Exploring Algal Community Dynamics Across Varying Enrichment Conditions using GIS and Statistical Methods to Develop Holistic Nutrient Criteria in CT River and Streams

Mary Becker

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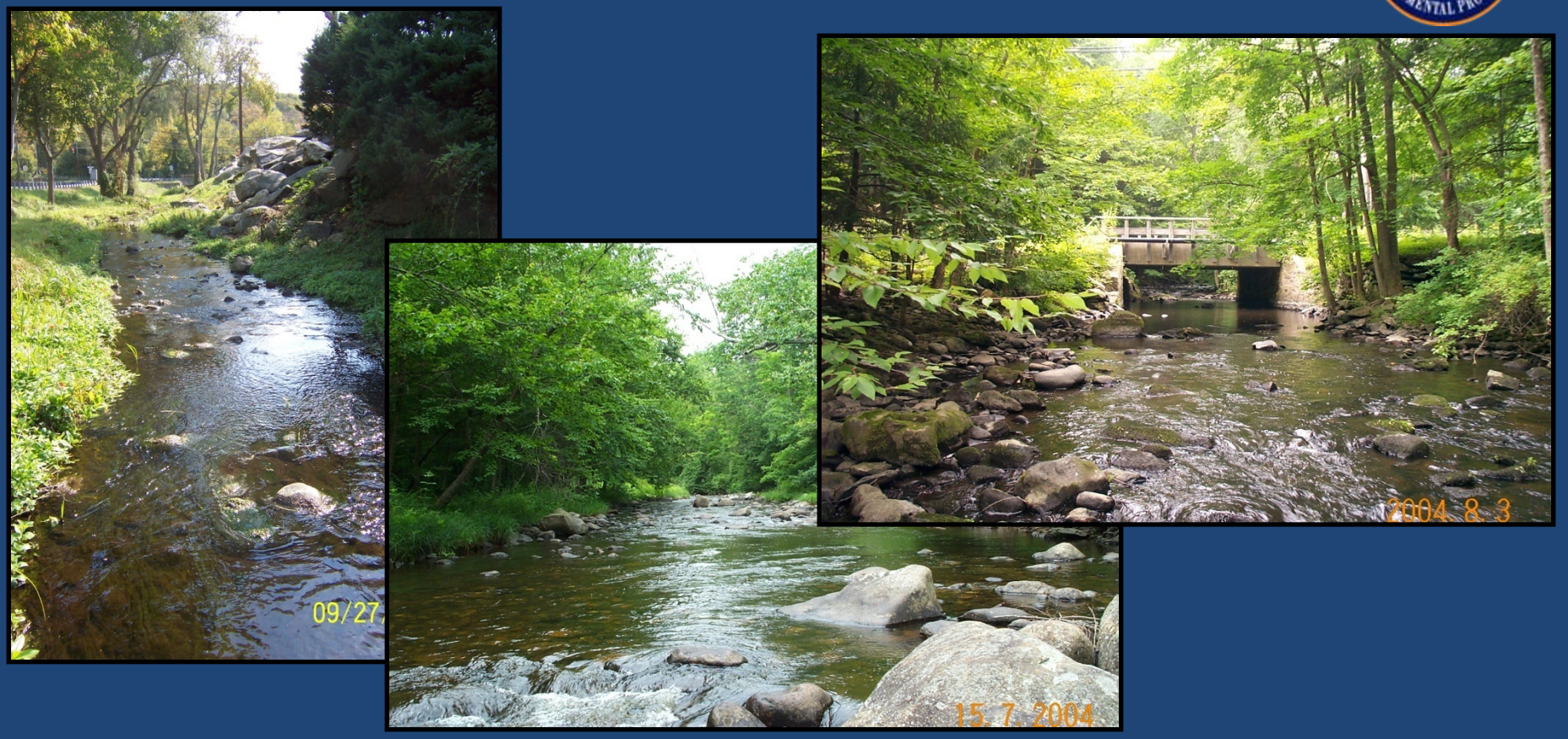
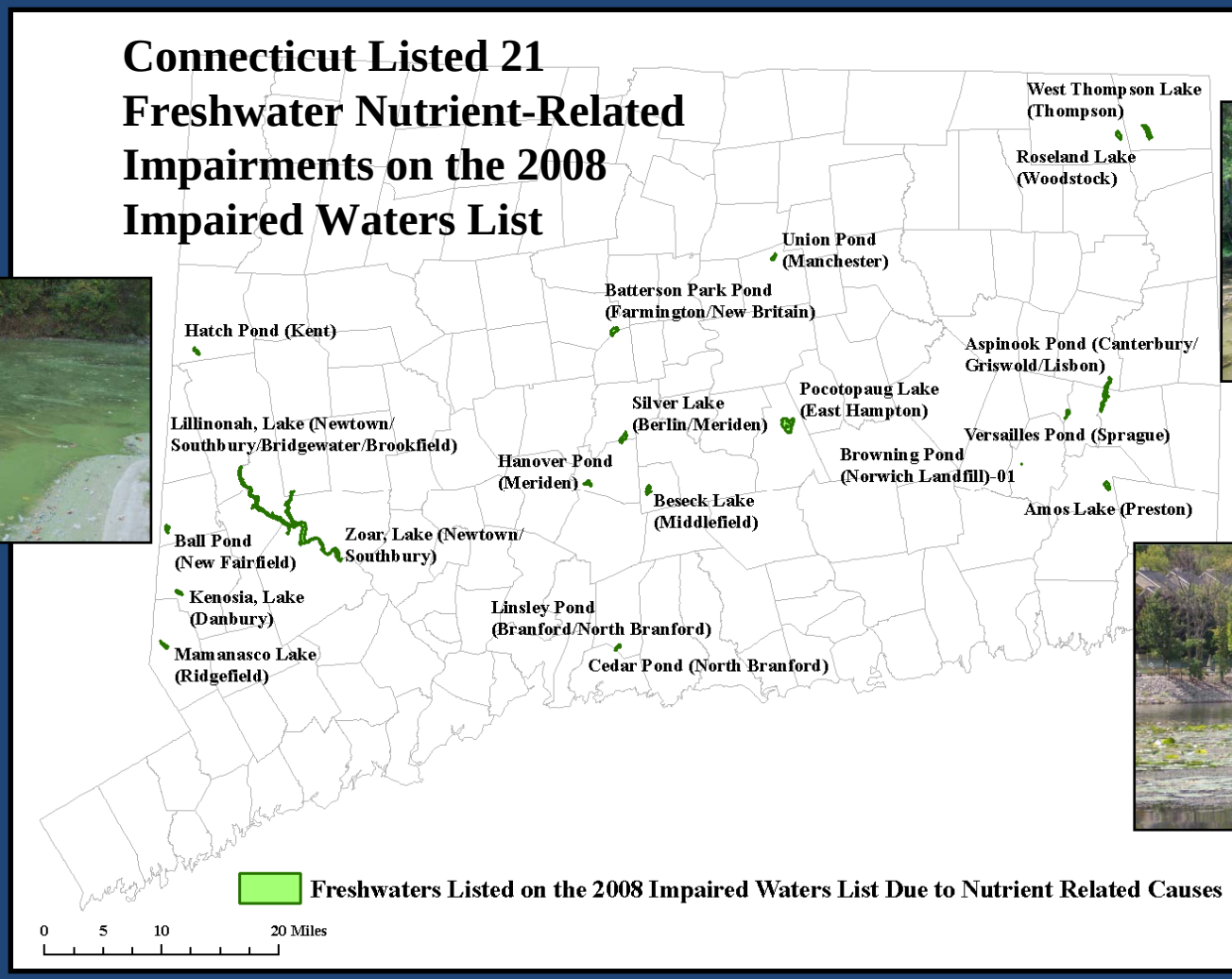
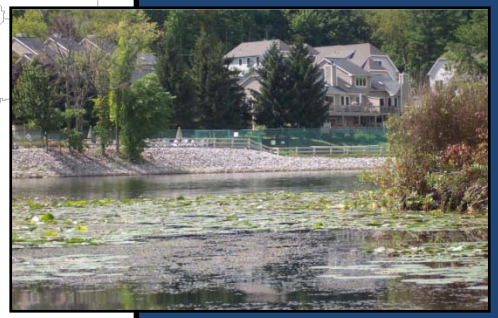


NEAEB 2010

NUTRIENT IMPAIRMENTS

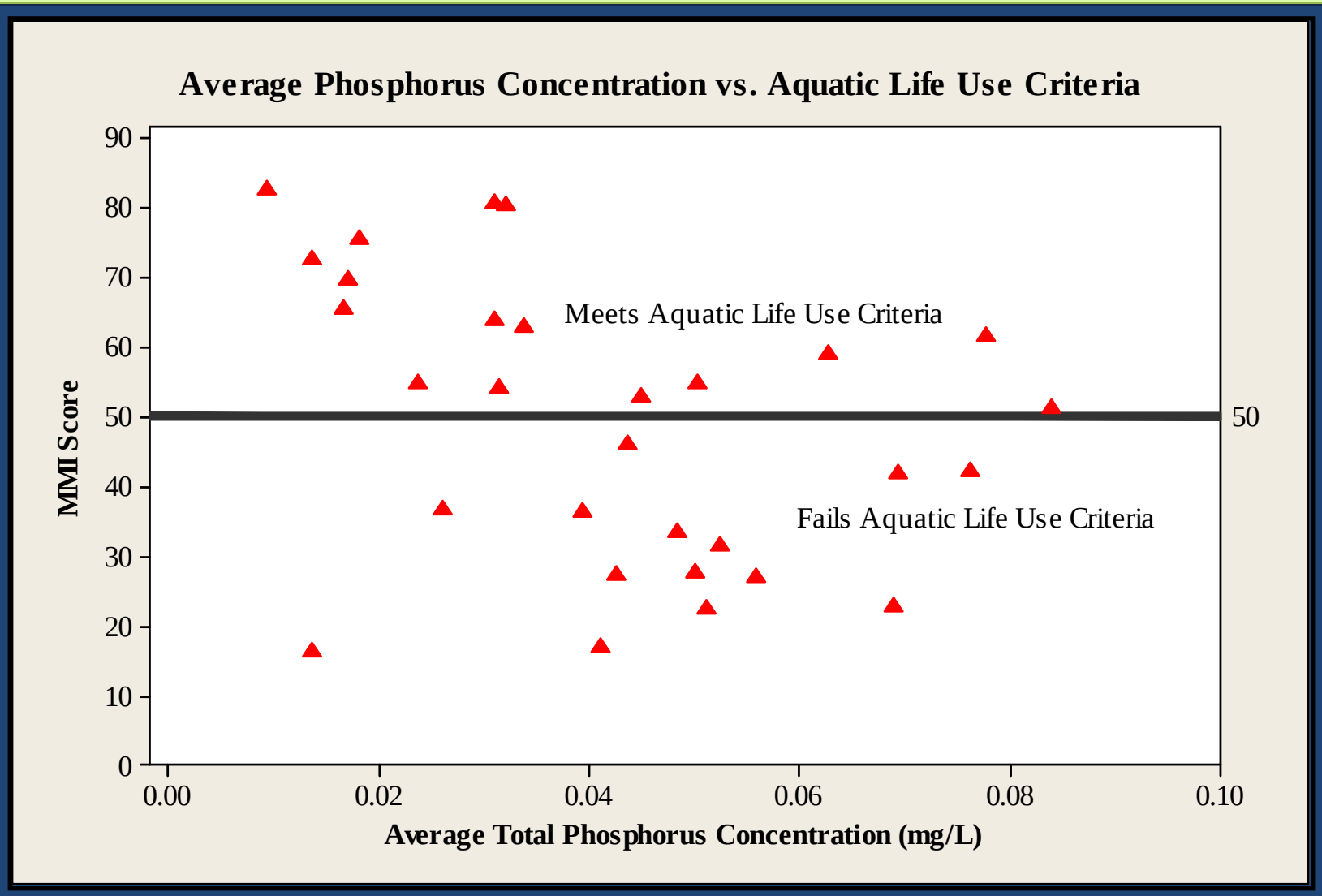
EPA cites nutrients (nitrogen and phosphorus) as one of the leading causes of water quality impairment in our Nation's rivers, lakes and estuaries.





Issues In Developing a Single Numeric Criterion

Phosphorus is Not a Threshold Pollutant. Traditional Toxicity Tests Do Not Result in Acute and Chronic Values. Traditional In-Stream Aquatic Life Measures Do Not Respond Directly to Nutrients.



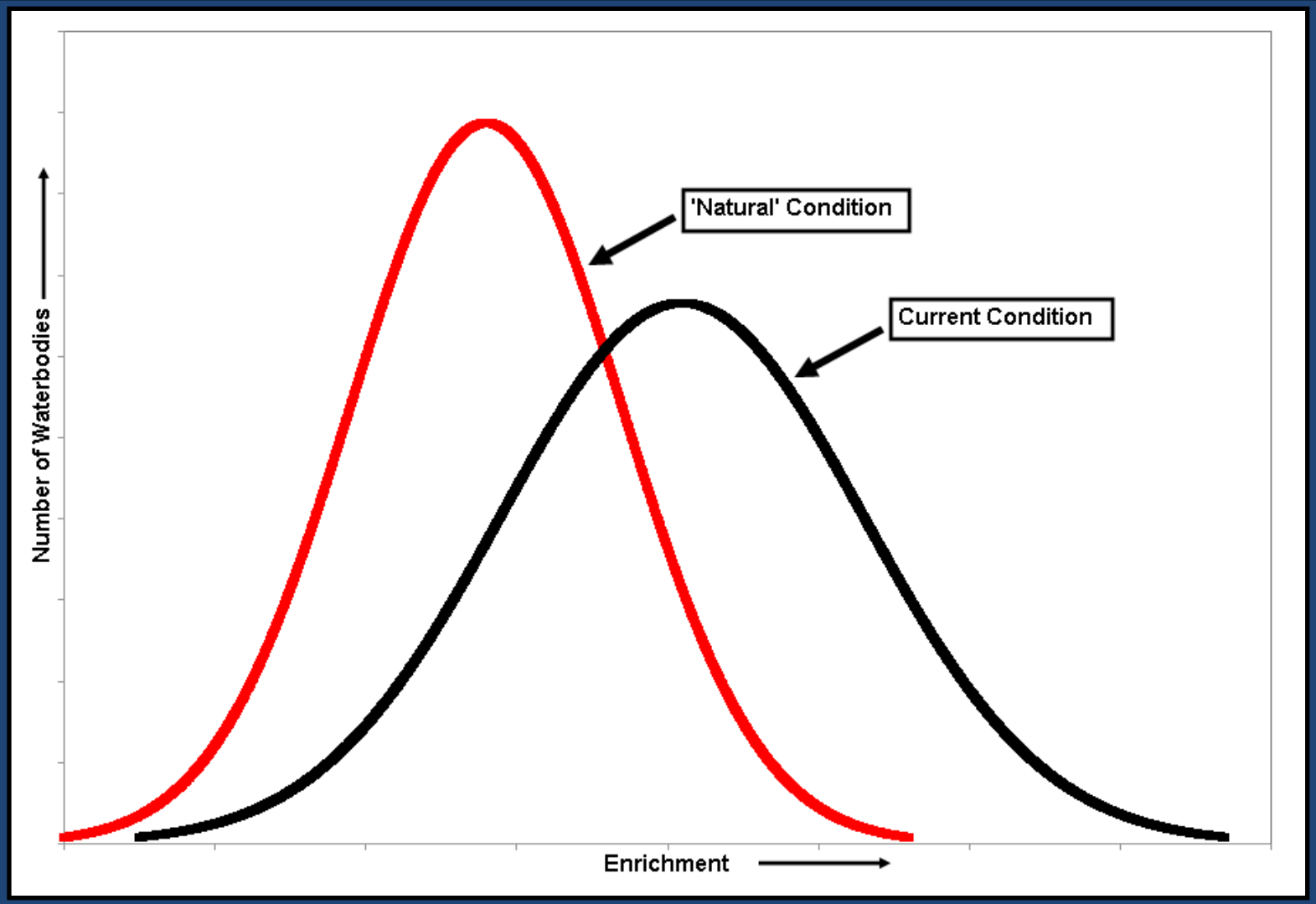
Issues In Developing a Single Numeric Criterion

Aquatic system response to nutrients fall along a gradient of effects. The level of enrichment in waterbodies results from nutrient input in addition to other habitat conditions (light, temperature and flow).

Varying Enrichment Conditions Supporting Healthy Aquatic Life Communities and Recreational Uses

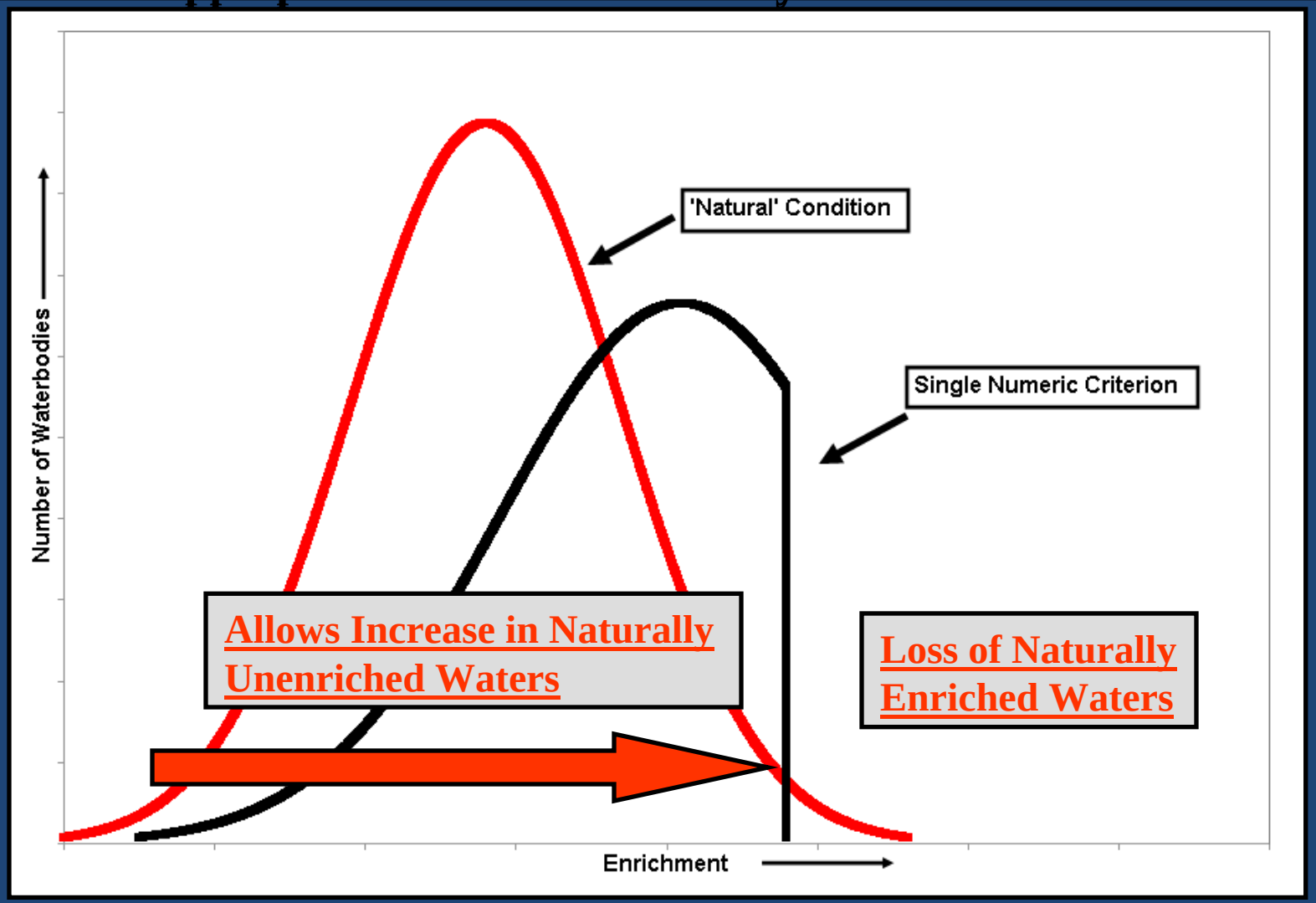
Issues In Developing a Single Numeric Criterion

Enrichment varies naturally in response to nutrient input as well as other habitat factors (light, temperature, flow etc.) Excess nutrient input and anthropogenic alterations to the habitat has shifted the range of enrichment conditions in streams.



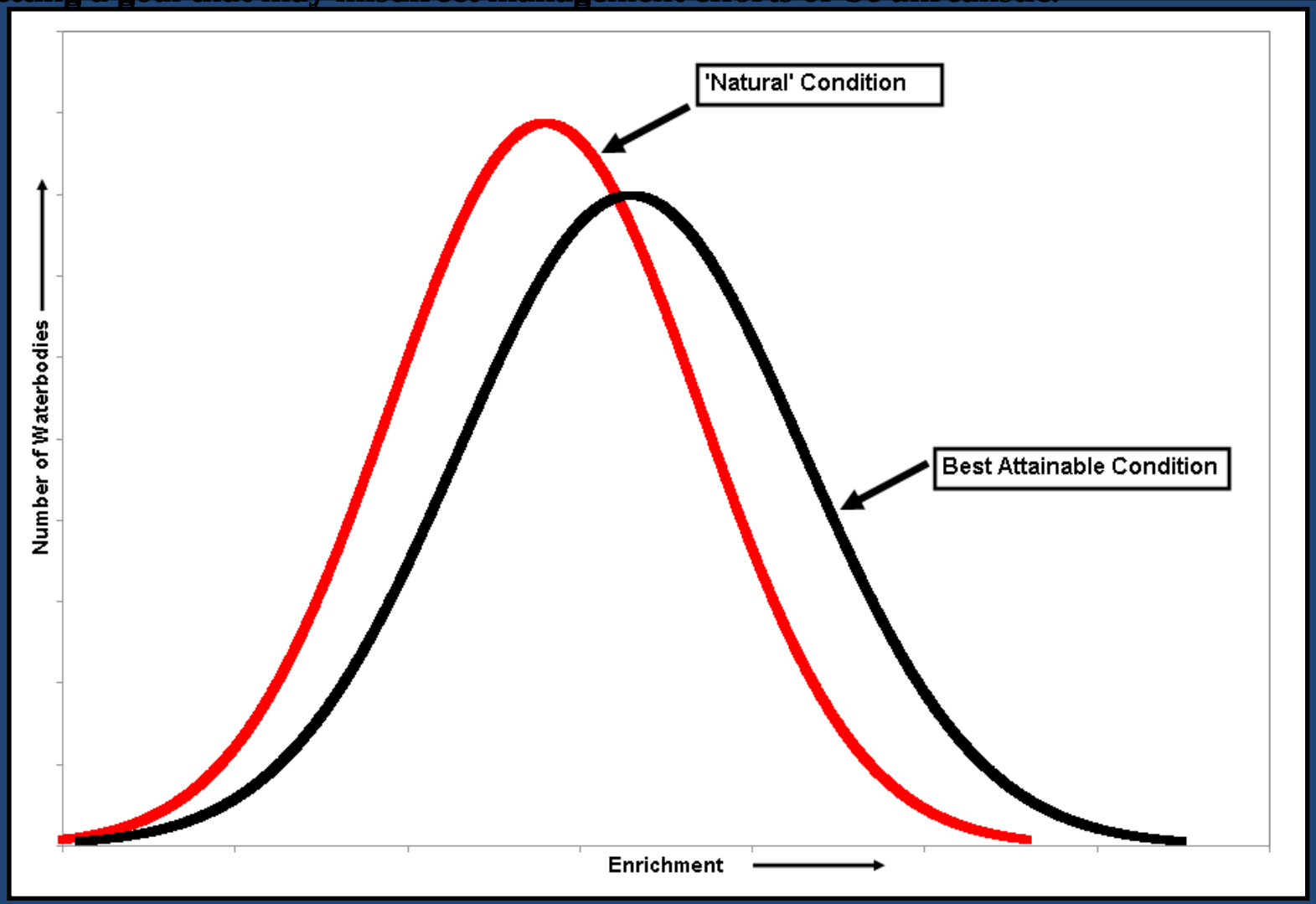
Issues In Developing a Single Numeric Criterion

Application of a single numeric criterion creates a truncated distribution. It allows for significant increases in enrichment to minimally enriched water resources before exceeding criteria and triggering management action. It also sets an inappropriate criteria for naturally enriched waters.



Issues In Developing a Single Numeric Criterion

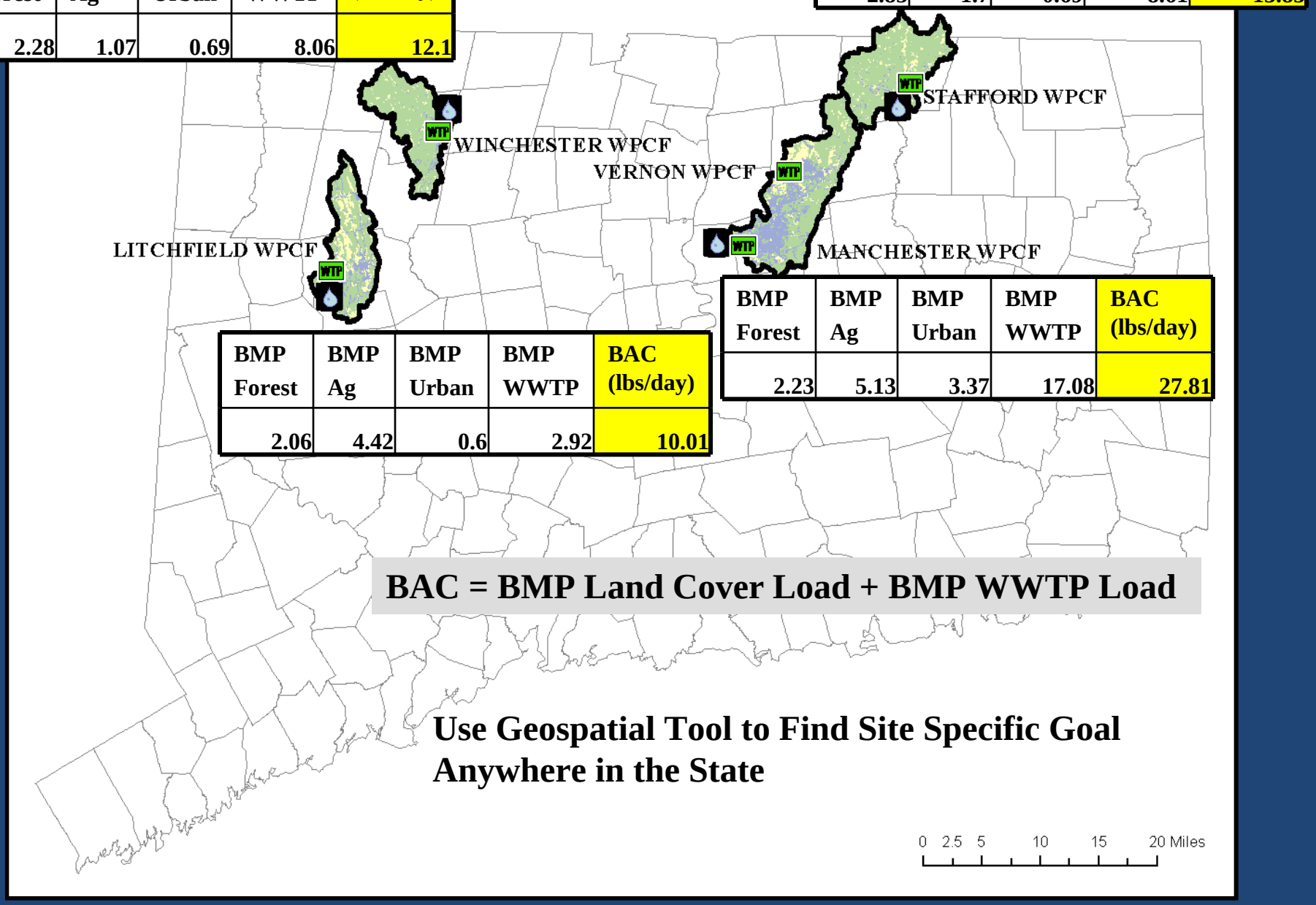
Aquatic systems cannot return to a pre-existing state or equilibrium due to the dynamic nature of those systems. Criteria development must not only allow for the trophic tendencies of the waterbody that should prevail, but also needs to allow for human presence that has permanently altered most ecosystems from effects of watershed uses and climate change rather than setting a goal that may misdirect management efforts or be unrealistic.



Current Nutrient Management Plan

BMP Forest	BMP Ag	BMP Urban	BMP WWTP	BAC (lbs/day)
2.28	1.07	0.69	8.06	12.1

BMP Forest	BMP Ag	BMP Urban	BMP WWTP	BAC (lbs/day)
2.85	1.7	0.69	8.61	13.85



BMP Forest	BMP Ag	BMP Urban	BMP WWTP	BAC (lbs/day)
2.06	4.42	0.6	2.92	10.01

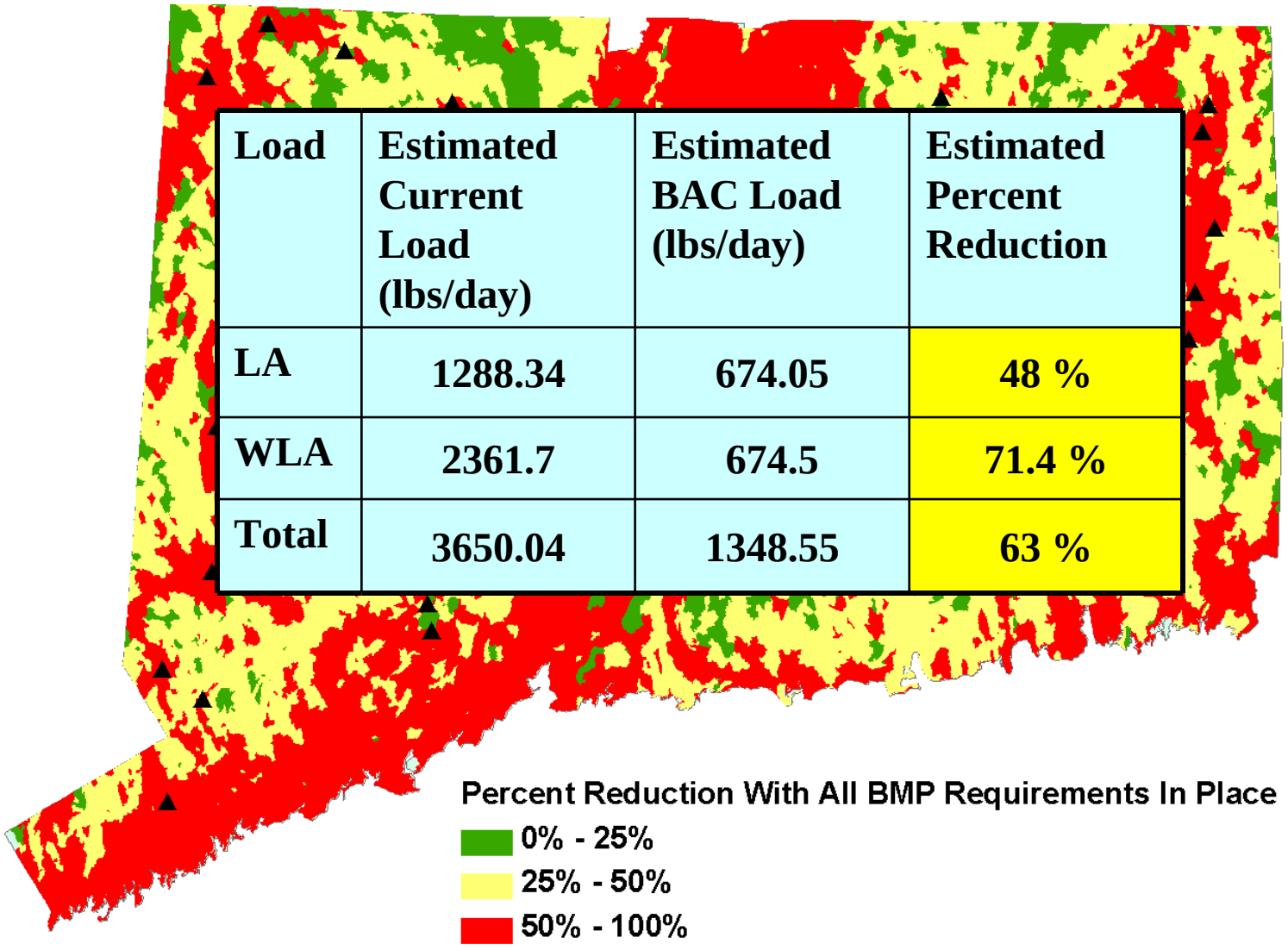
BMP Forest	BMP Ag	BMP Urban	BMP WWTP	BAC (lbs/day)
2.23	5.13	3.37	17.08	27.81

BAC = BMP Land Cover Load + BMP WWTP Load

Use Geospatial Tool to Find Site Specific Goal Anywhere in the State

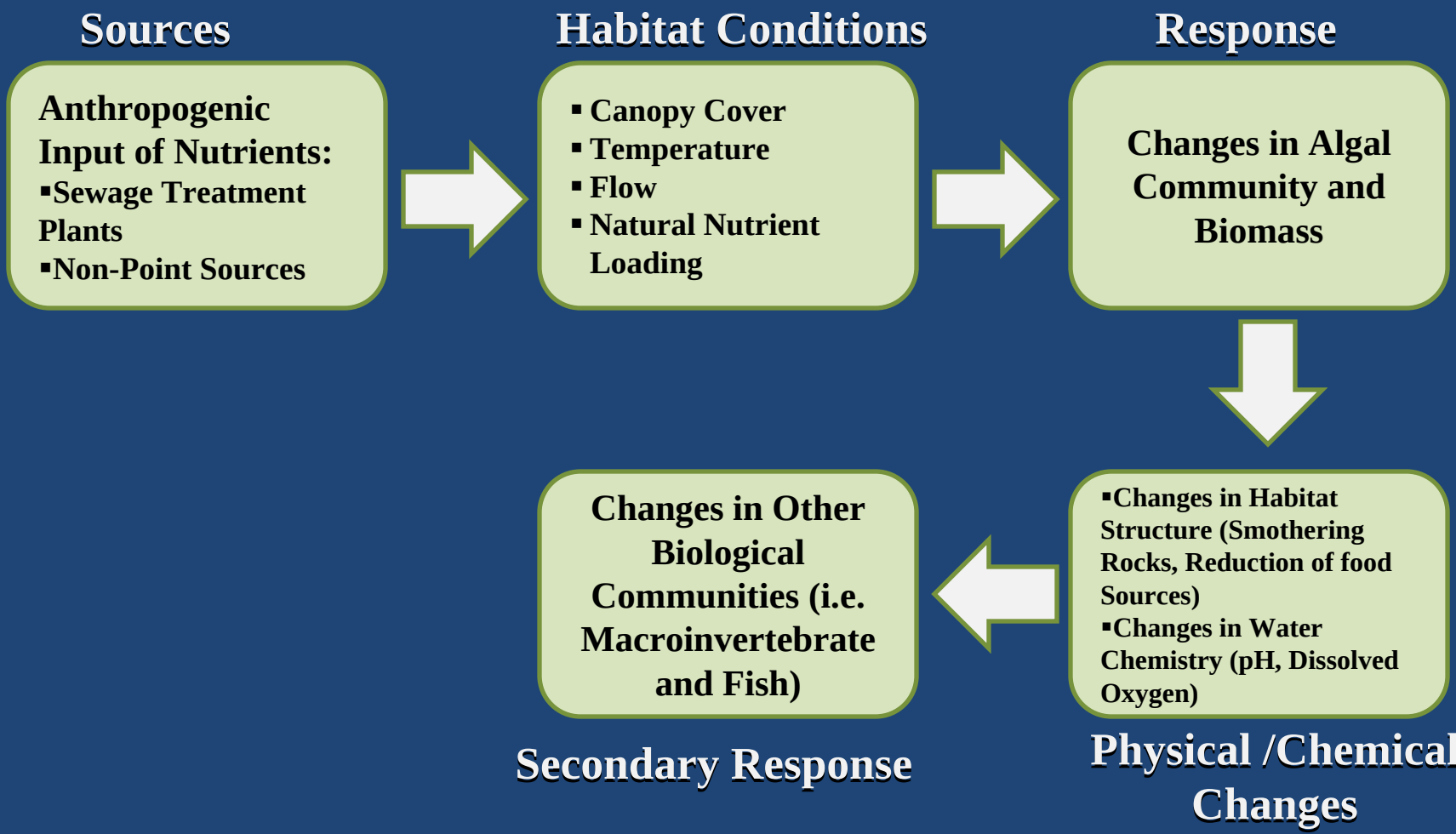
Current Nutrient Management Plan

Load	Estimated Current Load (lbs/day)	Estimated BAC Load (lbs/day)	Estimated Percent Reduction
LA	1288.34	674.05	48 %
WLA	2361.7	674.5	71.4 %
Total	3650.04	1348.55	63 %



Next Steps

- *Link Excess Nutrients with Direct Aquatic Life Responses*
- *Capture Spatial and Temporal Variation*
- *Account for Excess Nutrients Interactions with Habitat Conditions*
- *Create Model to Establish Goals on a Statewide Scale that can be Continually Modified with Monitoring Data*



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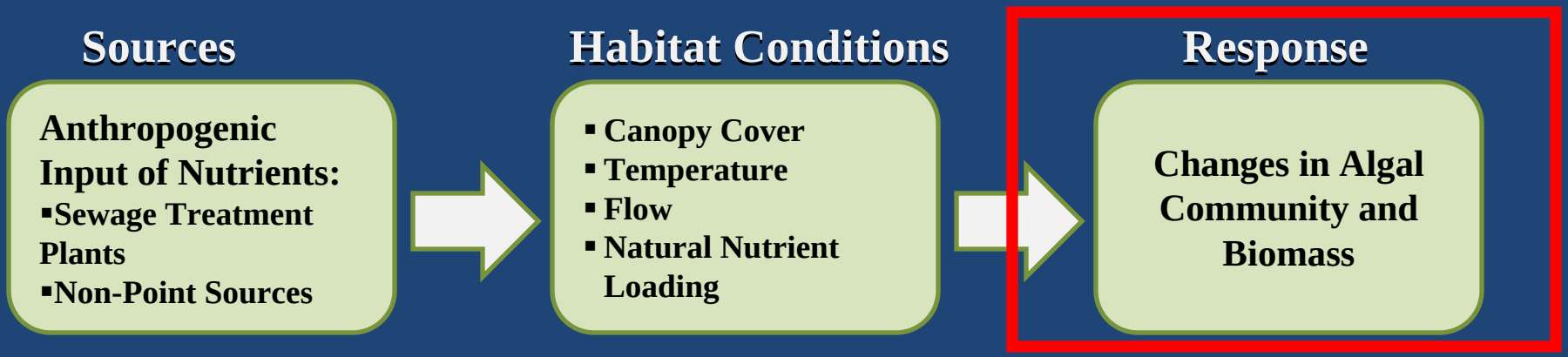

Stream Benthic Algal Community: Epilithic Diatoms

Next Steps

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Sources

Anthropogenic Input of Nutrients:
- **Sewage Treatment Plants**
- **Non-Point Sources**

Habitat Conditions
- **Canopy Cover**
- **Temperature**
- **Flow**
- **Natural Nutrient Loading**

Response

Changes in Algal Community and Biomass

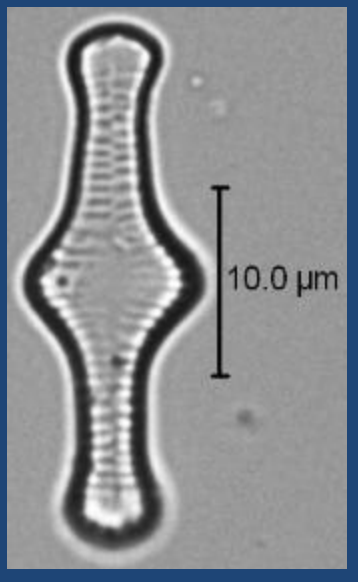
Enrichment Factor (EF)

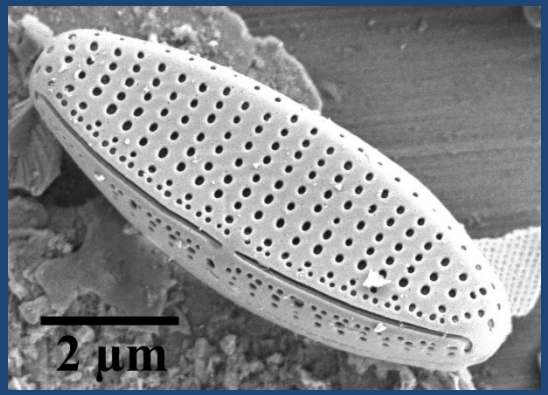
Example:

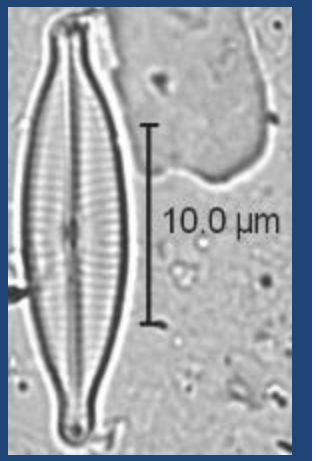
Current Load (lbs/day)	205.3
Forested Load (lbs/day)	4.80
Enrichment Factor	**42.79**

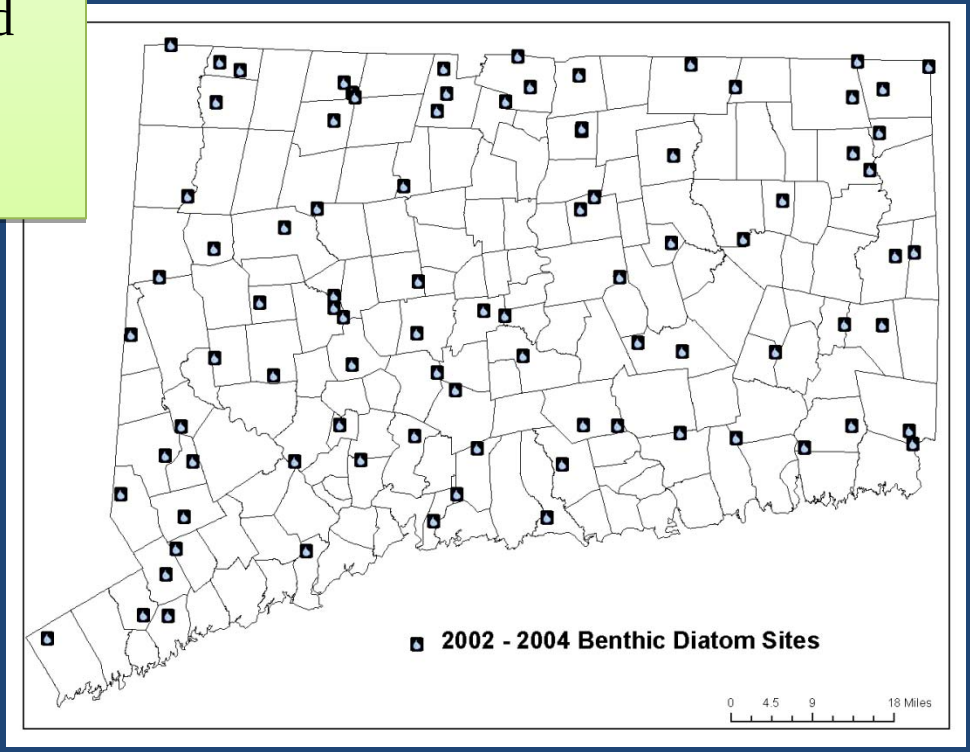
Exploratory Data Analysis: Existing Data

- Diatom Species Data Collected From 2002 – 2004
- 87 Sites
- 2002 – 2003 Probabilistic Sites
- 2004 Additional Sites at Established Reference and Known Highly Enriched Sites
- Readily Available GIS Data and Tools



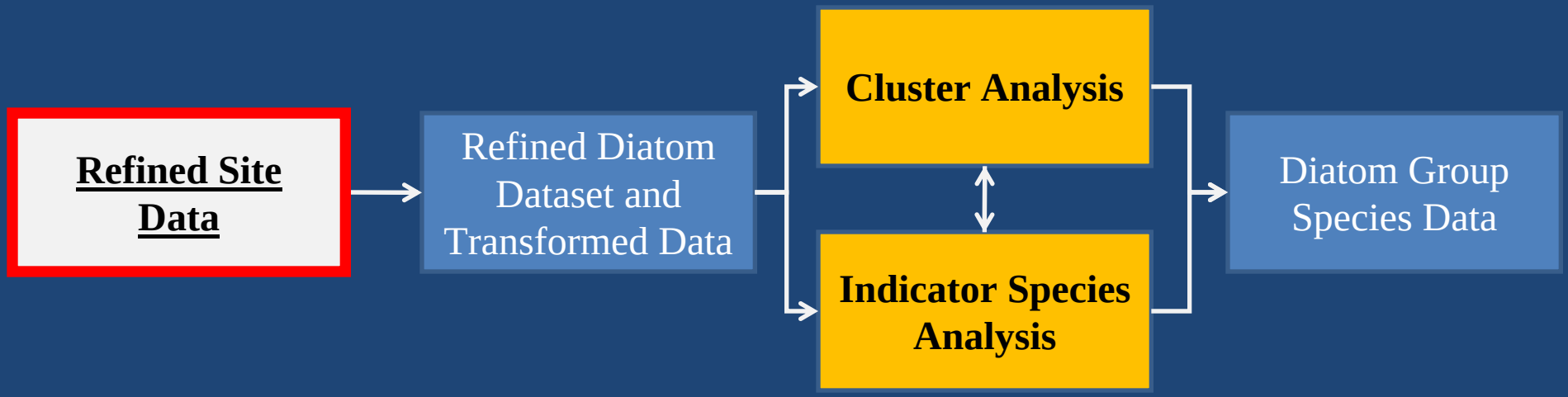






Diatom Images From : ANSP Algae Image Database from the Phycology Section, Patrick Center for Environmental Research, The Academy of Natural Sciences at http://diatom.acnatsci.org/AlgaeImage/

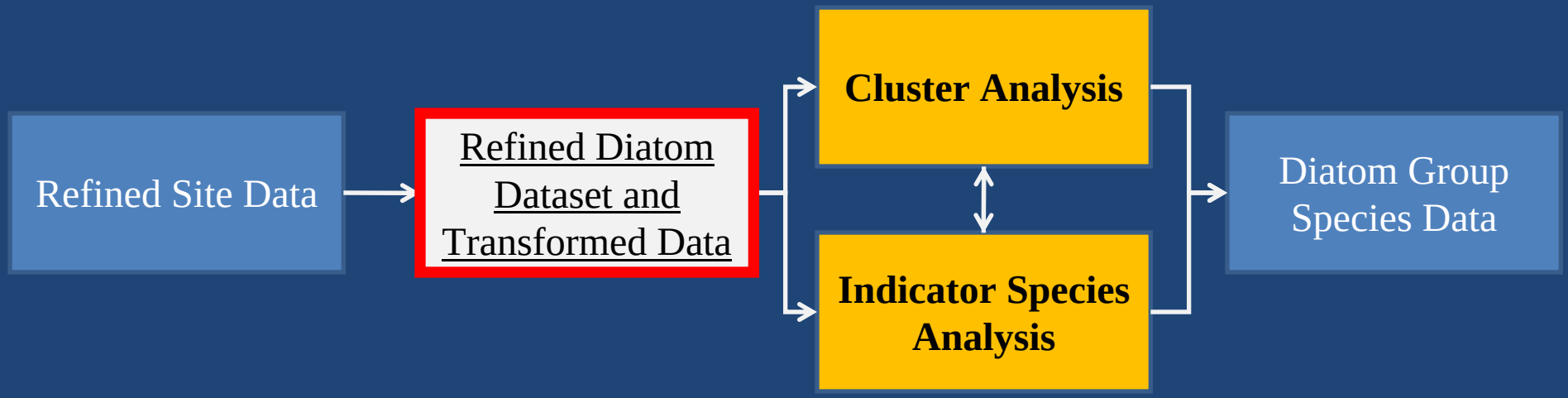
Exploratory Analysis: Diatom Species Data



- Removed streams with large majority of drainage basin outside State borders from dataset
- Excluded some outliers
- Refined to 79 Sites

AREA (2MI)	IC	EF
Min. : 0.456	Min. : 1.464	Min. : 1.205
1st Qu.: 3.401	1st Qu.: 3.097	1st Qu.: 2.806
Median : 10.527	Median : 4.158	Median : 3.974
Mean : 30.330	Mean : 5.272	Mean : 7.714
3rd Qu.: 38.849	3rd Qu.: 7.862	3rd Qu.: 6.324
Max. :259.256	Max. :13.644	Max. :76.038

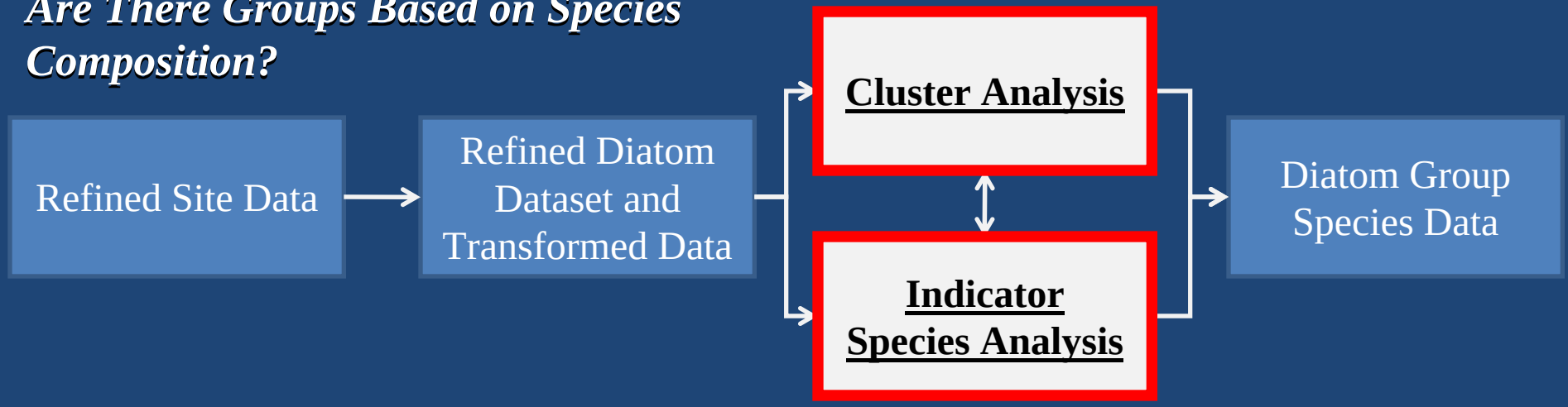
Exploratory Analysis: Diatom Species Data



- Examined Data at the Species Level. Removed Taxa Reported at Higher than Species Level.
- Calculated the Percent Abundance of Each Species for Each Site
- Removed Rare Species (Species Occurring at Less than 5% of the Sites)
- Transformed Data to Normalize

Exploratory Analysis: Diatom Species Data

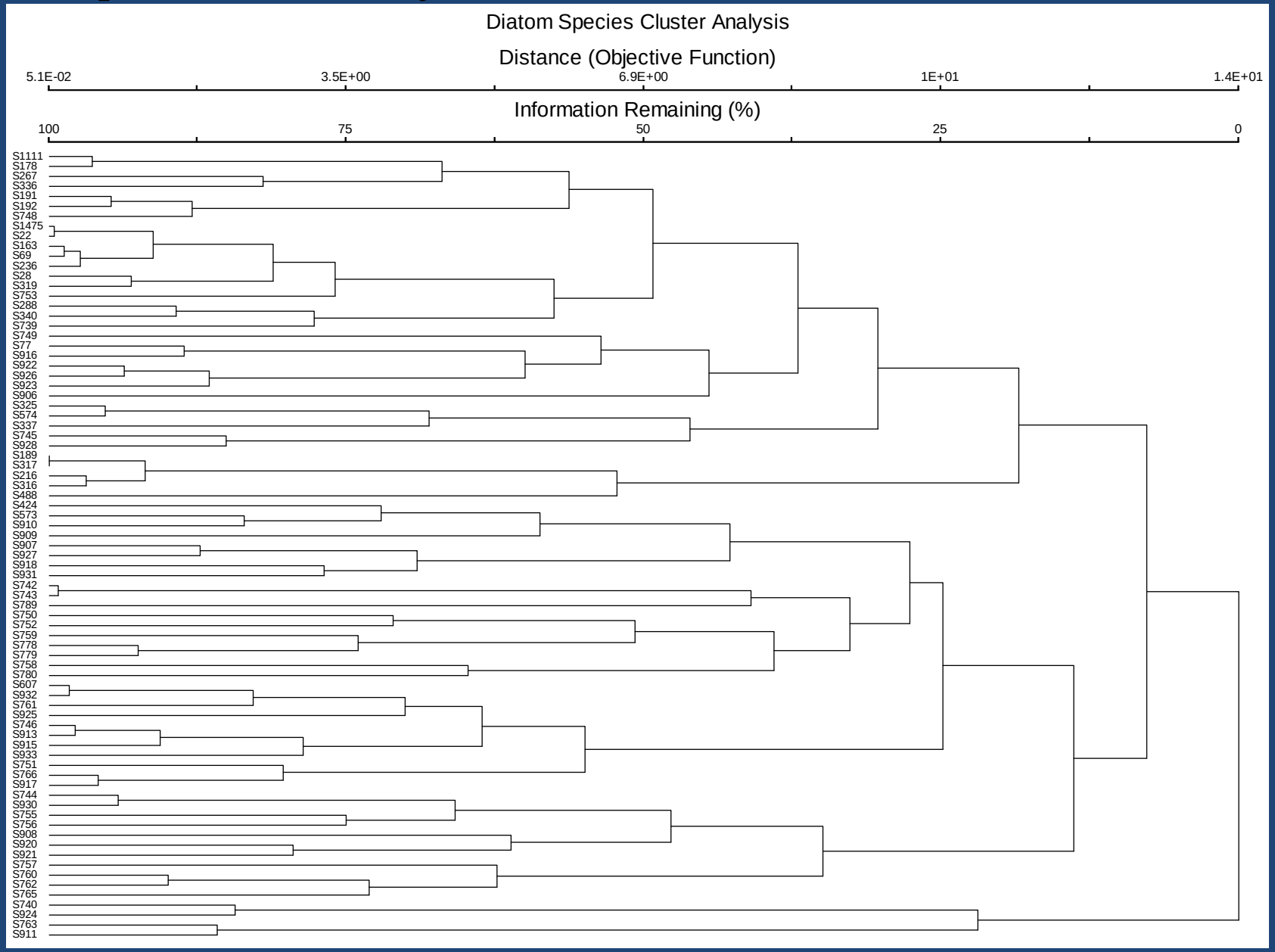
Are There Groups Based on Species Composition?



- Ran Cluster Analysis to Form Groups of Sites
- Used Indicator Species Analysis to Choose Optimum Number of Clusters and To Describe Community Types

Exploratory Analysis: Diatom Species Data

Diatom Species Cluster Analysis



Exploratory Analysis: Diatom Species Data

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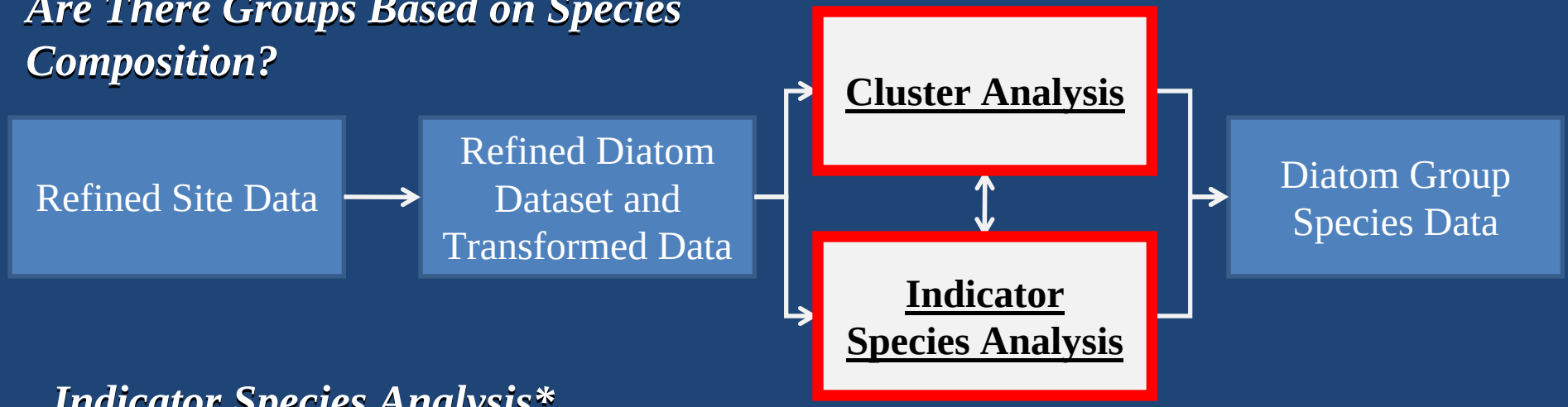


*Indicator Species Analysis**

Relative Abundance: Concentration of species abundance into a particular group

Relative Frequency: Faithfulness or constancy of occurrence of a species in a particular group

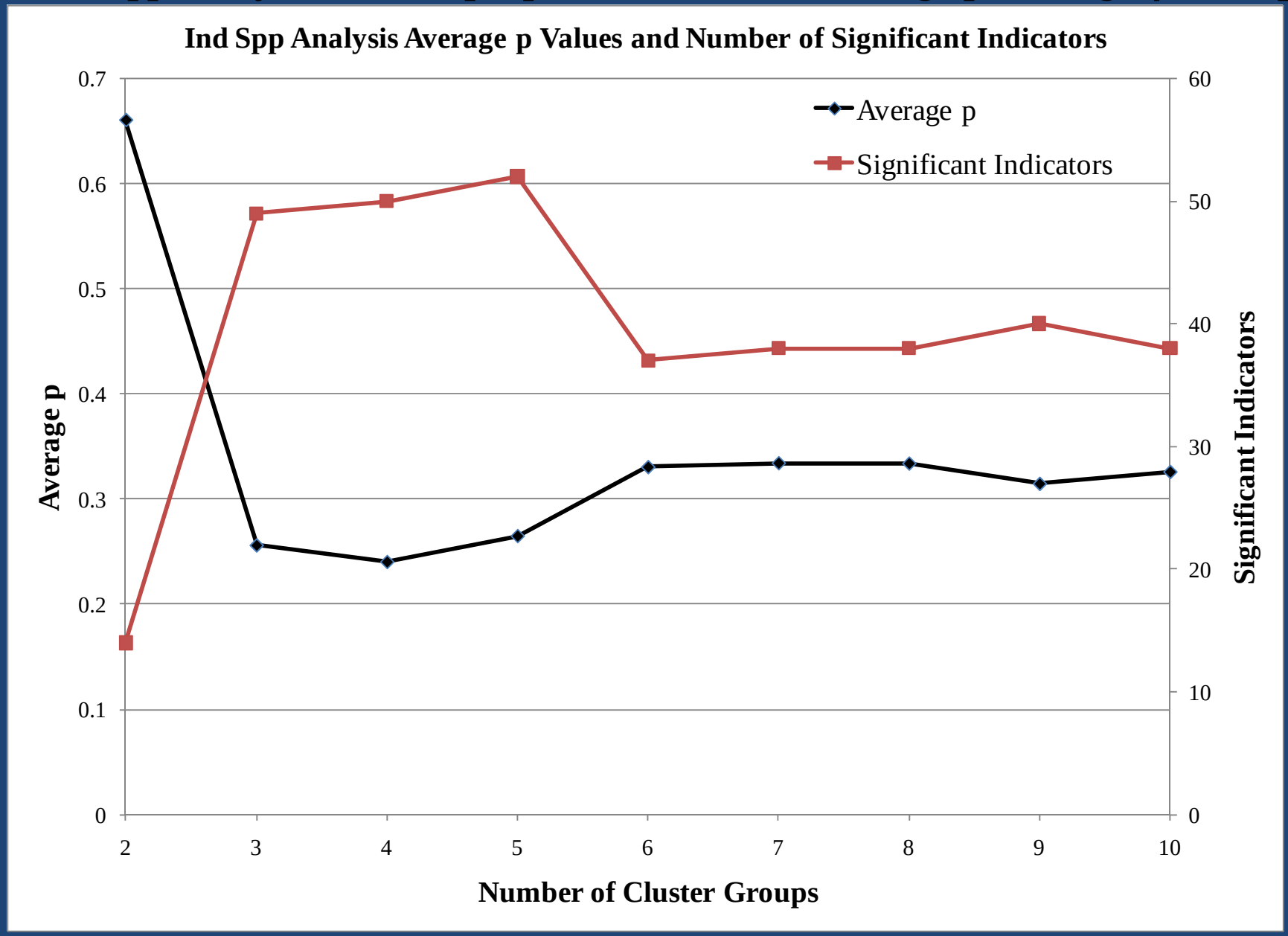
Indicator Value: Ranges from 0 (no indication) to 100 (perfect indication). Perfect indication means that the presence of a species points to a particular group without error. A perfect indicator of a particular group should be faithful to that group (always present) and exclusive to that group (never occurring in other groups).

p Value: Statistical significance by a Monte Carlo method. The null hypothesis is that the highest indicator value for a given species across groups is no larger than would be expected by chance.

Dufrene & Legendre (1997)
McCune & Grace (2002)

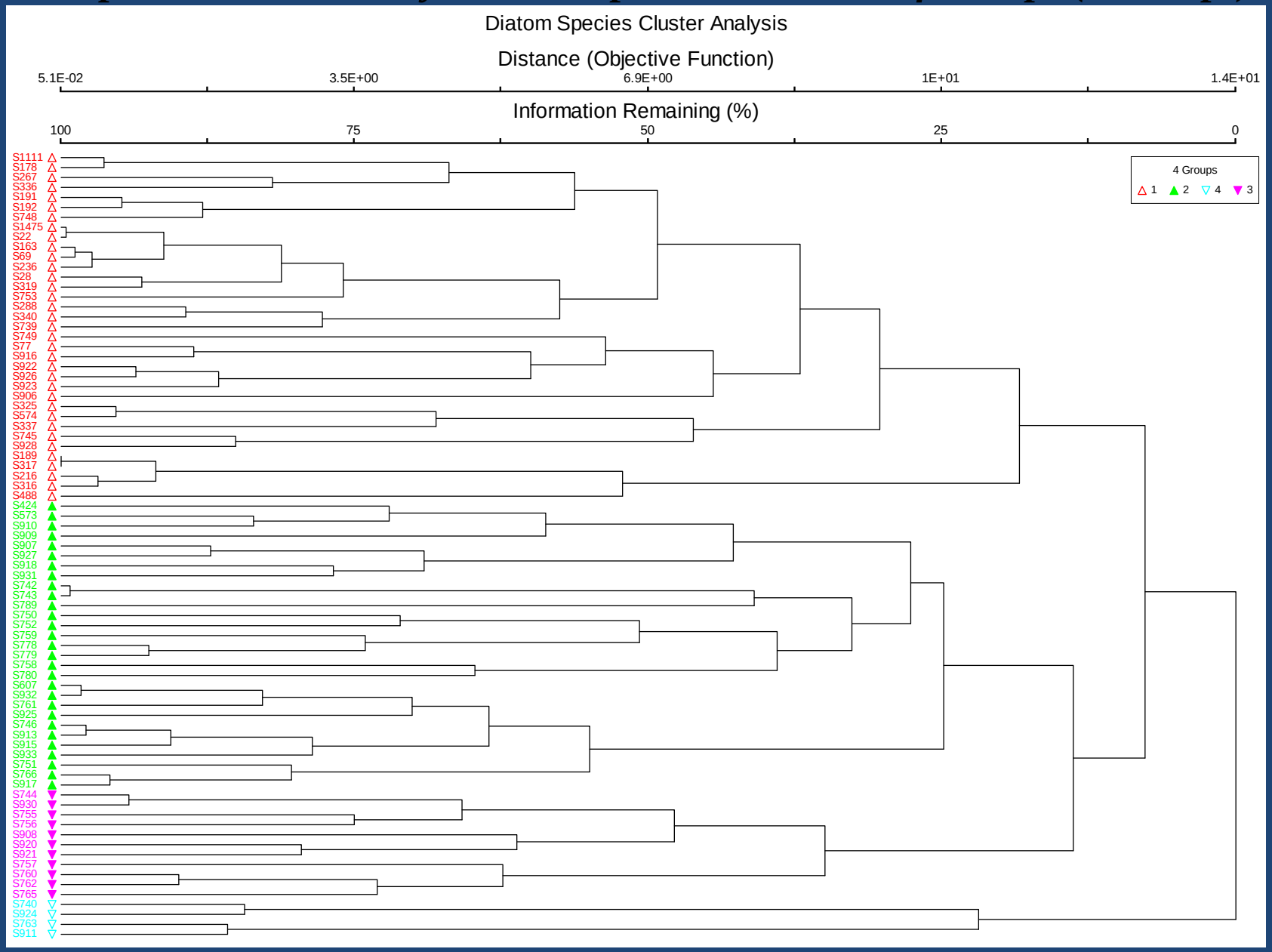
Exploratory Analysis: Diatom Species Data

Indicator Spp Analysis: 4 Group Optimum Based on Average p and Significant Spp

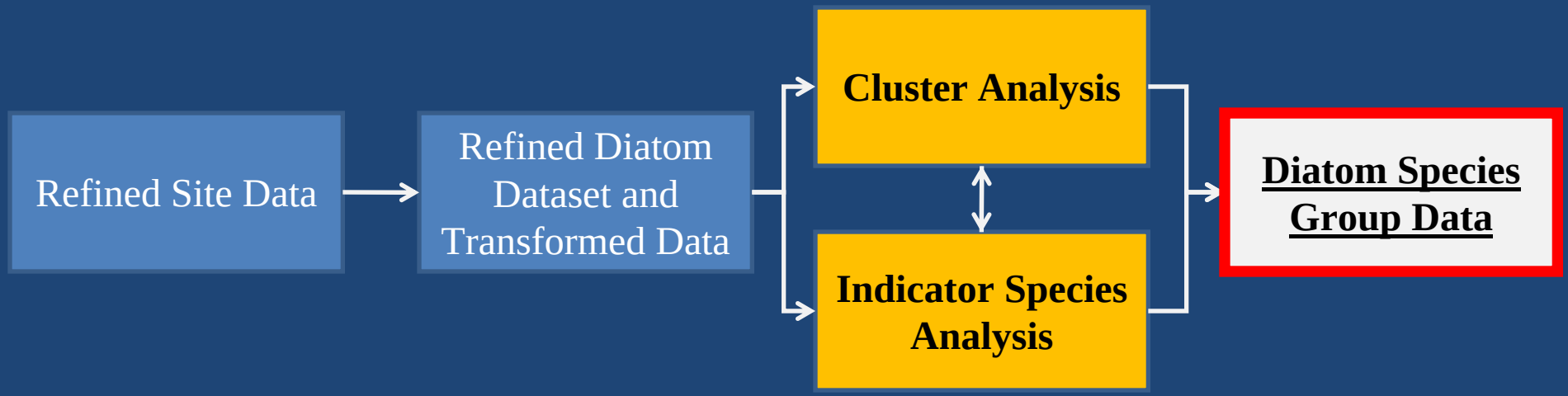


Exploratory Analysis: Diatom Species Data

Diatom Species Cluster Analysis With Optimum Number of Groups (4 Groups)



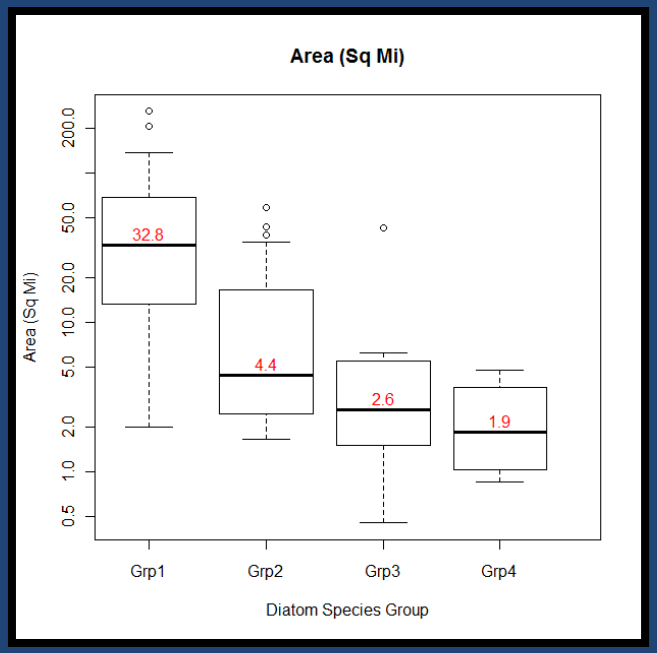
Exploratory Analysis: Diatom Species Groups

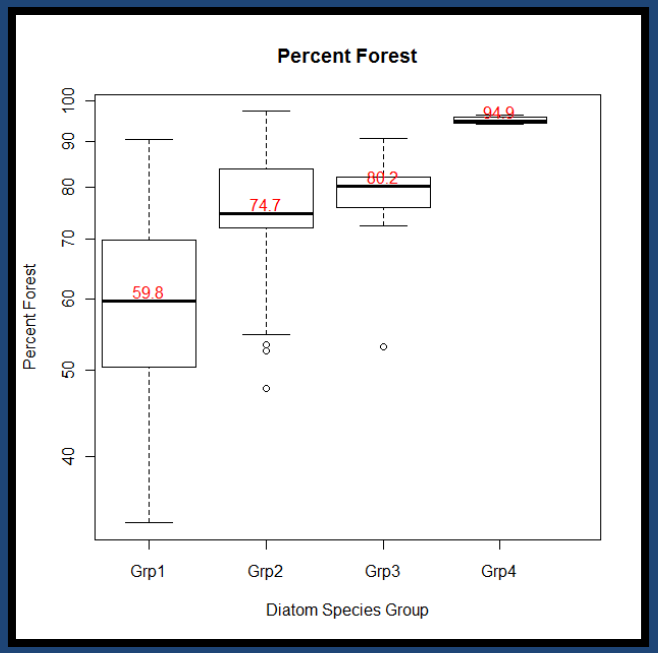


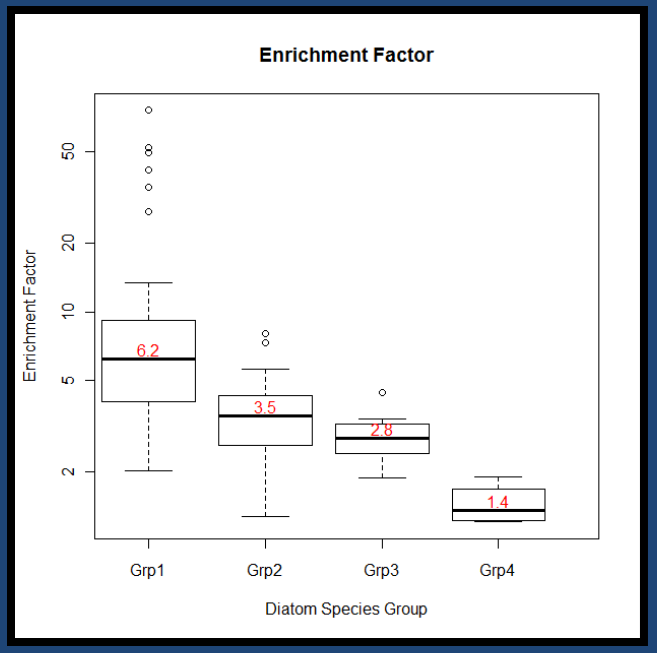
Five Highest Significant Indicator Species Values for Each Group

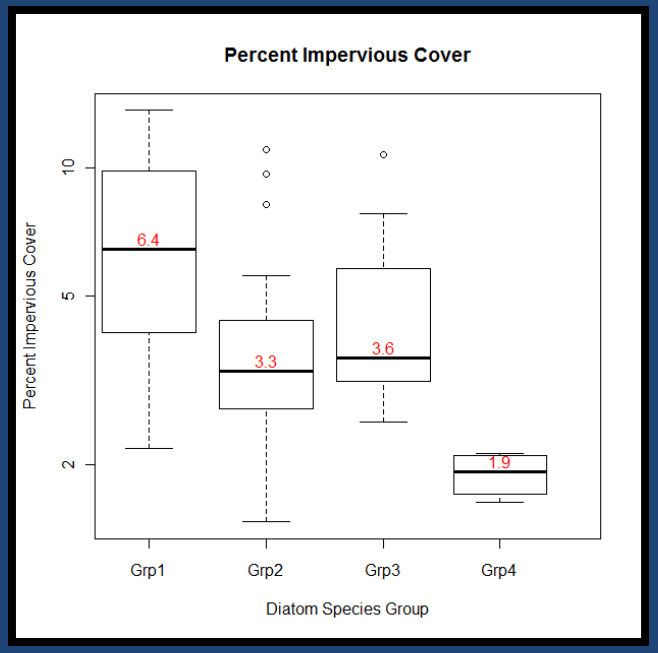
Group 1		Group 2		Group 3		Group 4	
Taxa	**IV**	**Taxa**	**IV**	**Taxa**	**IV**	**Taxa**	**IV**
Navicula gregaria	**77**	*Achnanthidium deflexum*	**57**	*Planothidium stewartii*	**54**	*Eunotia rhomboidea*	**93**
Navicula lanceolata	**77**	*Cocconeis placentula*	**48**	*Achnanthidium minutissimum*	**53**	*Anomoeoneis brachysira*	**92**
Nitzschia inconspicua	**70**	*Achnanthes subhudsonis*	**23**	*Navicula schmassmanni*	**46**	*Eunotia pectinalis*	**91**
Rhoicosphenia abbreviata	**66**	*Reimeria sinuata*	**22**	*Eunotia minor*	**41**	*Eunotia indica*	**64**
Nitzschia amphibia	**59**	*Navicula cryptotenella*	**22**	*Gomphonema gracile*	**41**	*Tabellaria flocculosa*	**62**

Exploratory Analysis: Diatom Species Groups









Exploratory Analysis: Watershed Variable Data

- *Delineated Watersheds and Calculated Readily Available Watershed Characteristics*
- *Reduced Dataset By Eliminating Highly Correlated Variables*
- *Transformed Variables to Better Normalize the Data*

Area

Population Density

Percent Agriculture

Percent Urbanization

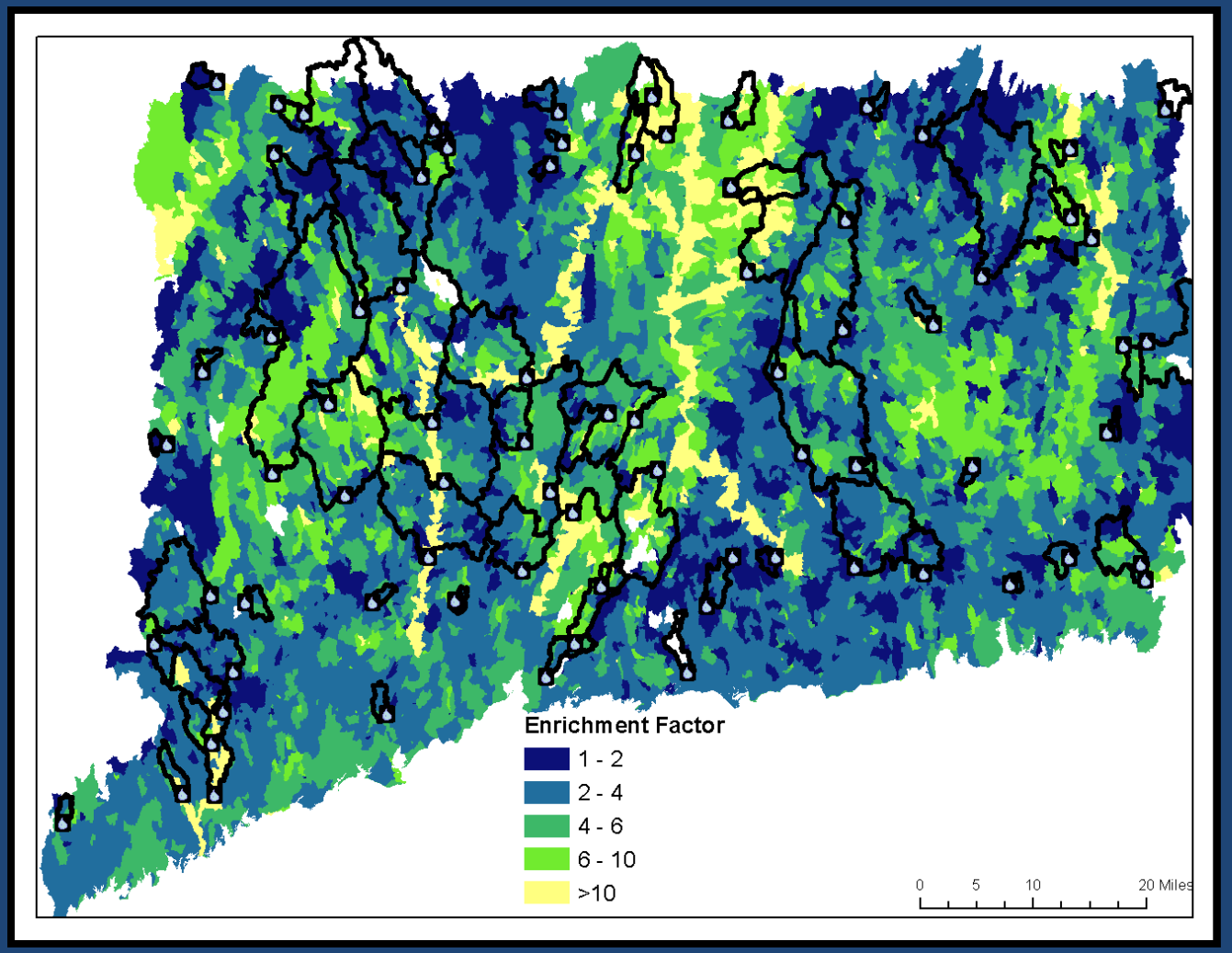
Percent Forest

Impervious Cover

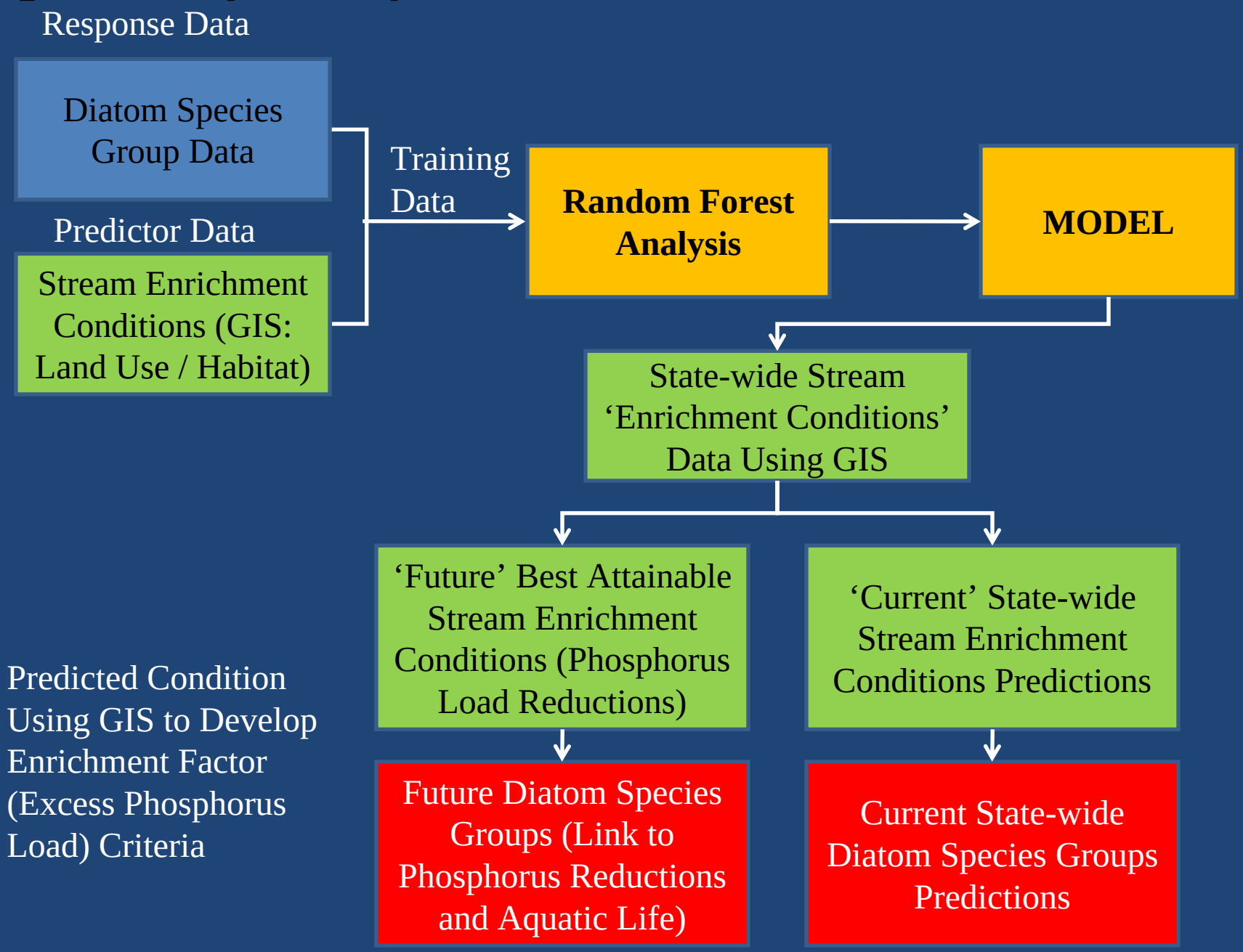
Upstream Waste Water Treatment Plant Phosphorus Load

Modeled Enrichment Factor

Modeled Total Phosphorus Load



Exploratory Analysis

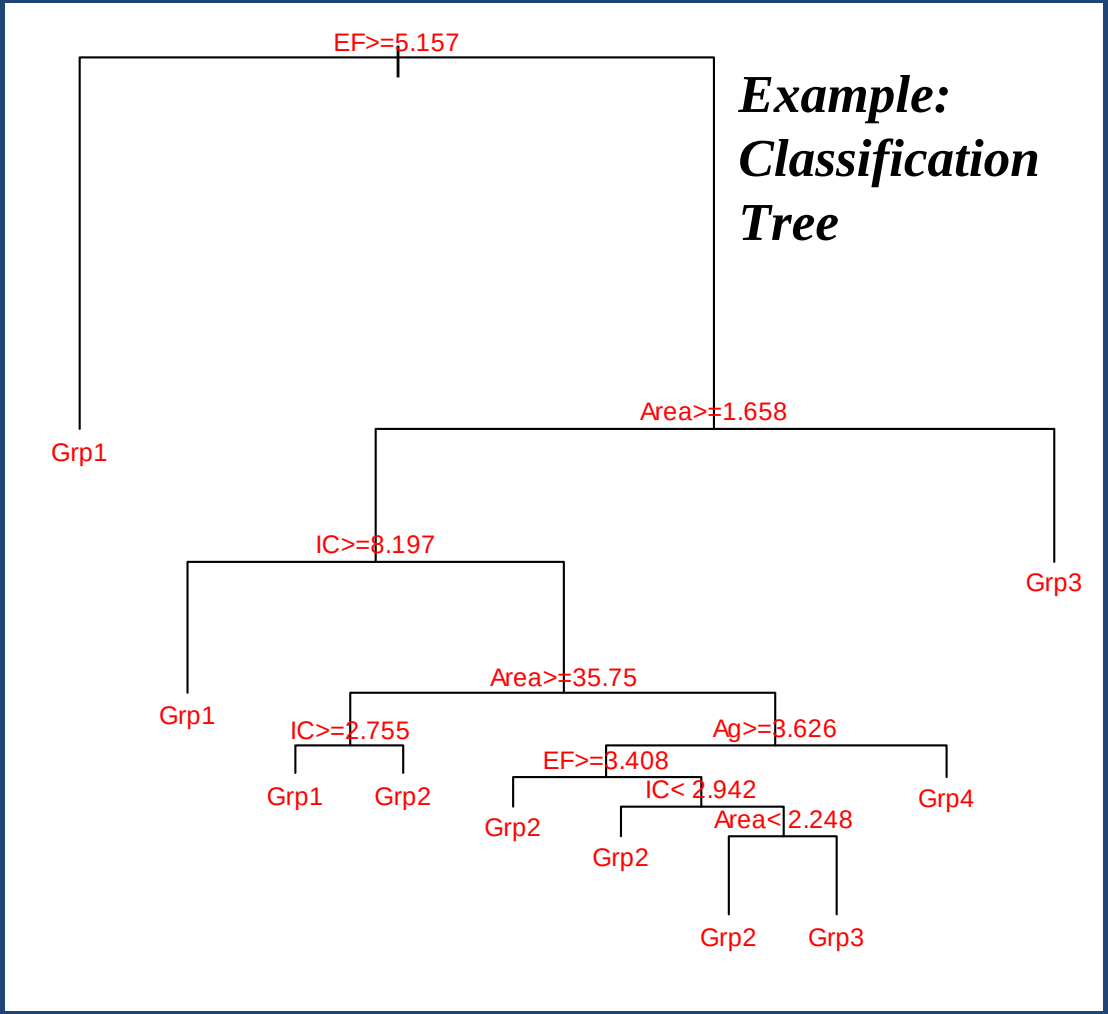


Predicted Condition Using GIS to Develop Enrichment Factor (Excess Phosphorus Load) Criteria

Exploratory Analysis

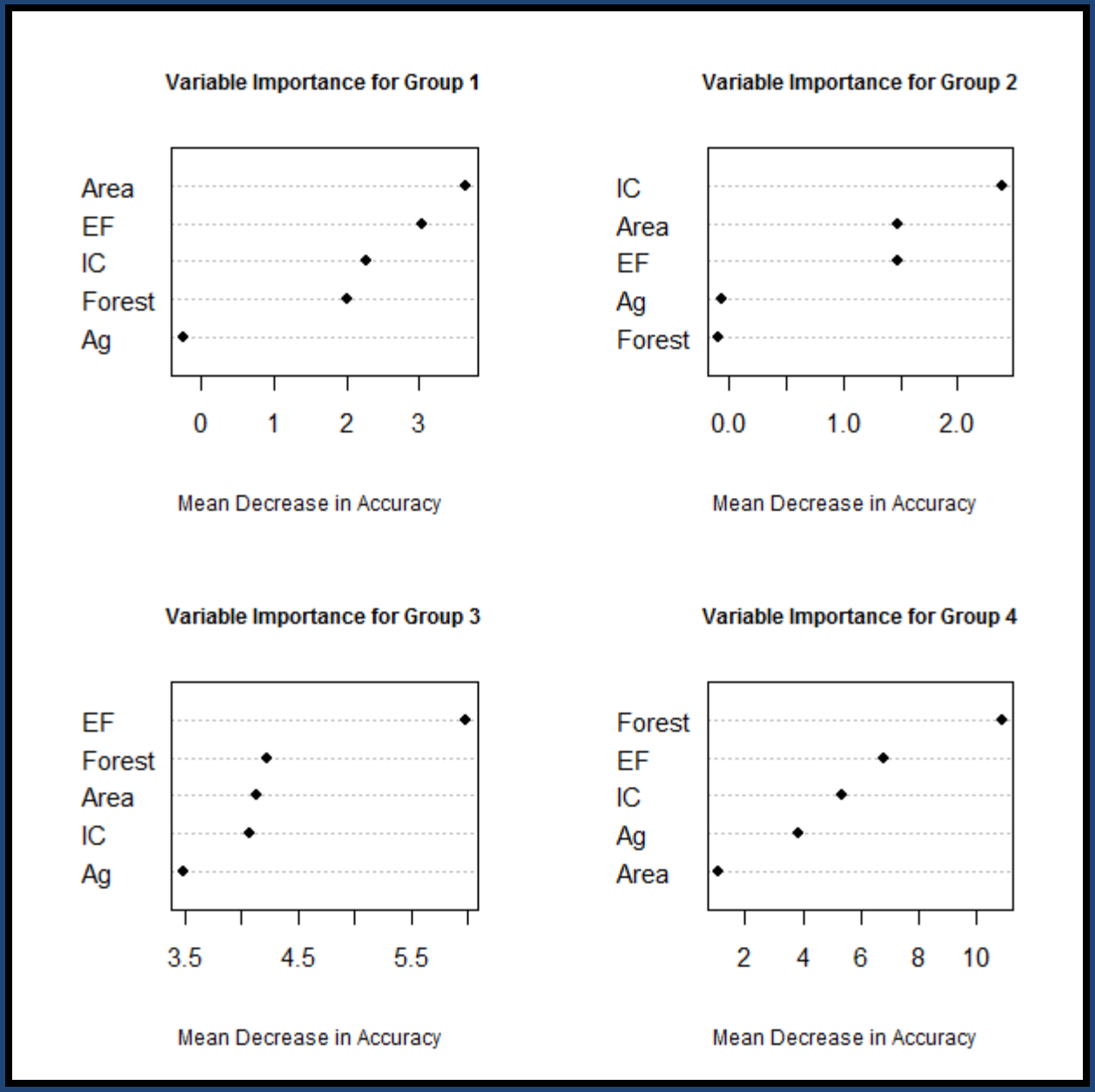
Random Forests*

- A ensemble learning technique that fits many classification trees to a data set and then combines the predictions from all trees
- Starting to emerge in ecological classification and prediction studies
- Studies show high classification accuracy compared to other techniques
- Handles complex model interactions
- Determines Variable Importance



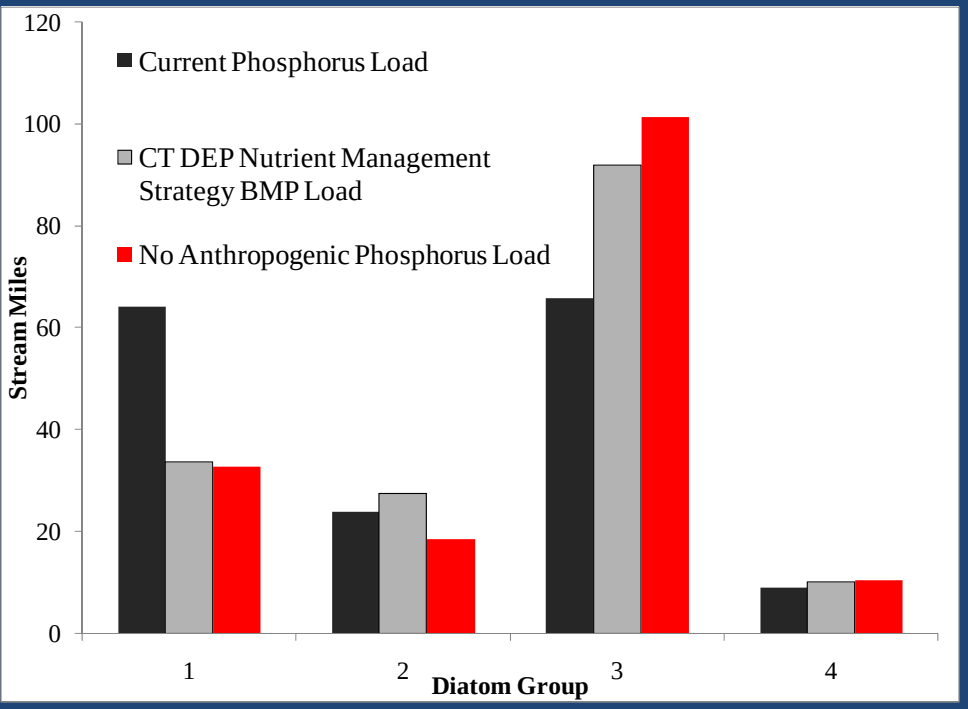
*Breiman (2001)
Breiman & Culter (2004)
Cutler et al. (2007)

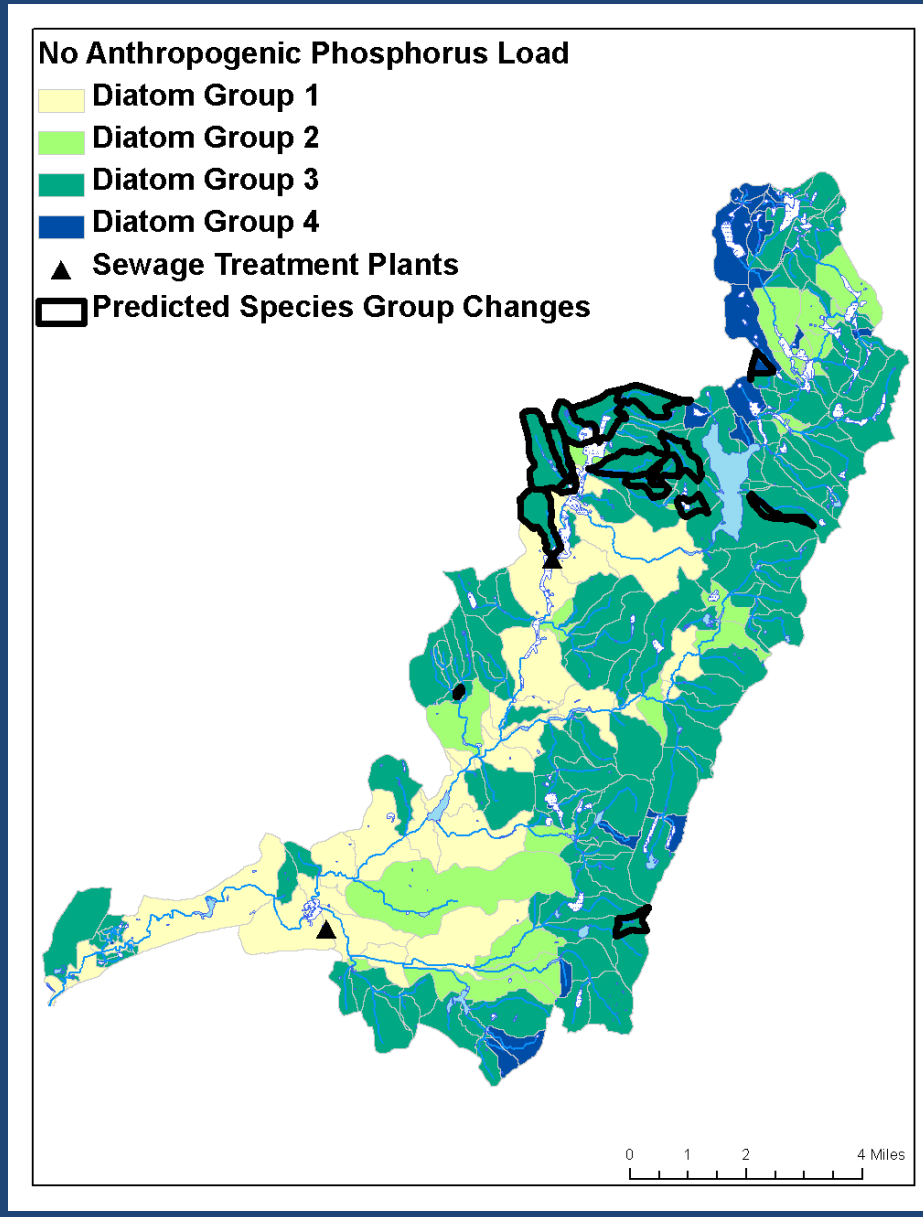
Exploratory Analysis



Exploratory Analysis

- *Predict Current Diatom Species Group for Streams Without Monitoring Data*
- *Model Diatom Species Group Changes Under Fully Implemented Management Plan*
- *Model Diatom Species Group Changes Under Varying Phosphorus Loading Scenarios to Guide Criteria Development*





Next Steps: Adaptive Management

- **Improve Model Accuracy and Validate Model with Additional Diatom Species Data and Watershed/Site Characteristic Data.**
- **Collect Additional Diatom Species Data to Test and Improve Groups.**
- **Ongoing monitoring and research that incorporates the responsiveness of the aquatic systems to these initial steps to manage phosphorus from NPDES permitted sources as well as growing emphasis on land-based management practices required by Connecticut's WQS**
- **Improve GIS Model to Better Calculate Enrichment Factor and Phosphorus Loadings**

Questions / Suggestions?

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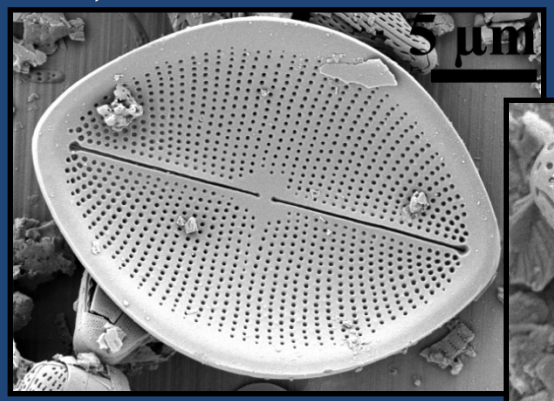

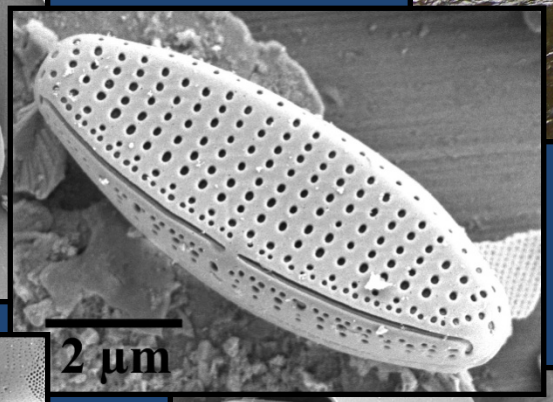

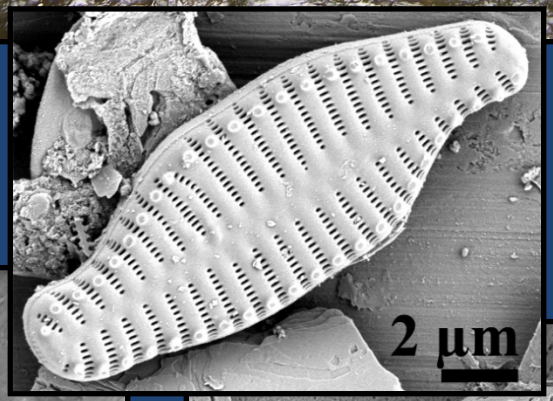

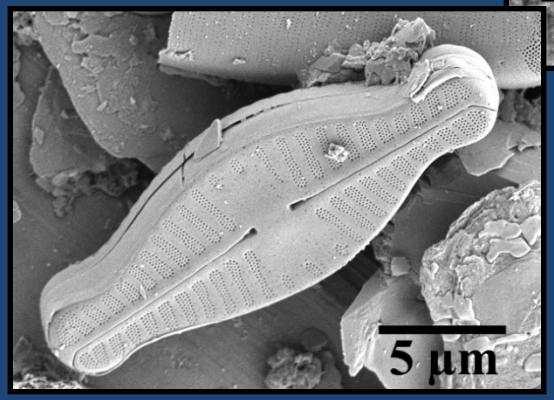

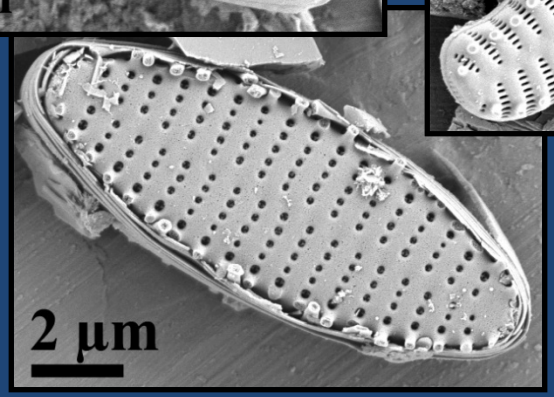

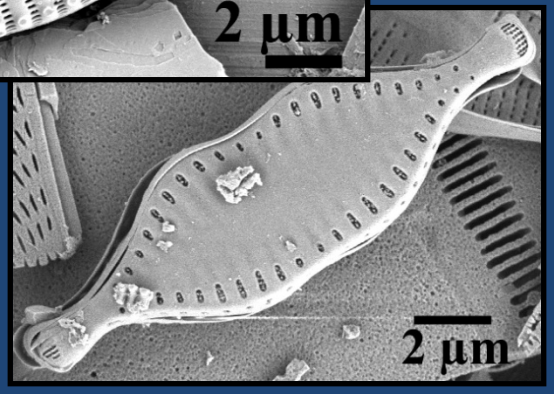

Diatom Images From Norwalk River At South Wilton CT: ANSP Algae Image Database from the Phycology Section, Patrick Center for Environmental Research, The Academy of Natural Sciences at http://diatom.acnatsci.org/AlgaeImage/