812.7
> 432812
12
Nin
p = 0.01
15
Outflow
p = 0.868
≤ 7477.767
> 7477.767
4
Nin
p = 0.024
9
n = 0
y = (0, 1)
0.0
> 0.0
13
n = 0
y = (0.917, 0
14
n = 0
y = (0.286, 0
16
n = 0
y = (0.429, 0
> 1269.598
17
n = 0
y = (0.286, 0.714)
≤ 0
> 0
5
n = 0
y = (0.75, 0.25)
6
Pin
p = 0.022
≤ 0
> 0
7
n = 0
y = (0, 1
8
n = 0
y = (0.375, 0.625)

Random Forest - Variable Importance



Model Prediction Accuracy Estimates

Appealing	Pristine	Recreation	Swimmable	Integrity	Secchi	Microcystin	Cyano
0.88	0.85	0.82	0.88	0.86	0.87	0.84	0.84


R Graphics: Device 5 (ACTIVE)
File History Resize
Appeal
Highest
Lowest
Pristine
Highest
Lowest
Recreation
Highest
Lowest
Swimmable
Highest
Lowest
Integrity
Highest
Lowest
Secchi
Highest
Lowest
Microcystin Risk
Highest
Lowest
Cyano Count Risk
Highest
Lowest

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.

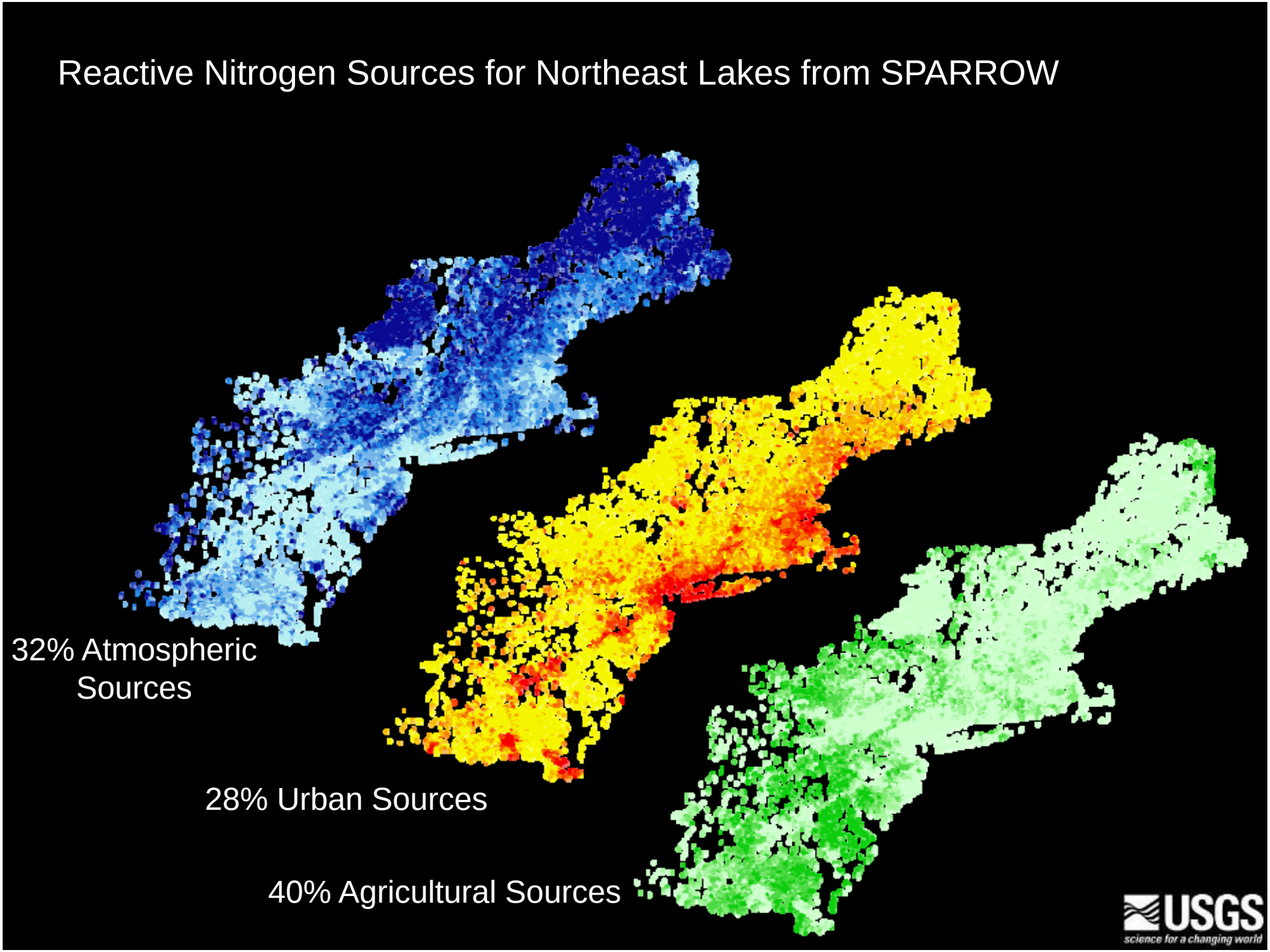
Agriculture
- Crops
- Animal Husbandry
- Forestry
- Aquaculture

Air
- Vehicle Emissions
- Power Production
- Fossil Fuel Combustion
- Industrial Processes

Urban
- Non-point Source
- Point Source

What are the Landscape Level Tradeoffs

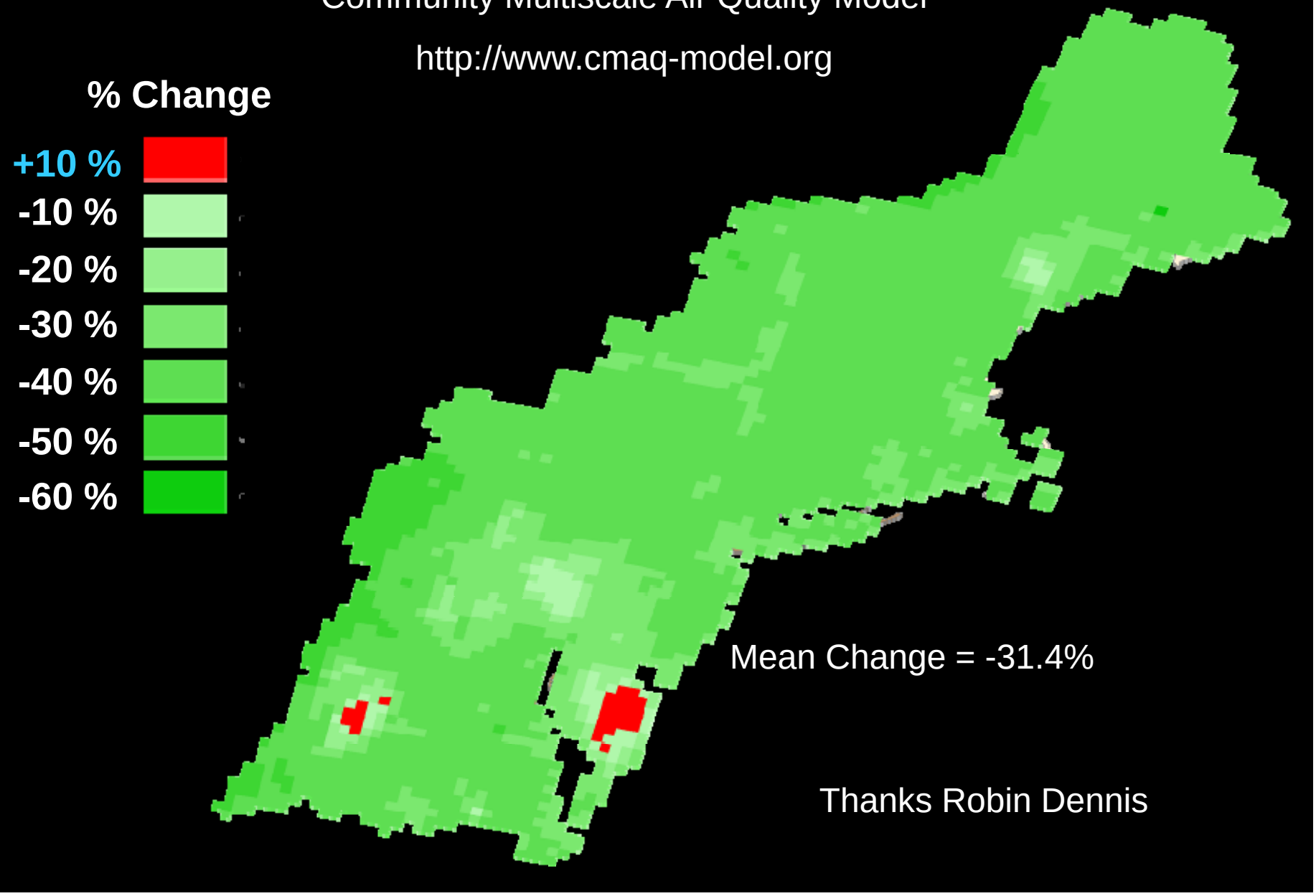
Reactive Nitrogen Sources for Northeast Lakes from SPARROW



Percent Change in Reactive Nitrogen Inputs 2012-2020

Community Multiscale Air Quality Model

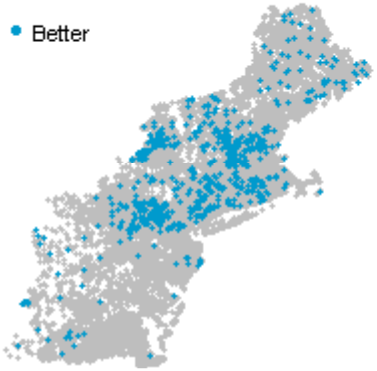
http://www.cmaq-model.org

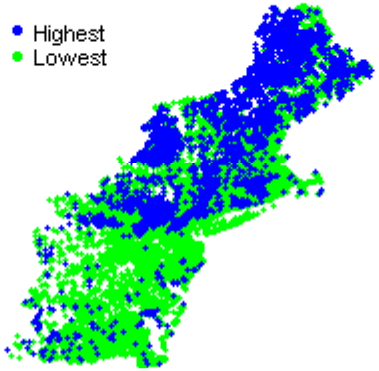


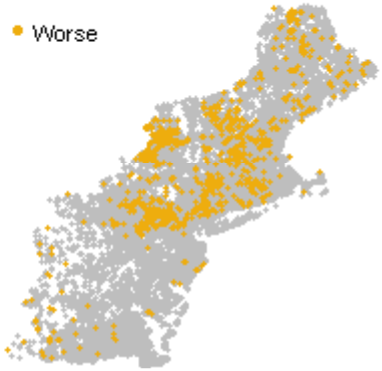
R Graphics: Device 7 (ACTIVE)

File History Resize

Aesthetic Appeal

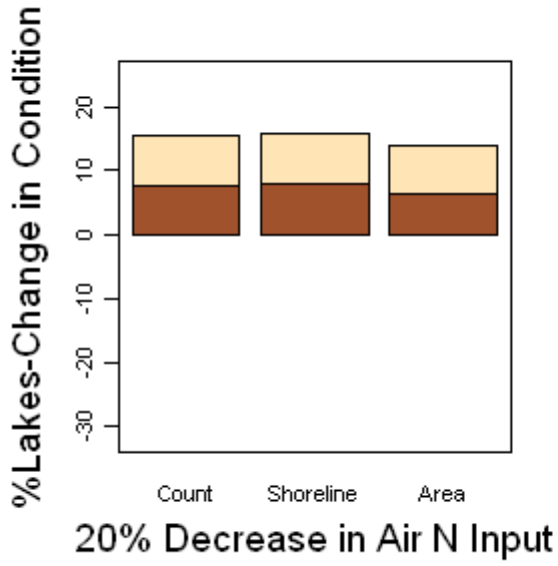


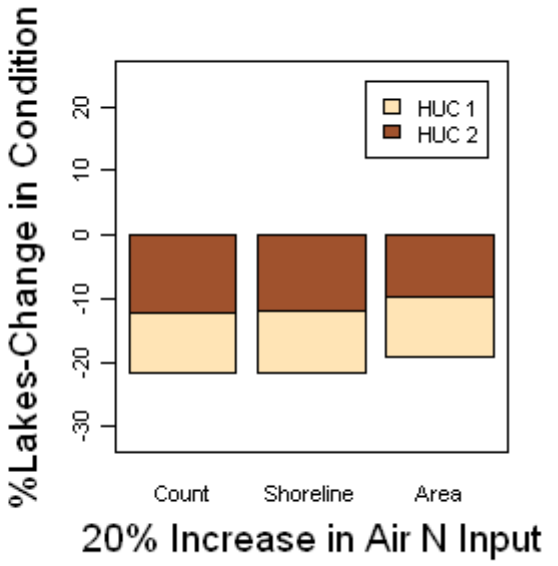




Base Condition – Lakes in Highest Appeal Class

Region	N	Shore Km	Area Km^2
1	2525	4422	490
2	1833	2688	216
Both	4358	7110	706

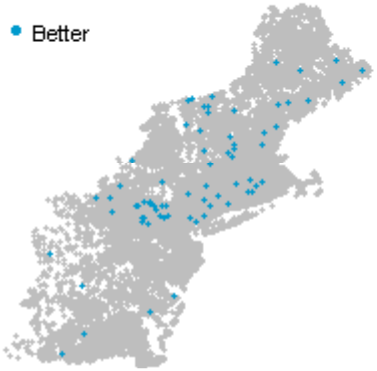


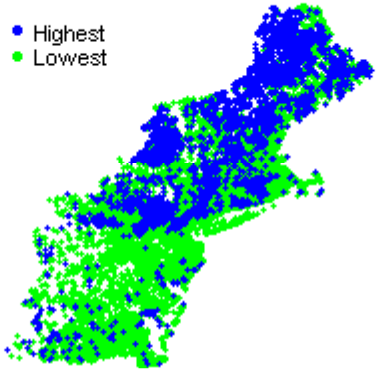


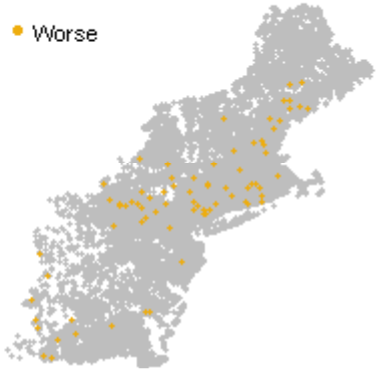
R Graphics: Device 8 (ACTIVE)

File History Resize

Aesthetic Appeal

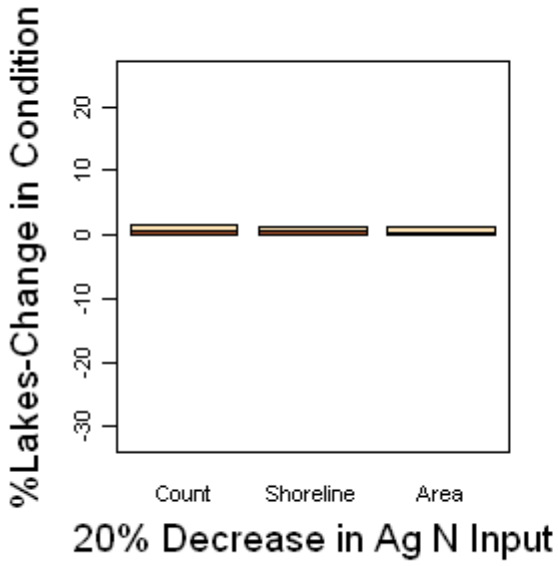


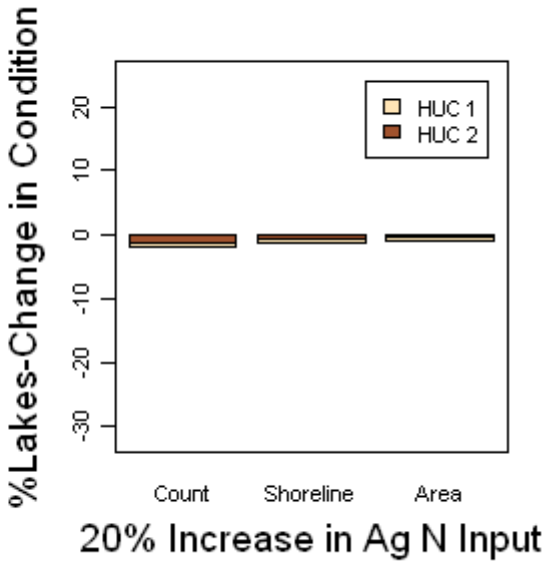




Base Condition – Lakes in Highest Appeal Class

Region	N	Shore Km	Area Km^2
1	2525	4422	490
2	1833	2688	216
Both	4358	7110	706

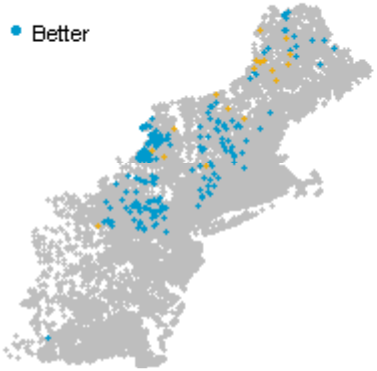


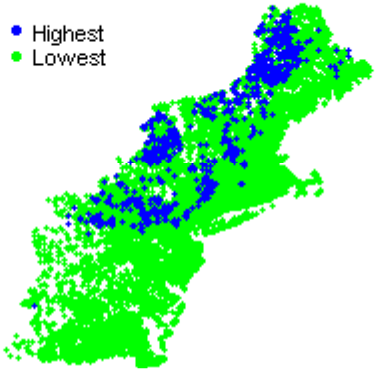


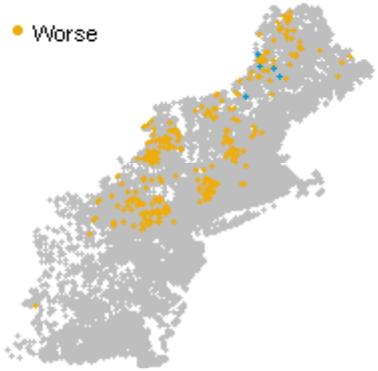
R Graphics: Device 2 (ACTIVE)

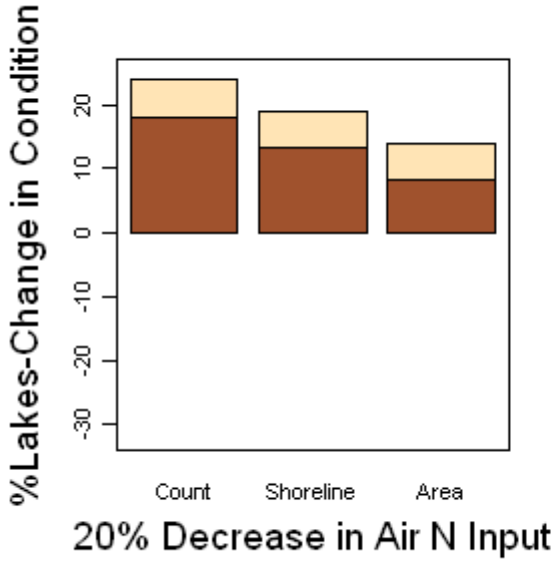
File History Resize

Secchi Transparency



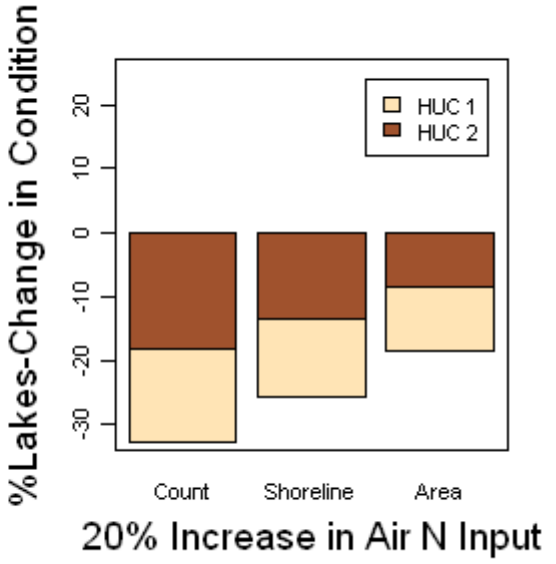






Base Condition – Lakes in Highest Secchi Class

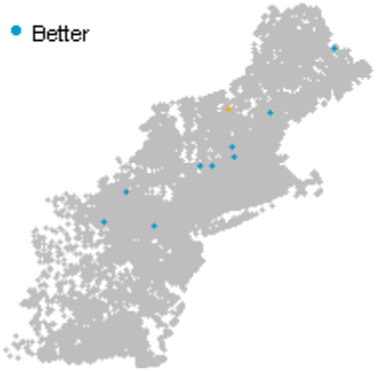
Region	N	Shore Km	Area Km^2
1	525	1446	240
2	389	814	94
Both	914	2260	334

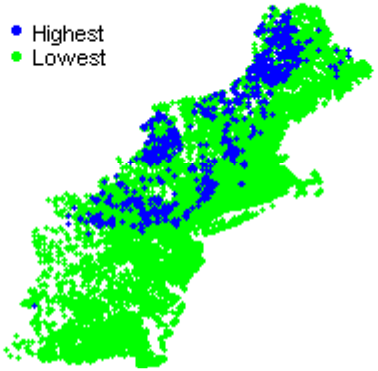


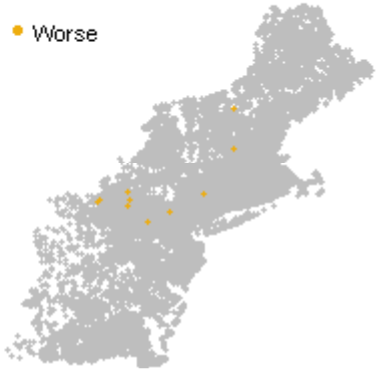
R Graphics: Device 3 (inactive)

File History Resize

Secchi Transparency

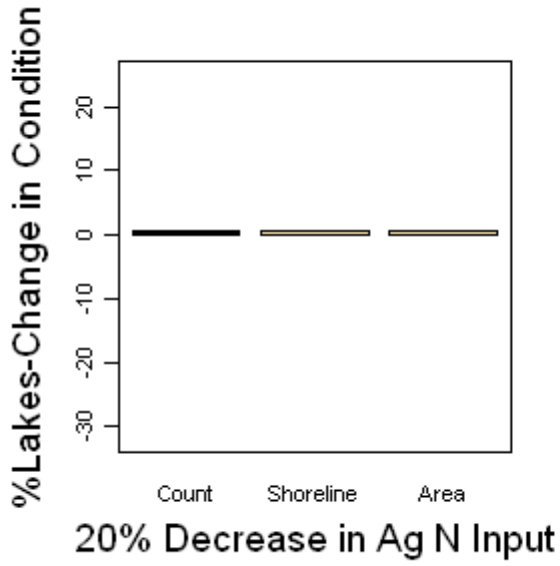


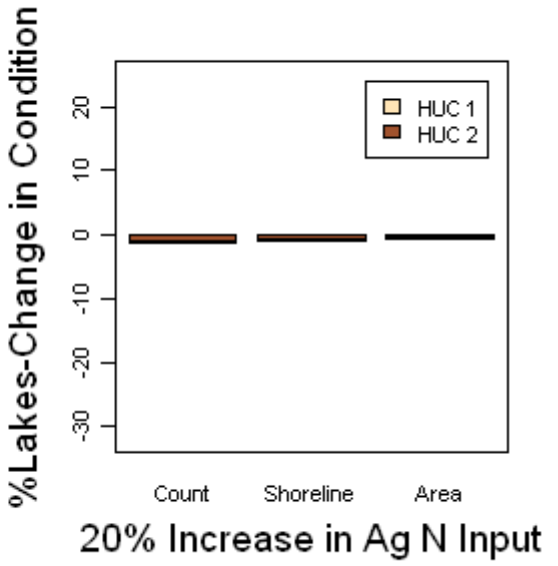




Base Condition – Lakes in Highest Secchi Class

Region	N	Shore Km	Area Km^2
1	525	1446	240
2	389	814	94
Both	914	2260	334

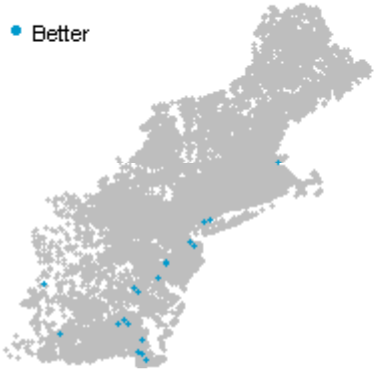


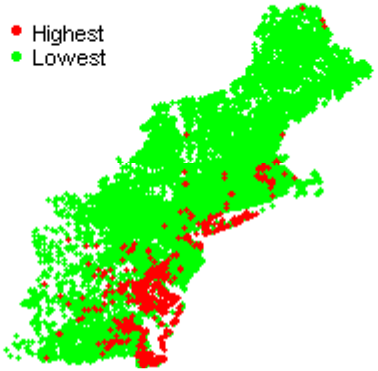


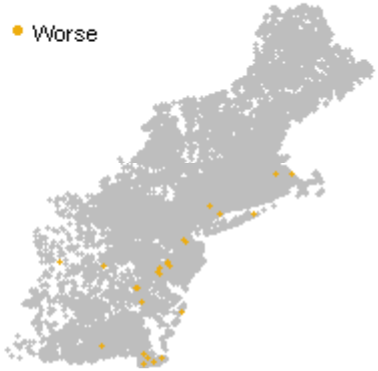
R Graphics: Device 8 (inactive)

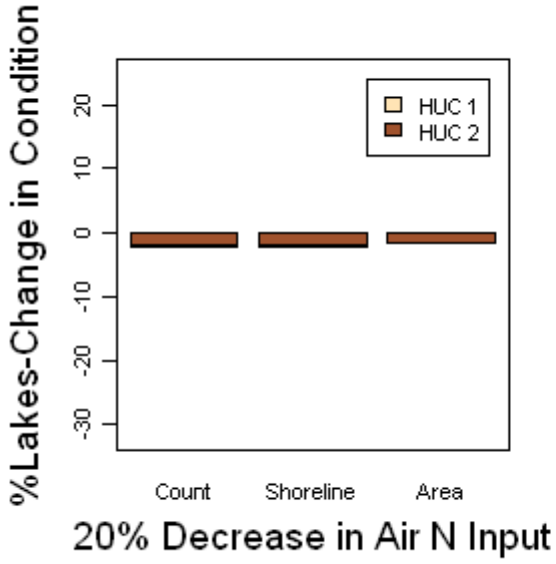
File History Resize

Microcystin Risk



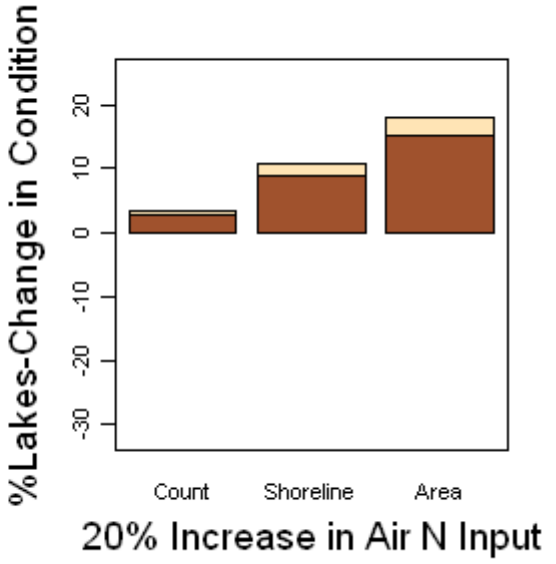






Base Condition – Lakes in Highest Risk Class

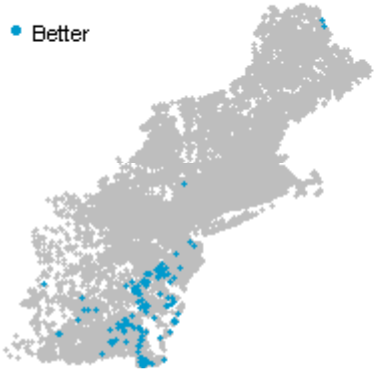
Region	N	Shore Area Km	Km^2
1	55	195	34
2	810	2730	11
Both	865	2925	245

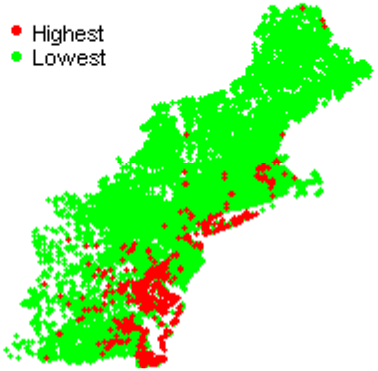


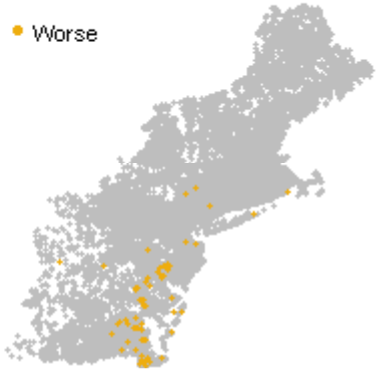
R Graphics: Device 8 (inactive)

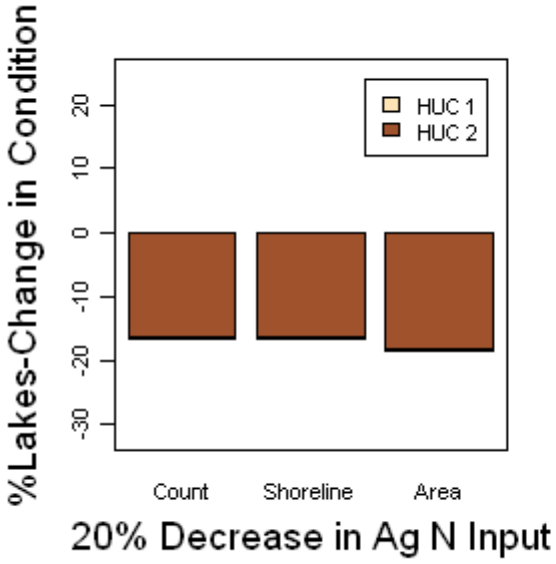
File History Resize

Microcystin Risk



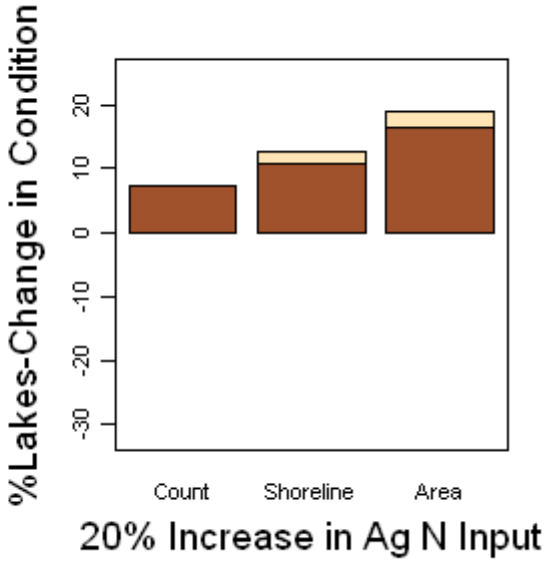


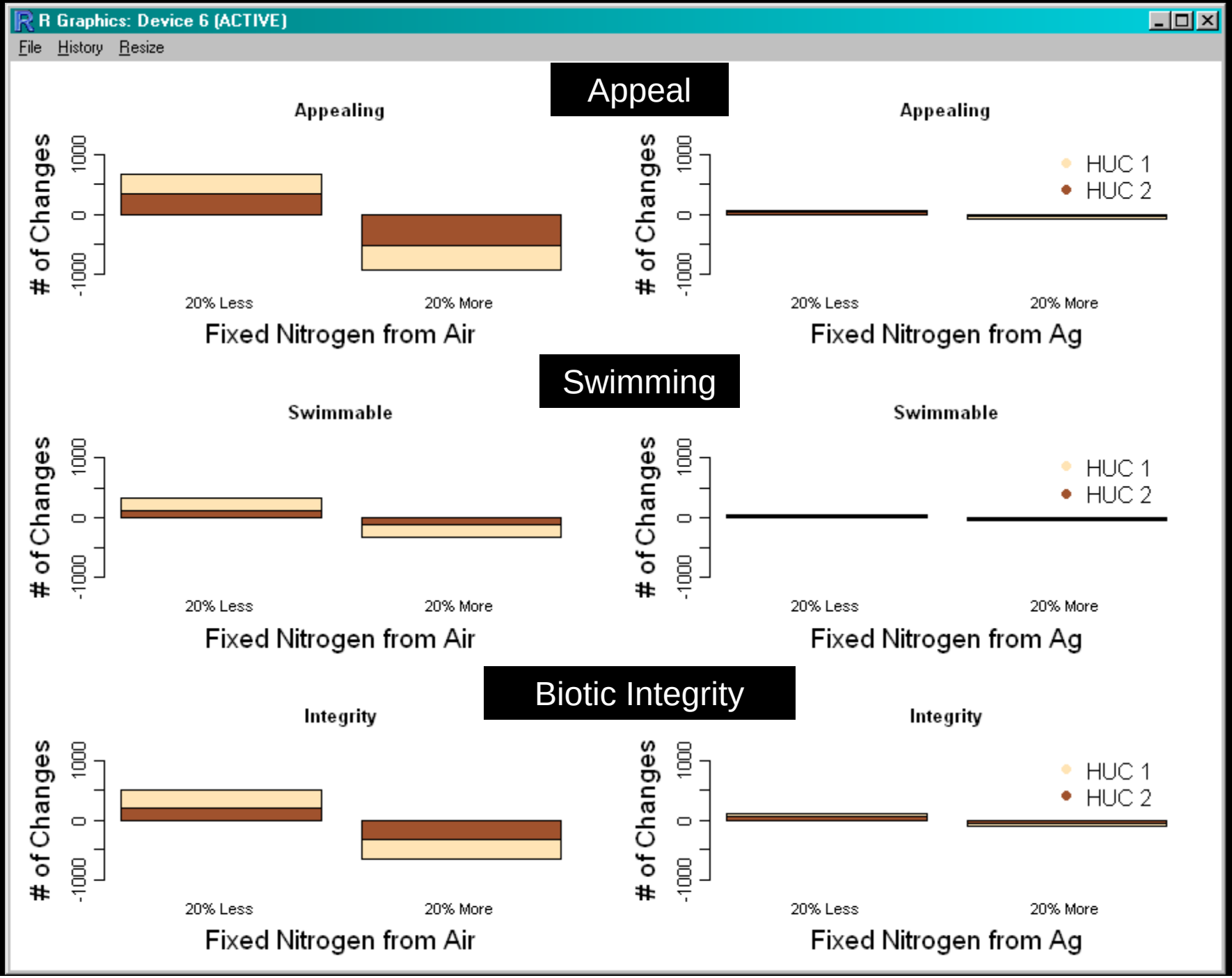


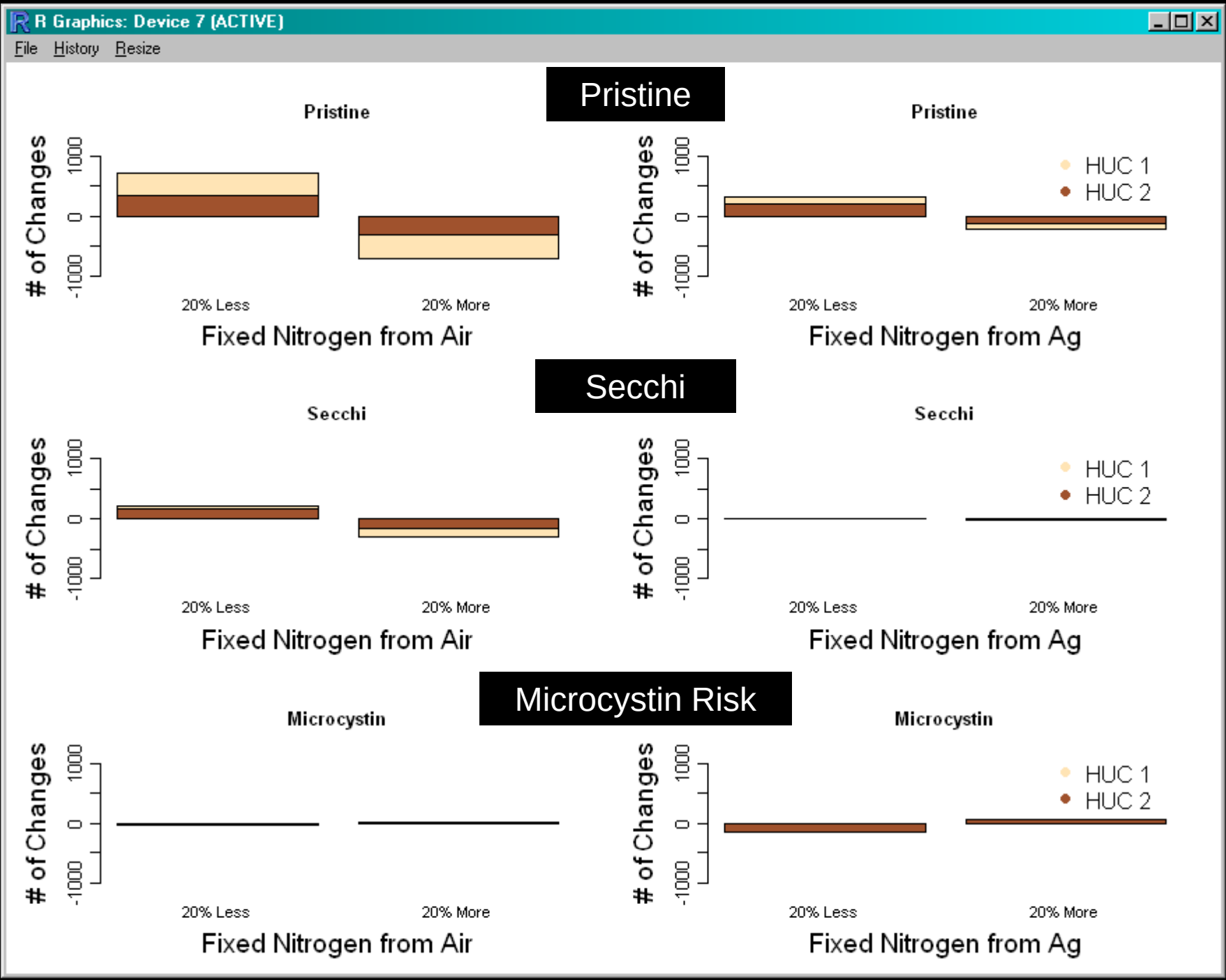


Base Condition – Lakes in Highest Risk Class

Region	N	Shore Km	Area Km²
1	55	195	34
2	810	2730	11
Both	865	2925	245




R Graphics: Device 6 (ACTIVE)
File History Resize
Appeal
Appealing
# of Changes
1000
0
-1000
20% Less
20% More
Fixed Nitrogen from Air
Appealing
HUC 1
HUC 2
# of Changes
1000
0
-1000
20% Less
20% More
Fixed Nitrogen from Ag
Swimming
Swimmable
# of Changes
1000
0
-1000
20% Less
20% More
Fixed Nitrogen from Air
Swimmable
HUC 1
HUC 2
# of Changes
1000
0
-1000
20% Less
20% More
Fixed Nitrogen from Ag
Biotic Integrity
Integrity
# of Changes
1000
0
-1000
20% Less
20% More
Fixed Nitrogen from Air
Integrity
HUC 1
HUC 2
# of Changes
1000
0
-1000
20% Less
20% More
Fixed Nitrogen from Ag


R Graphics: Device 7 (ACTIVE)
File History Resize
Pristine
Pristine
# of Changes
1000
0
-1000
20% Less
20% More
Fixed Nitrogen from Air
Pristine
# of Changes
1000
0
-1000
HUC 1
HUC 2
20% Less
20% More
Fixed Nitrogen from Ag
Secchi
Secchi
# of Changes
1000
0
-1000
20% Less
20% More
Fixed Nitrogen from Air
Secchi
# of Changes
1000
0
-1000
HUC 1
HUC 2
20% Less
20% More
Fixed Nitrogen from Ag
Microcystin Risk
Microcystin
# of Changes
1000
0
-1000
20% Less
20% More
Fixed Nitrogen from Air
Microcystin
# of Changes
1000
0
-1000
HUC 1
HUC 2
20% Less
20% More
Fixed Nitrogen from Ag

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


Thank You