2011

The Missing Link: The Ecology of the Serpentine and the Implications for East and North Ponds [Presentation]

Colby Environmental Assessment Team, Colby College

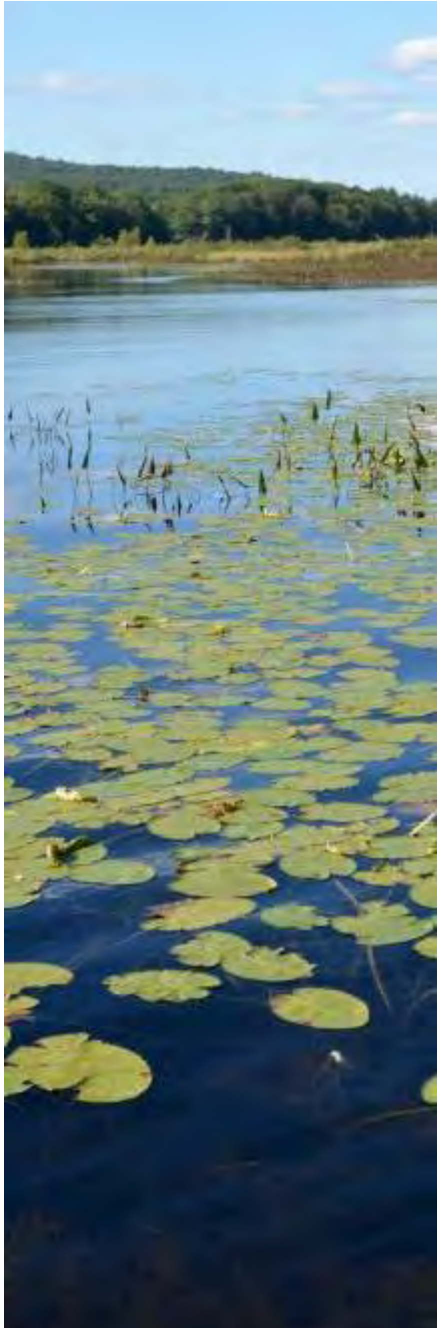
Problems in Environmental Science course (Biology 493), Colby College

The Missing Link: The Ecology of the Serpentine and the Implications for East and North Ponds

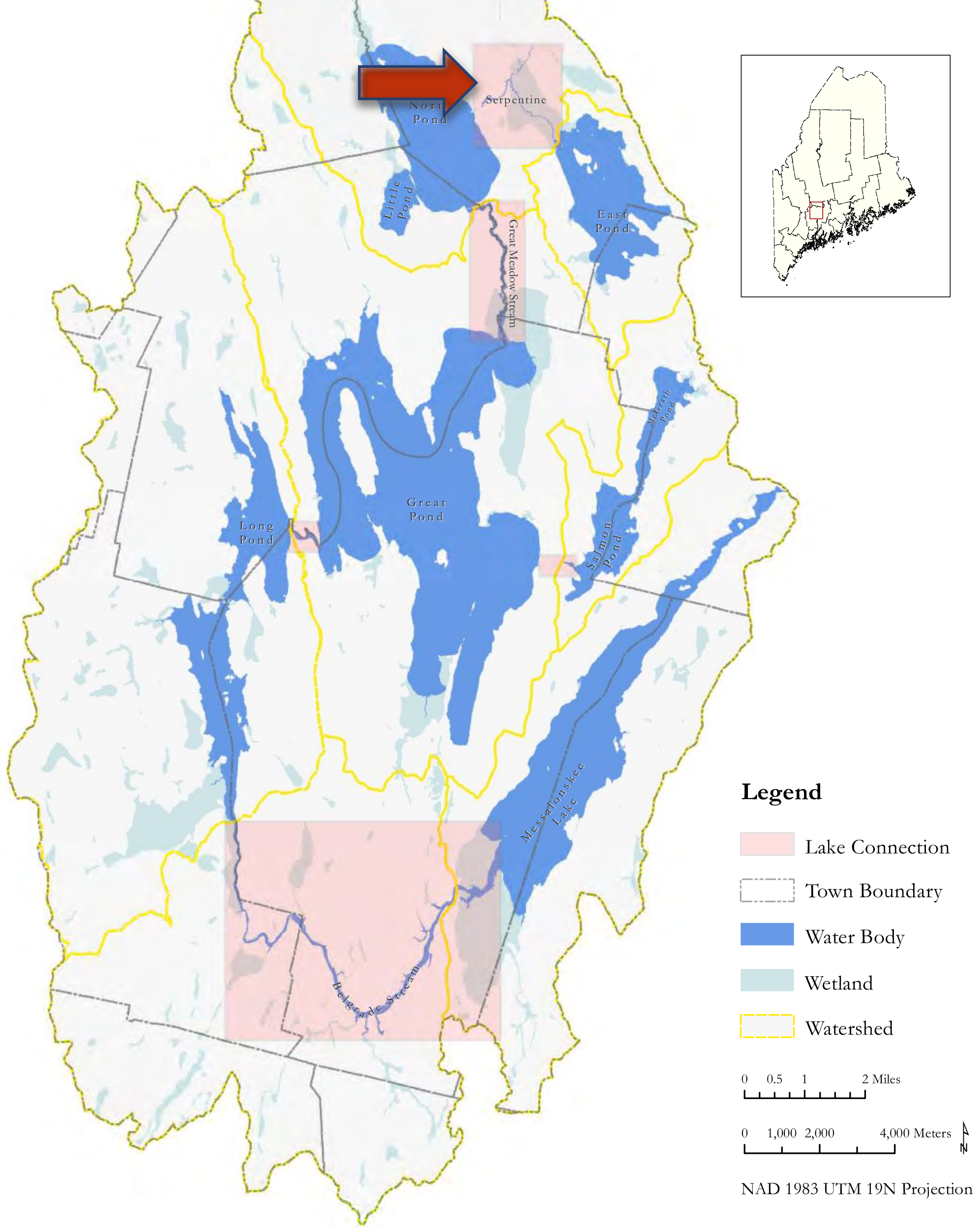
Colby Environmental Assessment Team
Smithfield Town Hall
December 8, 2011

Importance of Freshwater Ecosystems

- **Tourism**
  - Over 6000 lakes in Maine
  - Fishing, boating, swimming, etc.
- **Lake Economics**
  - $6.7 billion dollars annually
- **Ecosystem services**
  - Water source for municipal and agricultural sectors
  - Water filtering
  - Flood buffer
  - Host of diverse plant, animal & fish species
- **Eutrophication Threat**

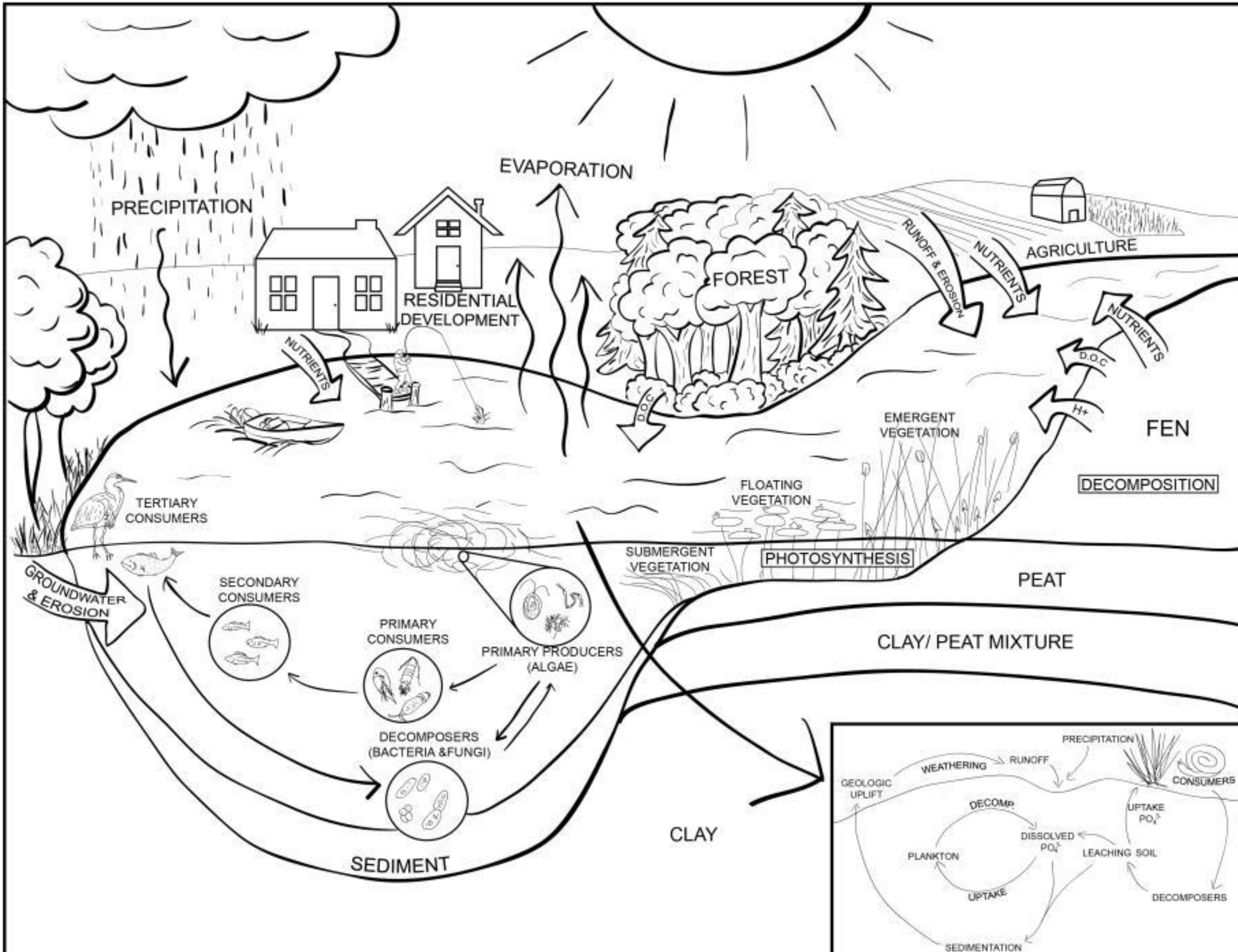


Belgrade Lakes Region



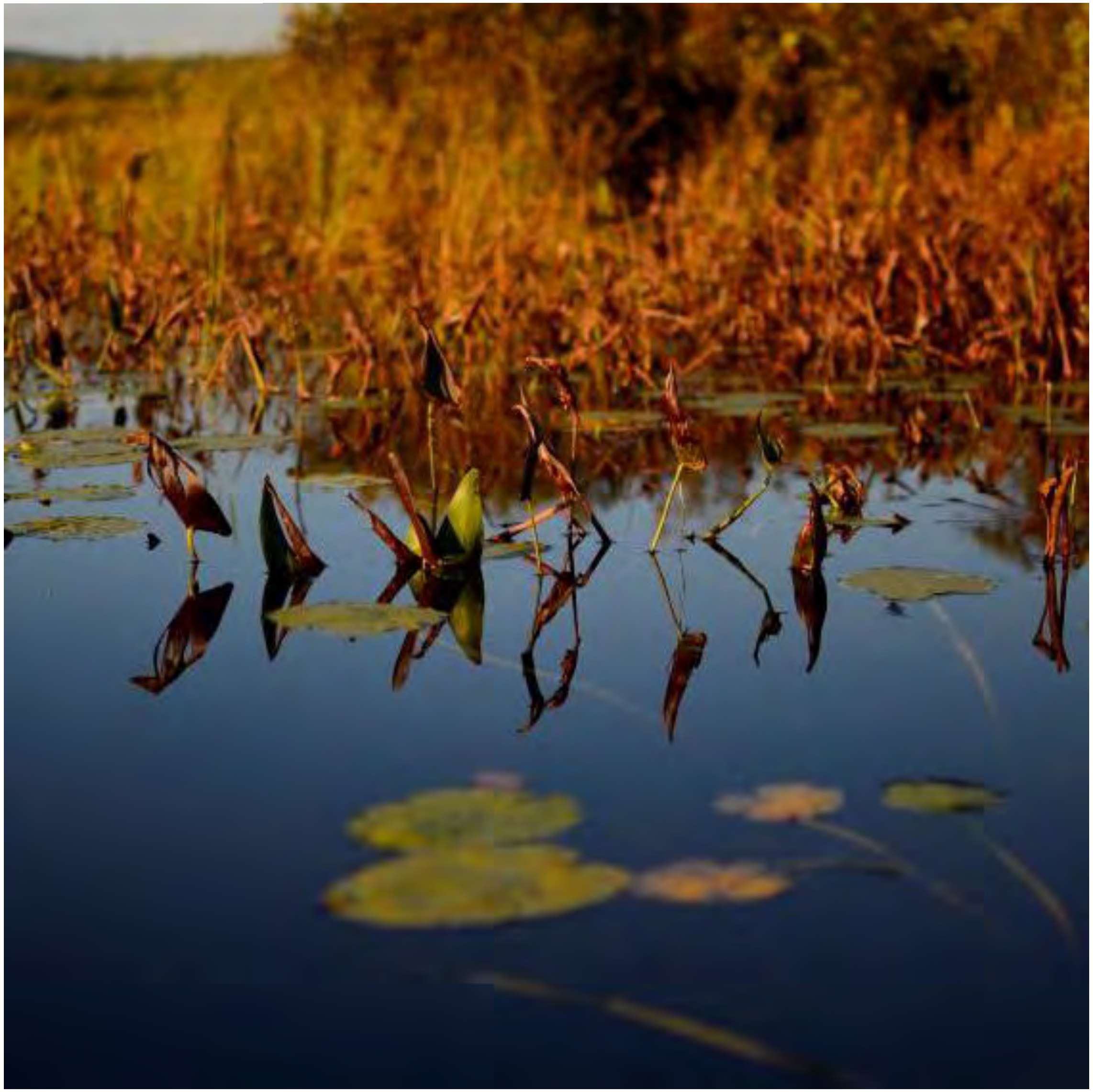
Purpose of Study

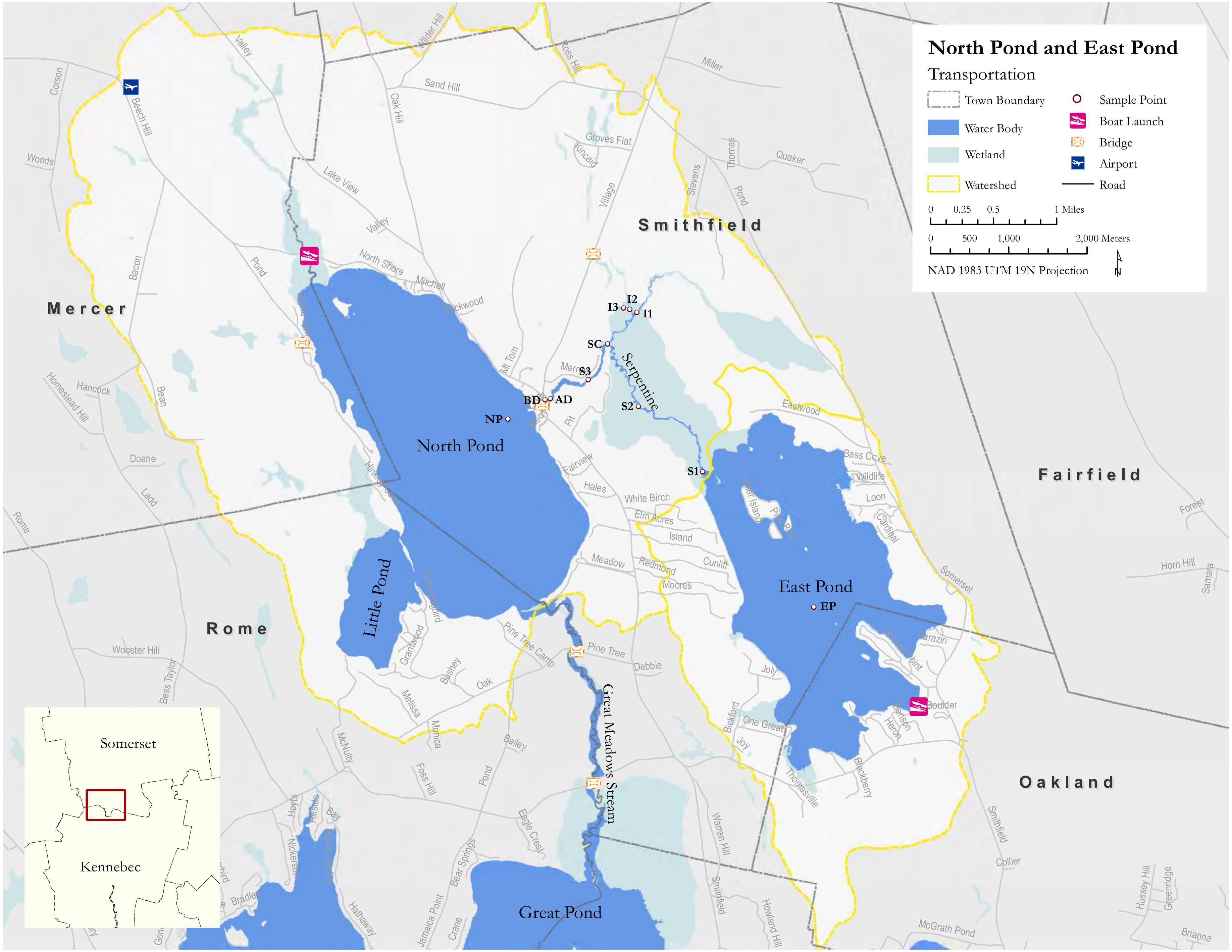
- Conduct a broad survey of the Serpentine system
- Understand what effects the Serpentine has on East and North Ponds


PRECIPITATION
EVAPORATION
RESIDENTIAL DEVELOPMENT
FOREST
RUNOFF & EROSION
NUTRIENTS
AGRICULTURE
NUTRIENTS
NUTRIENTS
D.O.C
D.O.C
H+
FEN
EMERGENT VEGETATION
DECOMPOSITION
FLOATING VEGETATION
TERTIARY CONSUMERS
SUBMERGENT VEGETATION
PHOTOSYNTHESIS
PEAT
GROUNDWATER & EROSION
SECONDARY CONSUMERS
PRIMARY CONSUMERS
PRIMARY PRODUCERS (ALGAE)
CLAY/ PEAT MIXTURE
DECOMPOSERS (BACTERIA &FUNGI)
CLAY
SEDIMENT
PRECIPITATION
WEATHERING
RUNOFF
GEOLOGIC UPLIFT
CONSUMERS
DECOMP.
UPTAKE PO₄⁻³
DISSOLVED PO₄⁻³
PLANKTON
LEACHING SOIL
UPTAKE
DECOMPOSERS
SEDIMENTATION

Project Organization

- Spatial Analysis
- Chemistry
- Algae
- Fish
- Plants
- Sediment
- Conclusions
- Implications
- Questions




North Pond and East Pond
Transportation
Town Boundary
Water Body
Wetland
Watershed
Sample Point
Boat Launch
Bridge
Airport
Road
0 0.25 0.5 1 Miles
0 500 1,000 2,000 Meters
NAD 1983 UTM 19N Projection
N
Smithfield
Mercer
Fairfield
Rome
Oakland
North Pond
East Pond
Little Pond
Great Pond
Great Meadows Stream
Serpentine
NP
EP
BD
AD
S1
S2
S3
SC
I1
I2
I3
Somerset
Kennebec
Valley
Wilder Hill
Ross Hill
Miller
Sand Hill
Oak Hill
Corson
Beech Hill
Woods
Lake View
Groves Flat
Kincaid
Village
Thomas
Quaker
Stevens
Pond
North Shore
Mitchell
Rockwood
Bacon
Mt Tom
Hancock
Homestead Hill
Bean
Doane
Ladd
Rome
Pit
Fairview
Hales
White Birch
Elm Acres
Island
Cunliff
Meadow
Redmond
Moores
Eastwood
Bass Cove
Wildlife
Loon
Cardinal
Somerset
Forest
Horn Hill
Samara
Carazin
Boulder
Heron
Joly
Bickford
One Great
Joy
Thomasville
Blackberry
Pine Tree Camp
Pine Tree
Debbie
Grantwood
Bushey
Oak
Melissa
Monica
Wooster Hill
Bess Taylor
McNulty
Foss Hill
Pond
Bailey
Eagle Crest
Warren Hill
Smithfield
Howland Hill
Collier
McGrath Pond
Hussey Hill
Greenridge
Brianna
Hoyts
Hillside
Bay
Nickerson
Bradley
Hathaway
Jamaica Point
Crane
Bear Springs

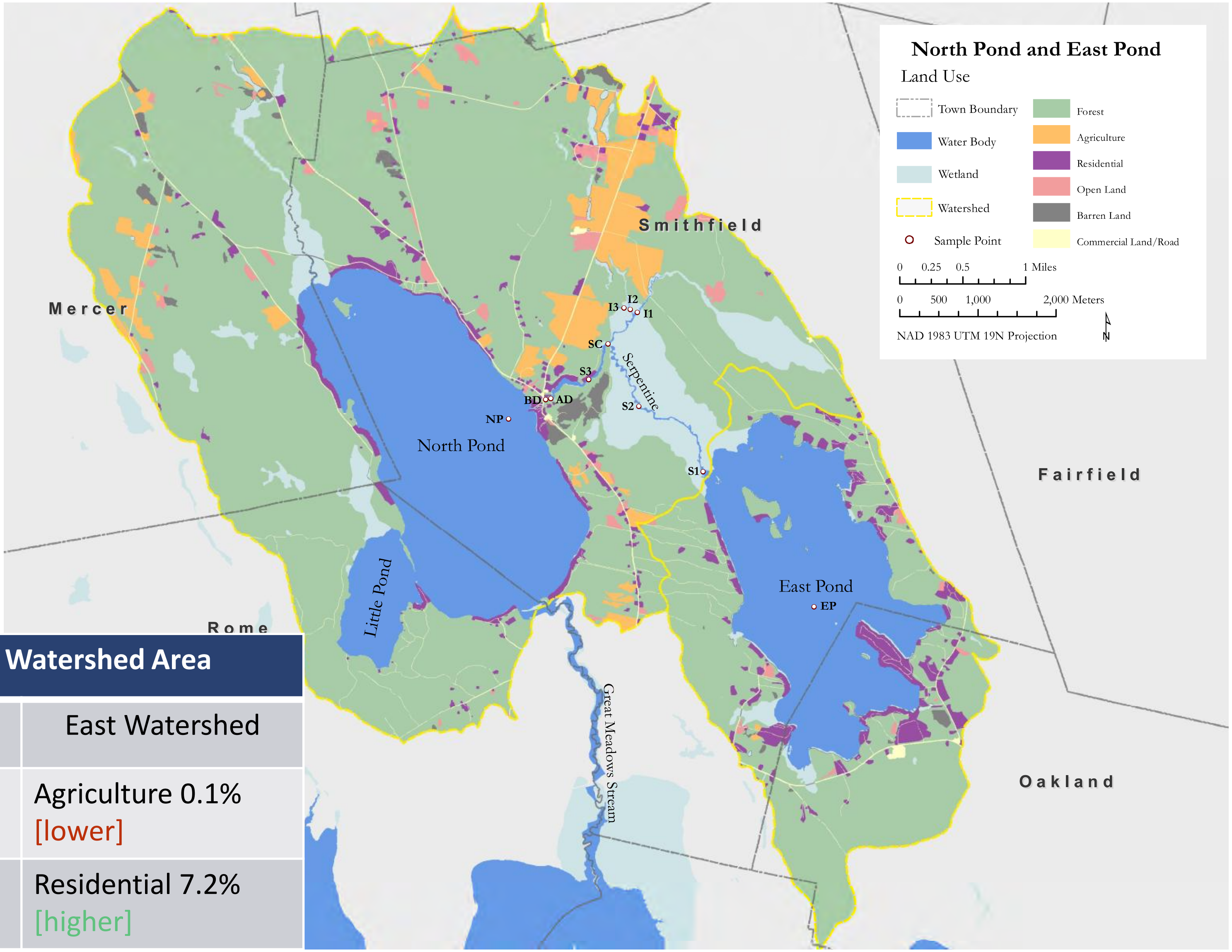
Watershed and Sample Sites

Spatial Analysis

Our objectives:

- Visually display physical parameters of our study area
- Quantify environmental factors contributing to ecosystem health
- Model environmental processes

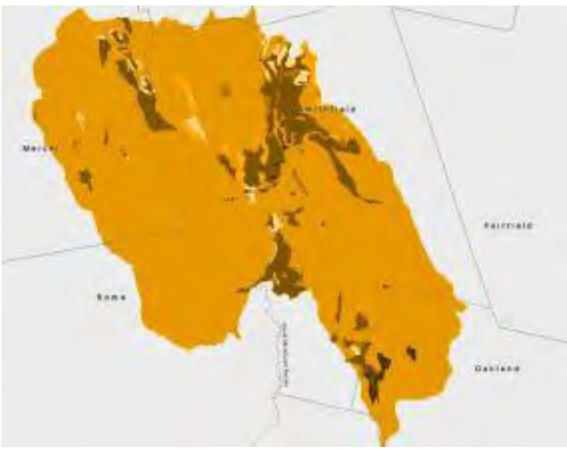
Land Use

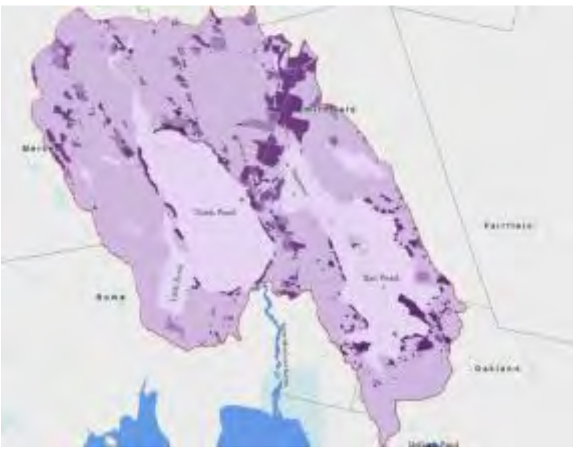


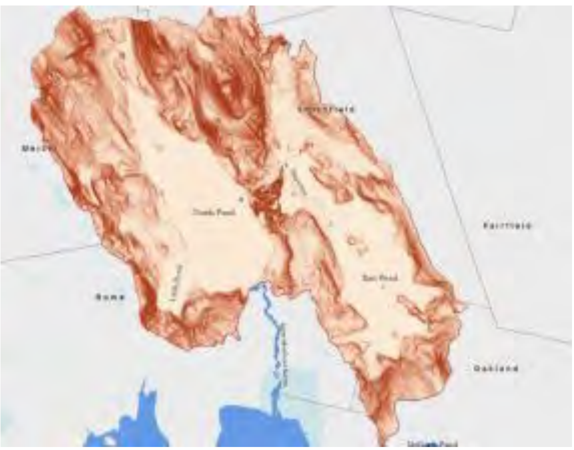
Percent Total Watershed Area	
North Watershed	East Watershed
Agriculture 4.9% [higher]	Agriculture 0.1% [lower]
Residential 2.2% [lower]	Residential 7.2% [higher]

Erosion Potential Modeling

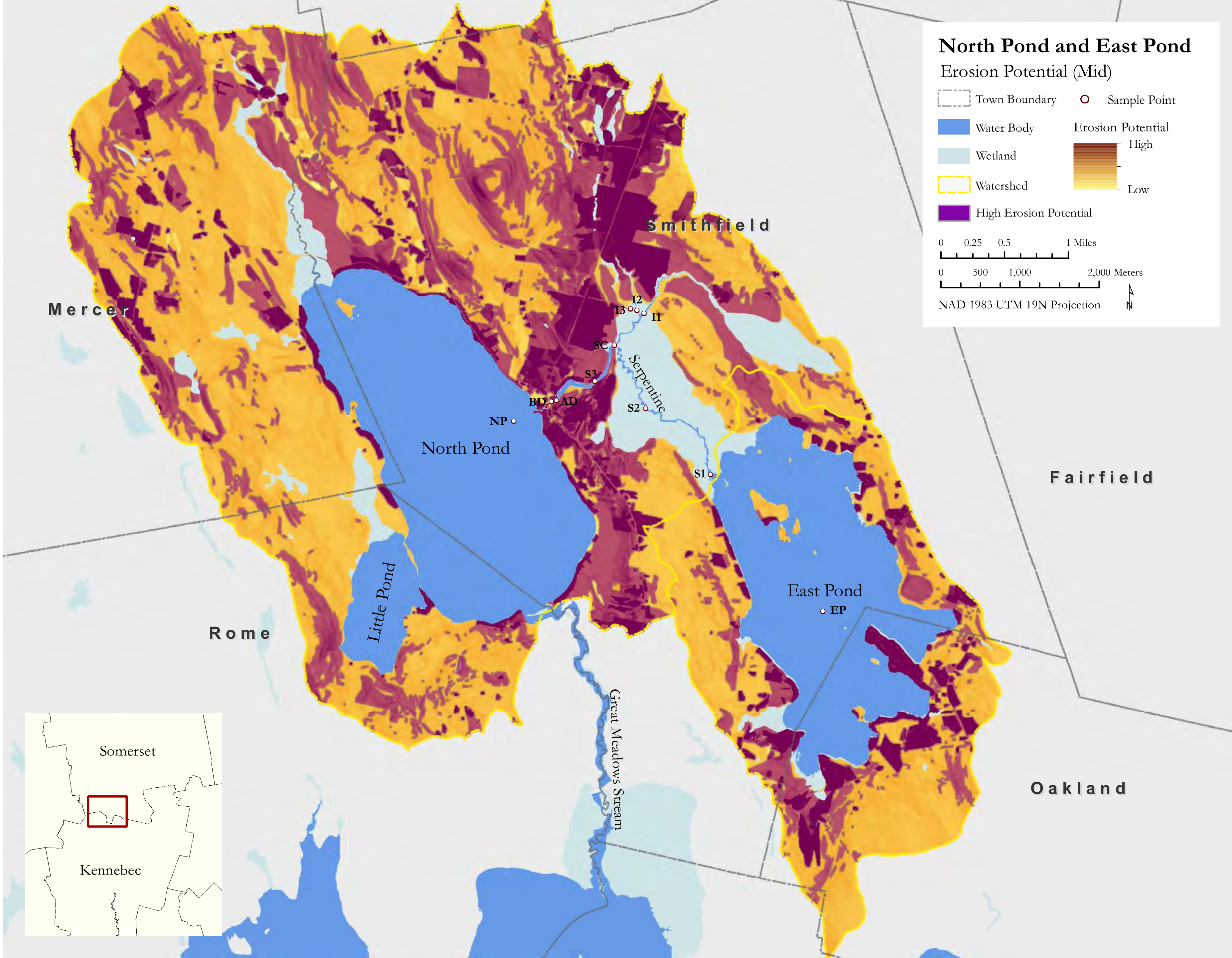
Erosion Potential Rating =







Soil Type EPR * 0.4 + Land Use EPR * 0.3 + Slope EPR * 0.3


North Pond and East Pond
Erosion Potential (Mid)
Town Boundary
Sample Point
Water Body
Erosion Potential
High
Low
Wetland
Watershed
High Erosion Potential
0 0.25 0.5 1 Miles
0 500 1,000 2,000 Meters
NAD 1983 UTM 19N Projection
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Smithfield
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Fairfield
Rome
Oakland
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East Pond
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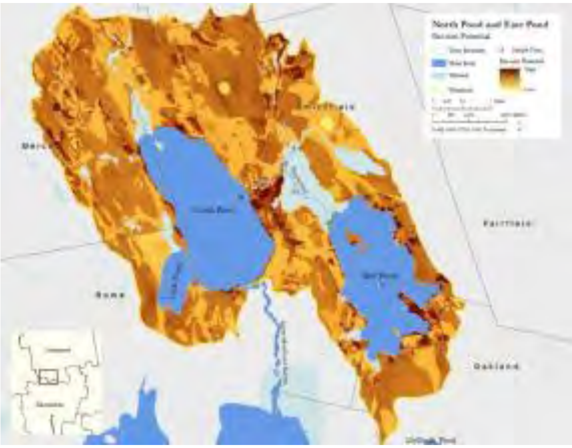
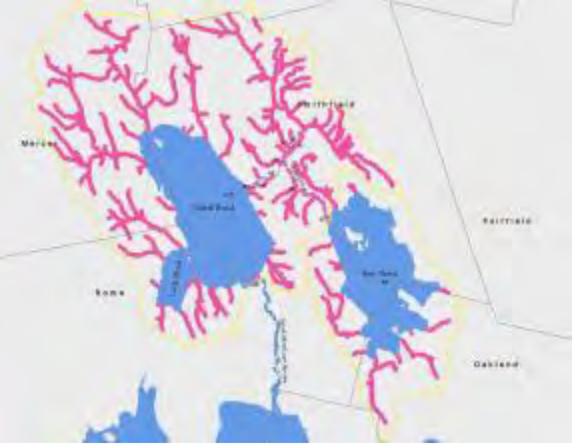
Serpentine
Great Meadows Stream
I1
I2
I3
SC
S3
S2
S1
BD
AD
NP
EP
Somerset
Kennebec

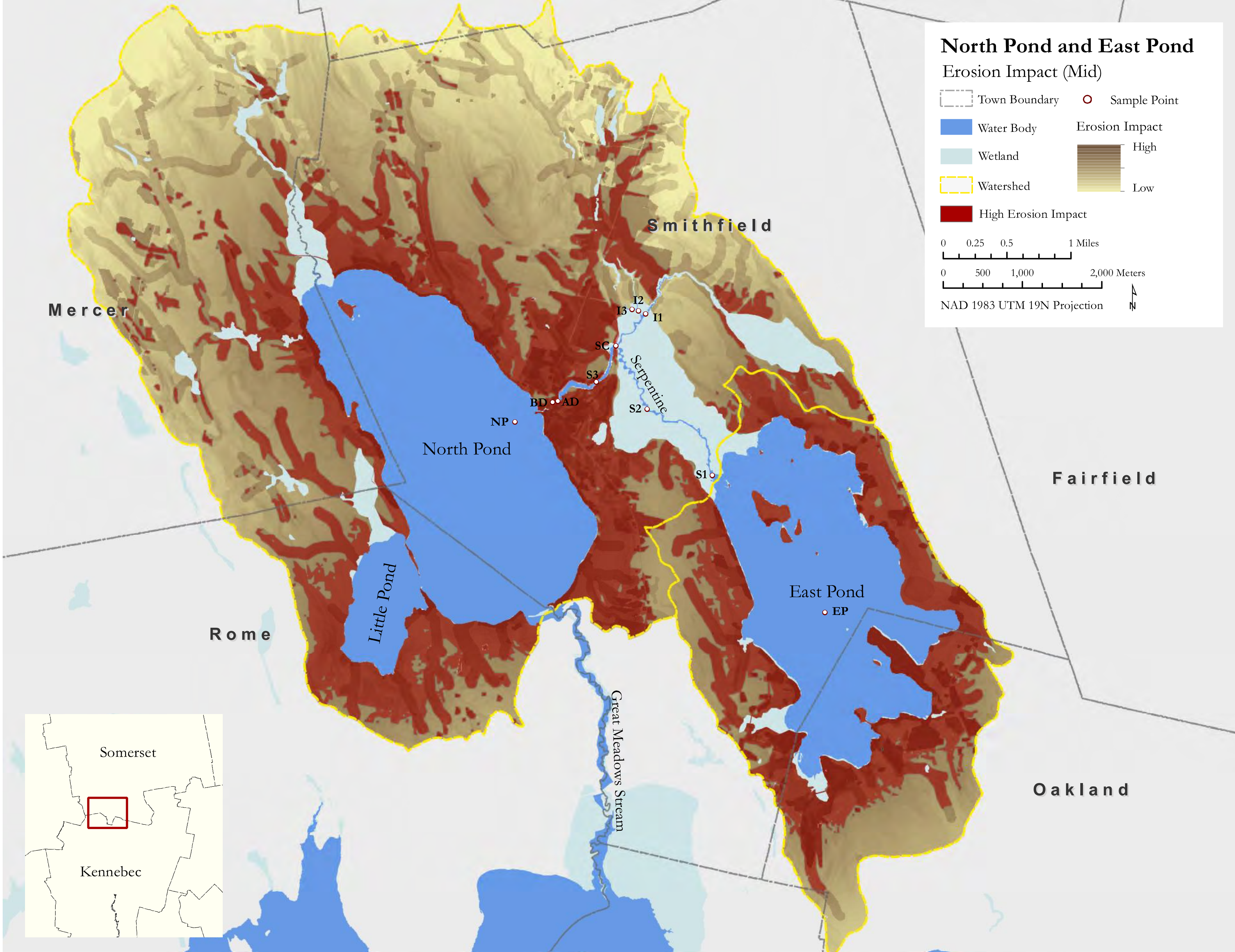
Erosion Impact Modeling

Erosion Impact Rating =





Erosion Potential * 0.5 + Lake Proximity EPR * 0.4 + Overland Flow Path Proximity * 0.1



North Pond and East Pond
Erosion Impact (Mid)
Town Boundary
Sample Point
Water Body
Erosion Impact
High
Low
Wetland
Watershed
High Erosion Impact
0 0.25 0.5 1 Miles
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I2
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Kennebec

Conclusions and Implications

- Still must maintain buffer zone
  - MEDEP regulations are effective at reducing nutrient transport
- Erosion models highlight areas of concern
  - Land use correlation
  - Proximity correlation
- Look into Lake Smart!
- Future: Targeted upland surveys

Water Chemistry

Our Objective:

- Determine if the water chemistry of the Serpentine influences the water chemistry in North Pond and East Pond

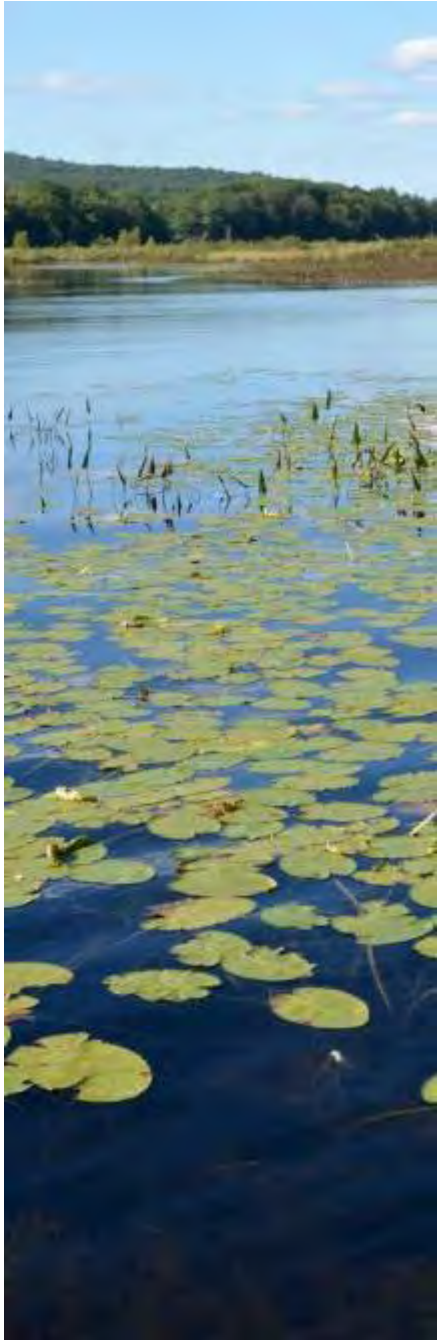
Why is water chemistry important?

- Directly influences timing, magnitude and frequency of algal blooms
- Anthropogenic inputs may cause excessive nutrients and cultural eutrophication
- Excessive nutrients can negatively impact recreation, human health and biotic communities

Sampling

- Samples were taken over the course of two weeks on 4 days: September 22, September 29, October 3 and October 6, 2011

- 10 sites in or directly connected to the Serpentine were sampled



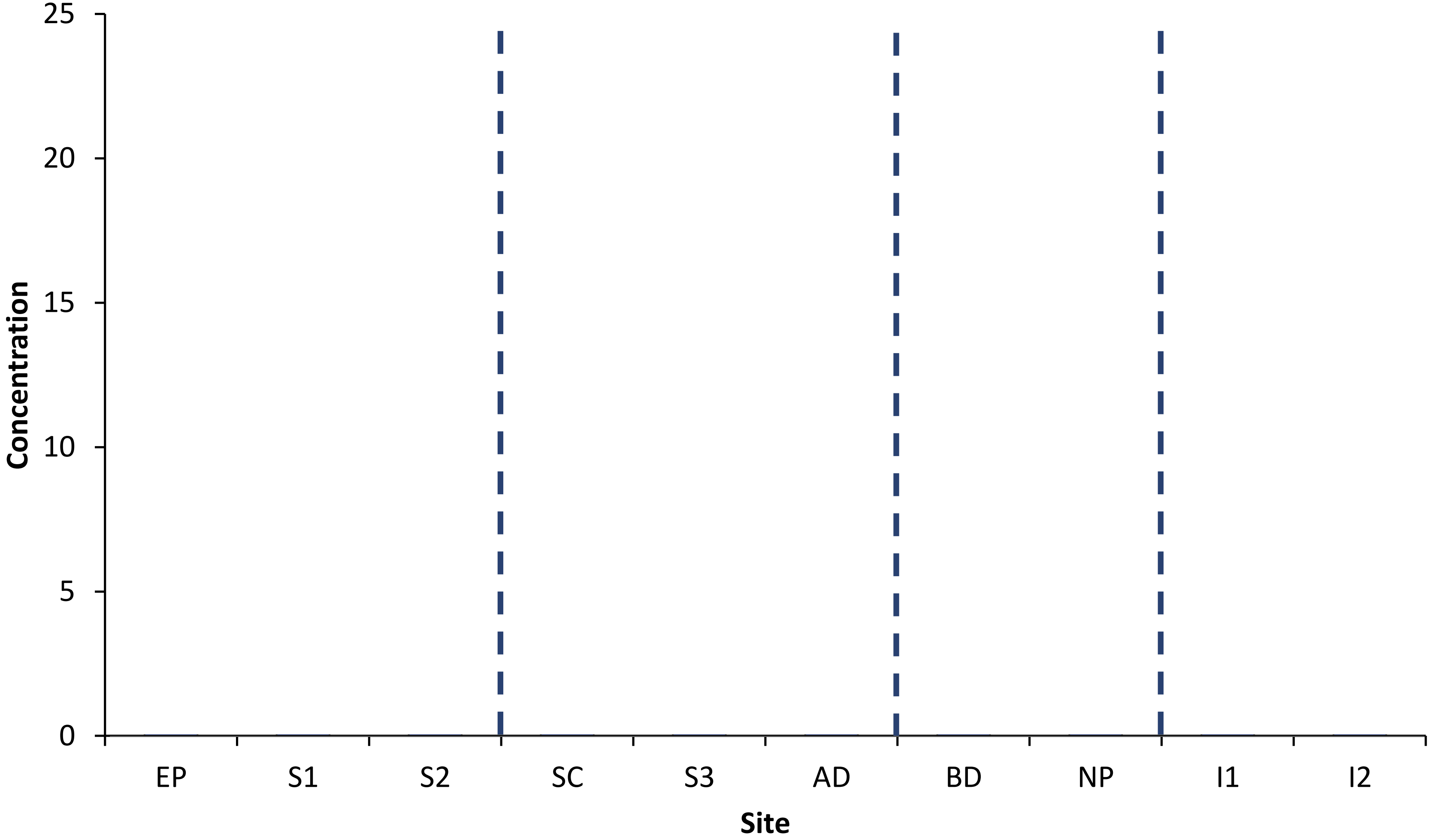
Analysis

- Measured dissolved oxygen (DO), temperature and pH in the field
- Filtered and unfiltered samples were analyzed using an ICP-AES
  - TP, Fe, Al, Ca, Mg
- DOC and TN concentrations were determined using a Shimadzu TOC analyzer
- A Lachat auto-analyzer was used to determine nitrate concentrations

Dissolved Oxygen

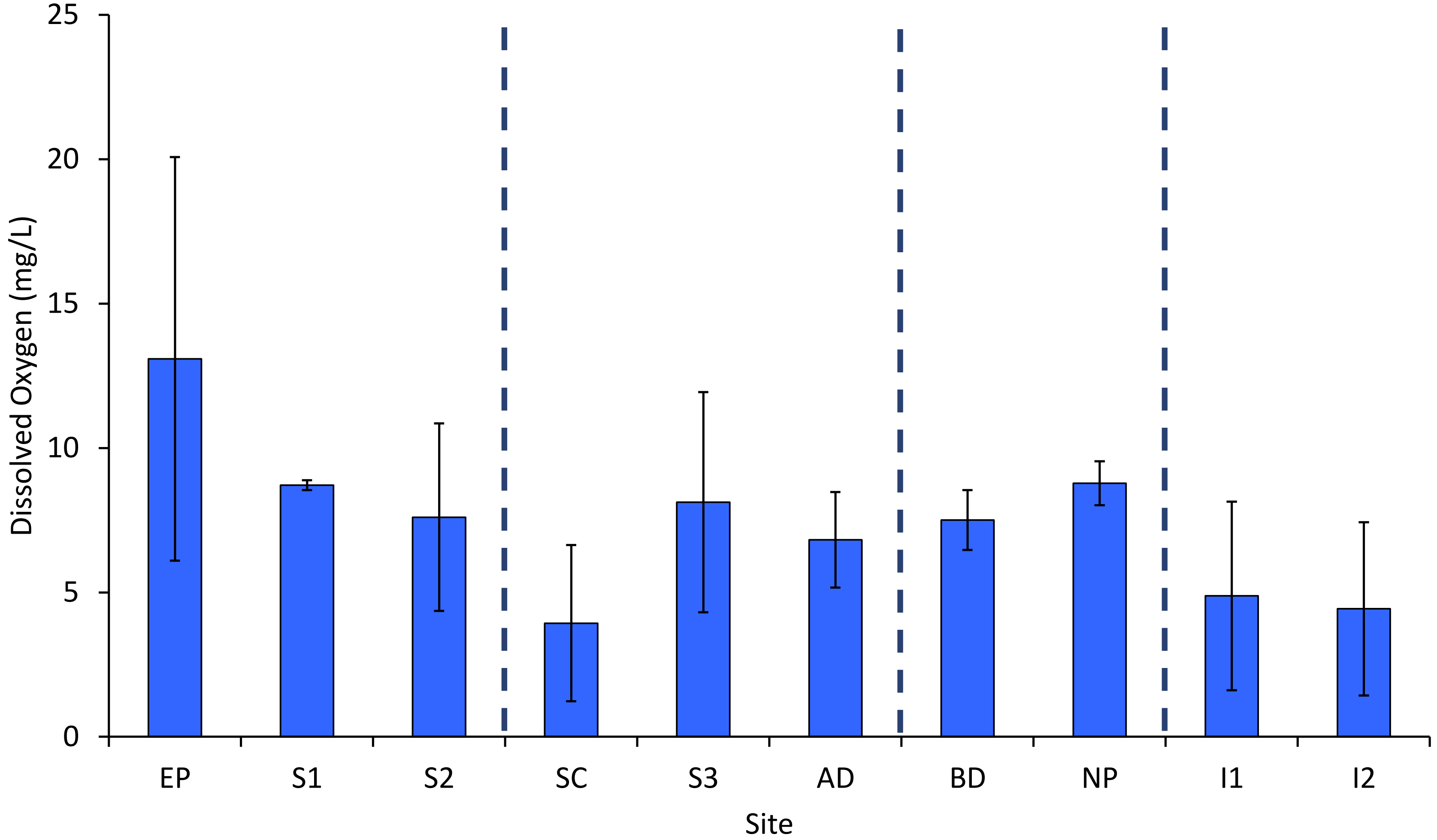
- A measure of the amount of oxygen dissolved in the water
- Influenced by temperature, barometric pressure, mixing and decomposition
- DO determines what fauna can survive
- Plays a role in redox chemistry
- Hypoxia is less than 5.0 mg/L
- Anoxia is less than 2.5 mg/L

Example of Results




I2
I3
I1
SC
S3
BD
AD
S2
NP
S1
EP
Somerset
Kennebec
Serpentine
Sample Point
Watershed
0 487.5 975 1,950 Feet
0 95 190 380 Meters
N
NAD 1983 UTM 19N Projection

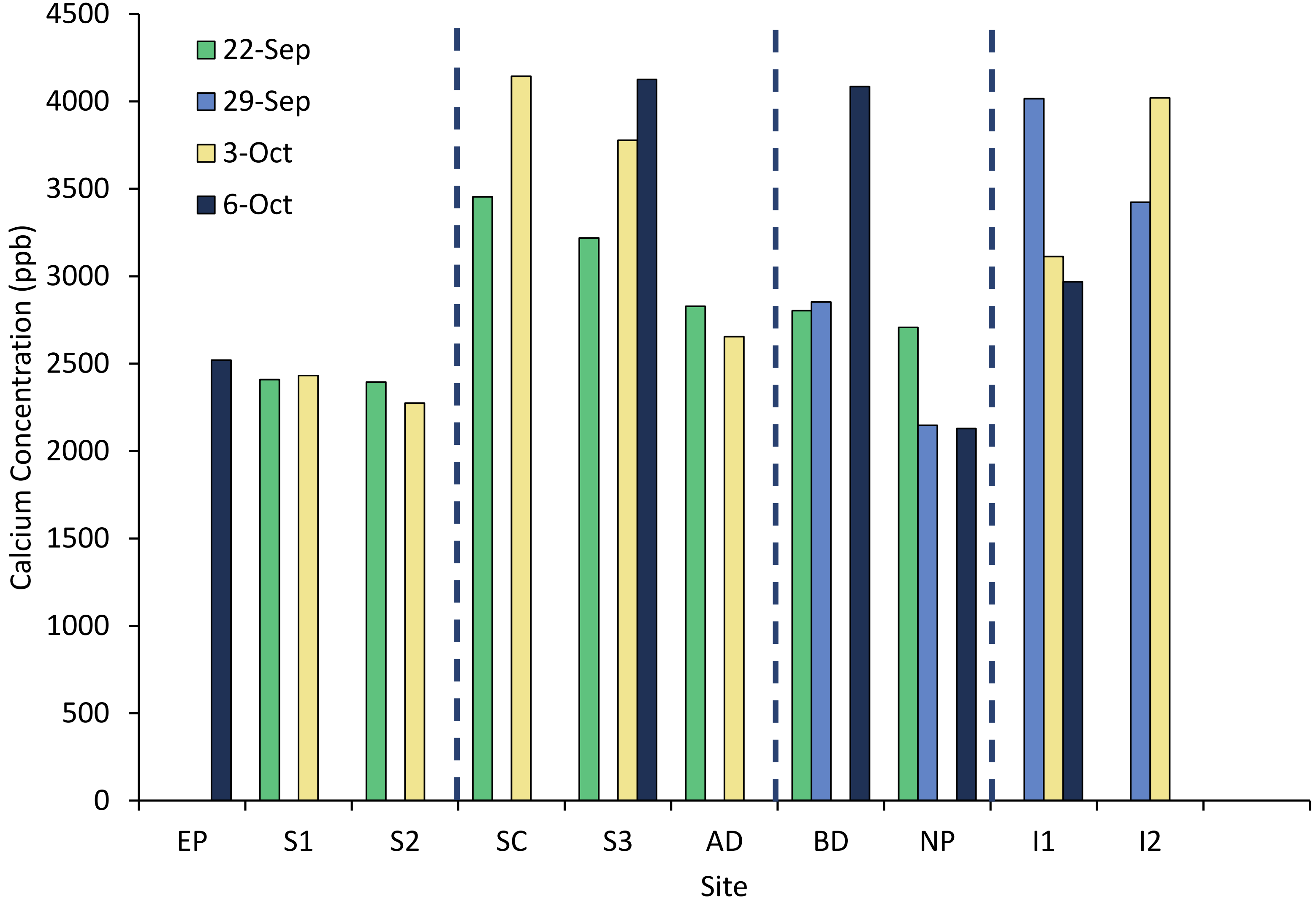
Average Dissolved Oxygen by Site



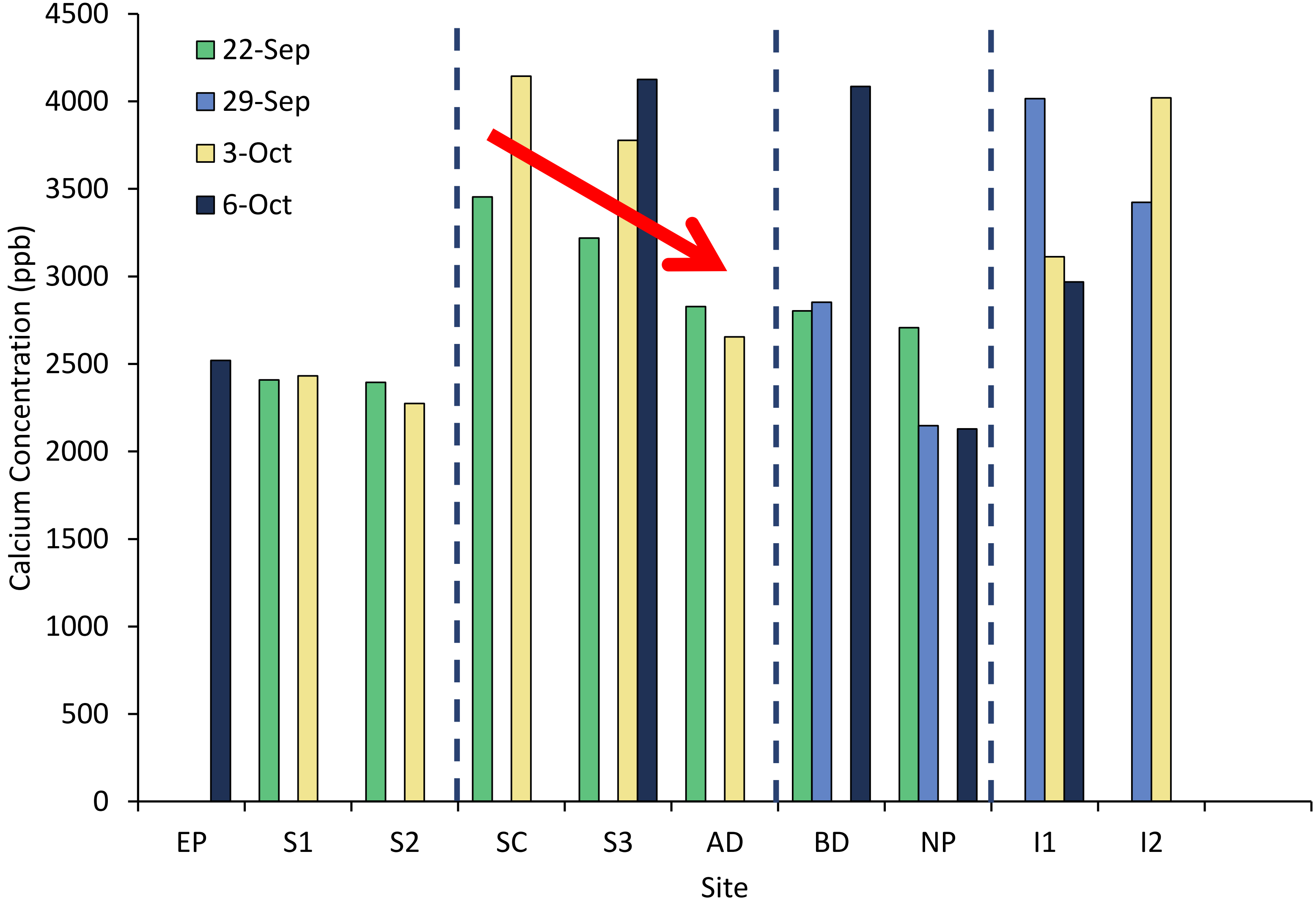
Calcium & Magnesium

- Considered non-reactive elements in the environment
- Both are found primarily in groundwater, however calcium has significant anthropogenic inputs (industry & agriculture)
- With fewer anthropogenic sources, magnesium is possibly more accurate in determining true groundwater sourcing than calcium
- < 10 ppm characteristic of precipitation or short groundwater flow paths

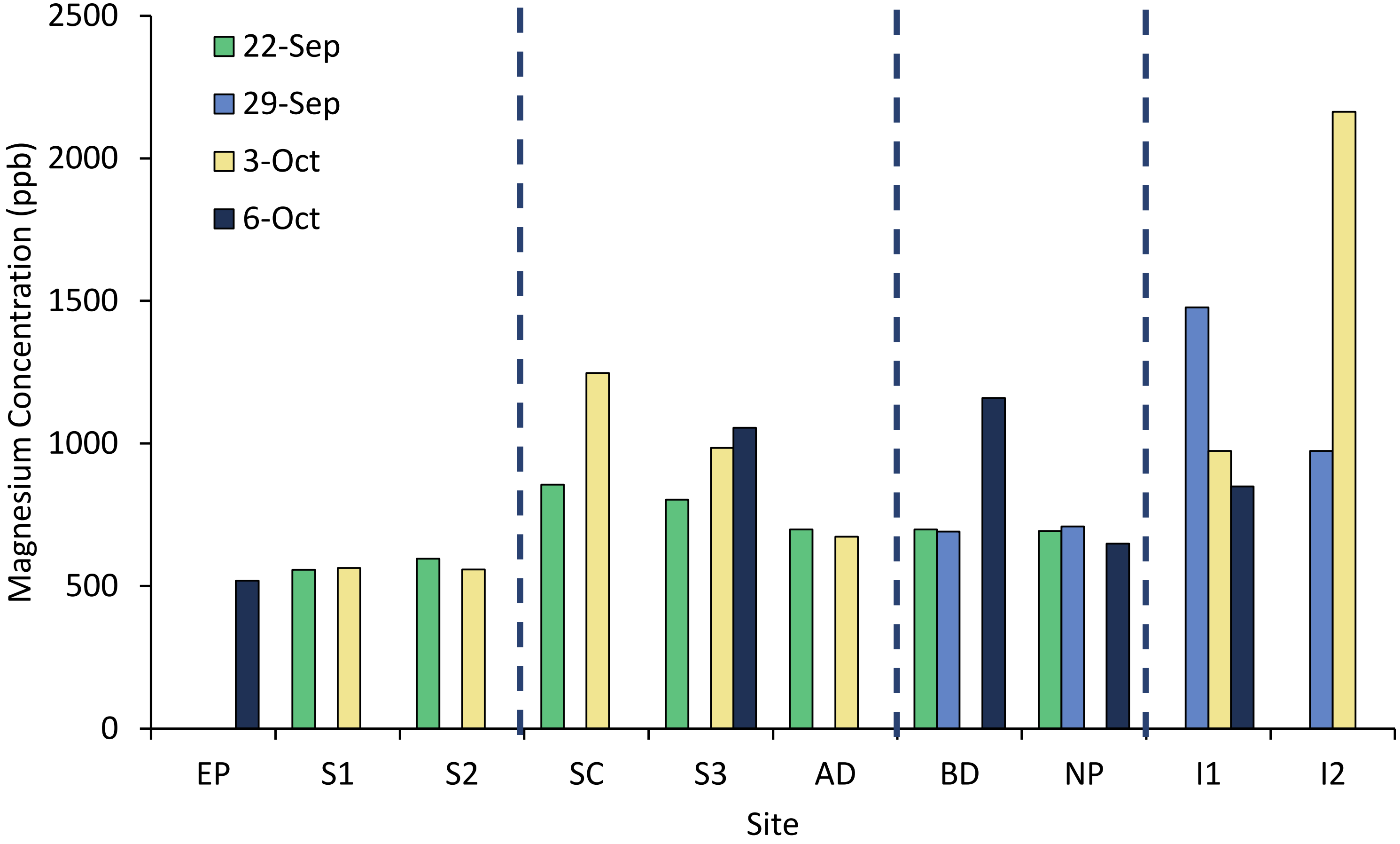
Calcium by Site by Day



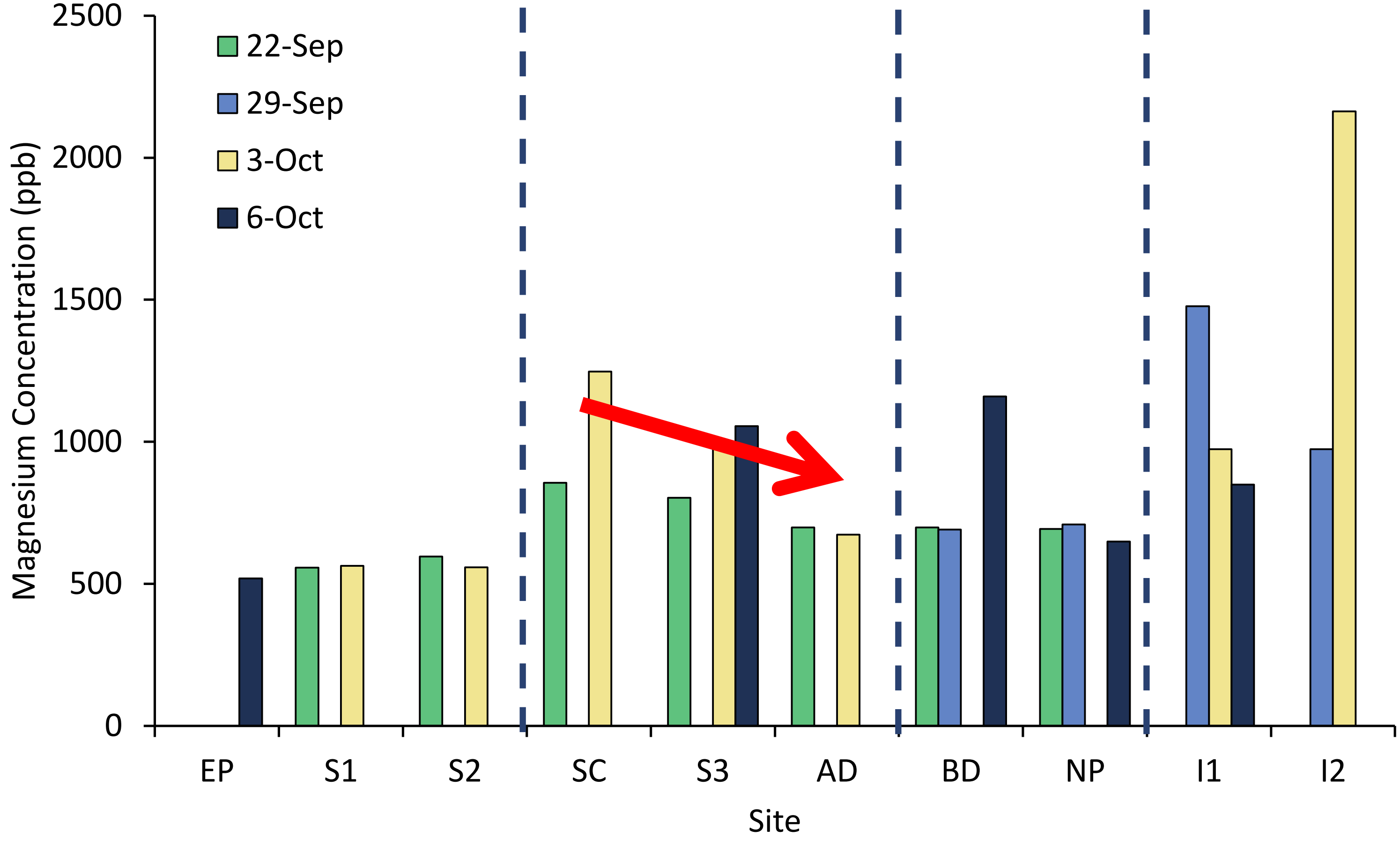
Calcium by Site by Day

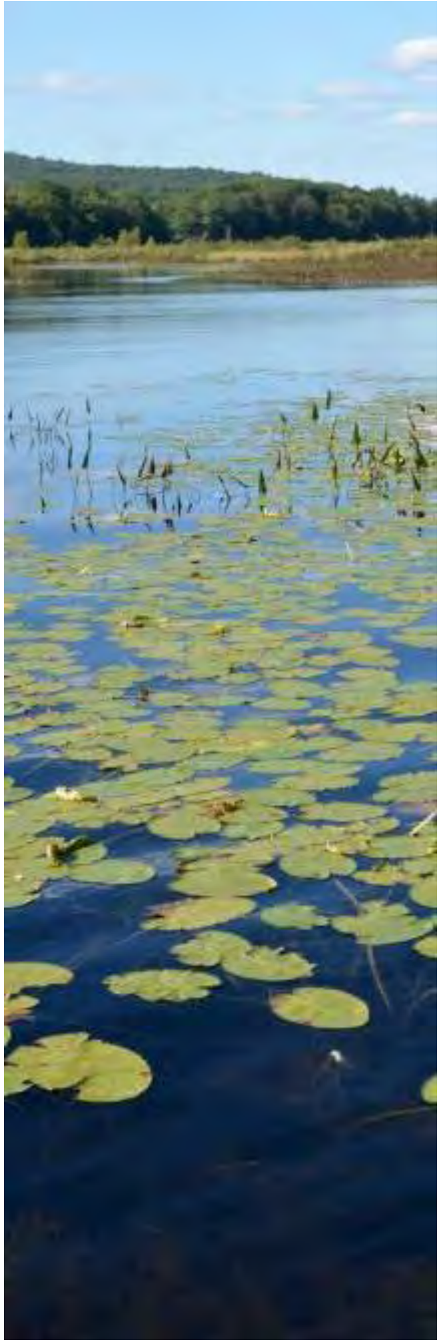


Magnesium by Site by Day



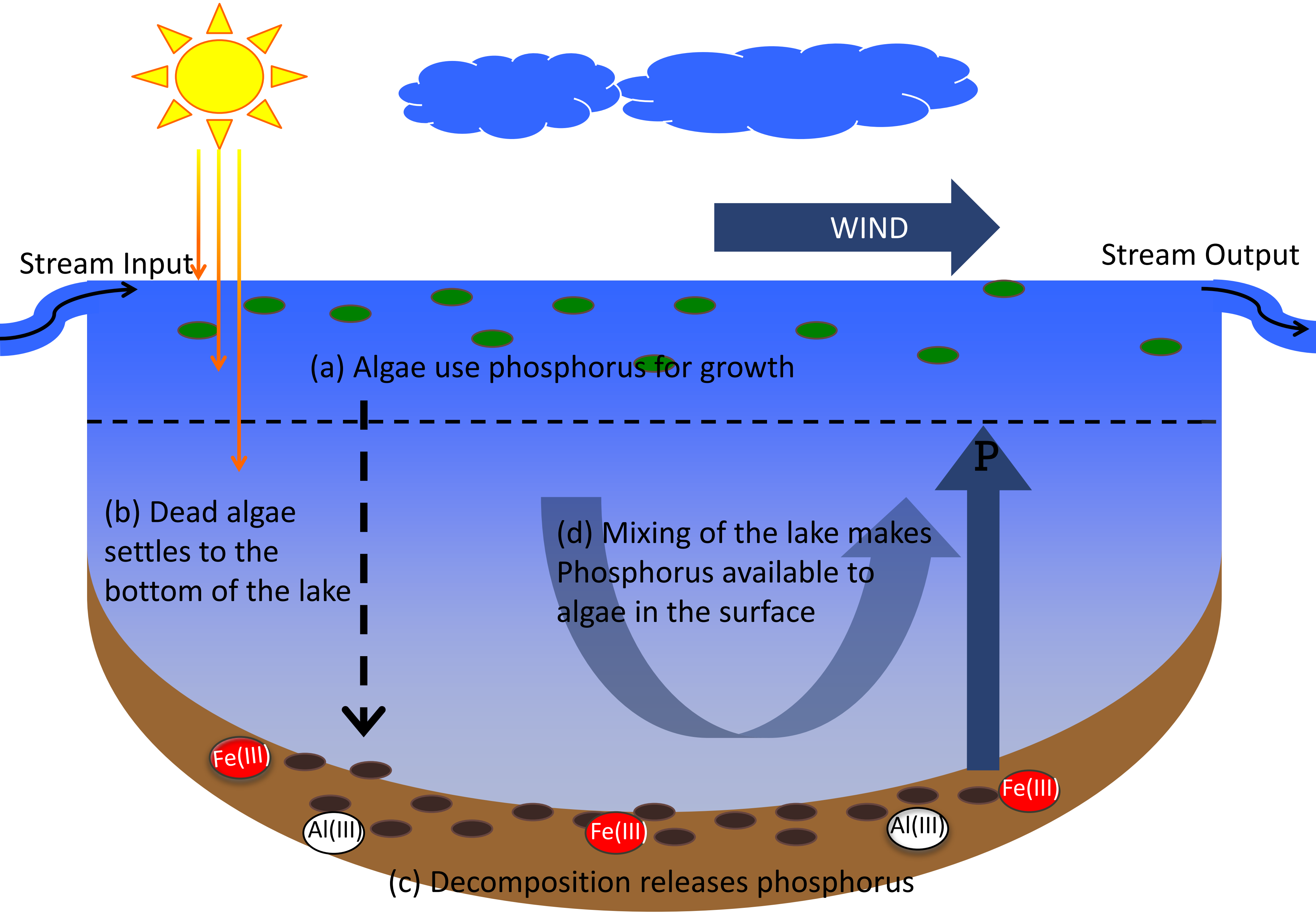
Magnesium by Site by Day





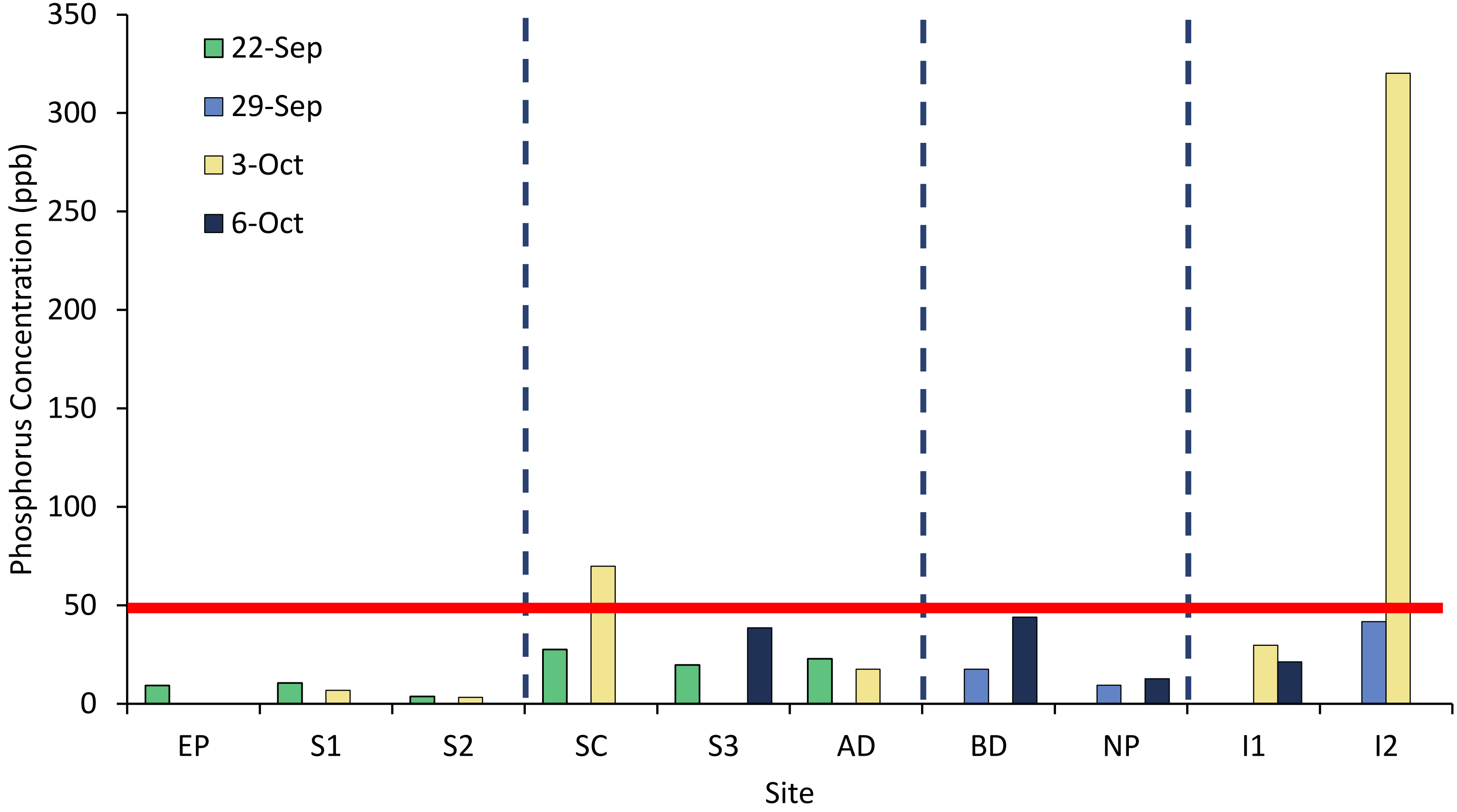
Phosphorus

- An important limiting nutrient, therefore enrichment could lead to eutrophication
- Humans have drastically increased available phosphorus in prior years, altering the nutrient cycling
- It can be introduced through surface runoff and released from internal loading
  - Released from Fe complexes during anoxia



WIND
Stream Input
Stream Output
(a) Algae use phosphorus for growth
(b) Dead algae settles to the bottom of the lake
P
(d) Mixing of the lake makes Phosphorus available to algae in the surface
Fe(III)
Al(III)
Fe(III)
Al(III)
Fe(III)
(c) Decomposition releases phosphorus

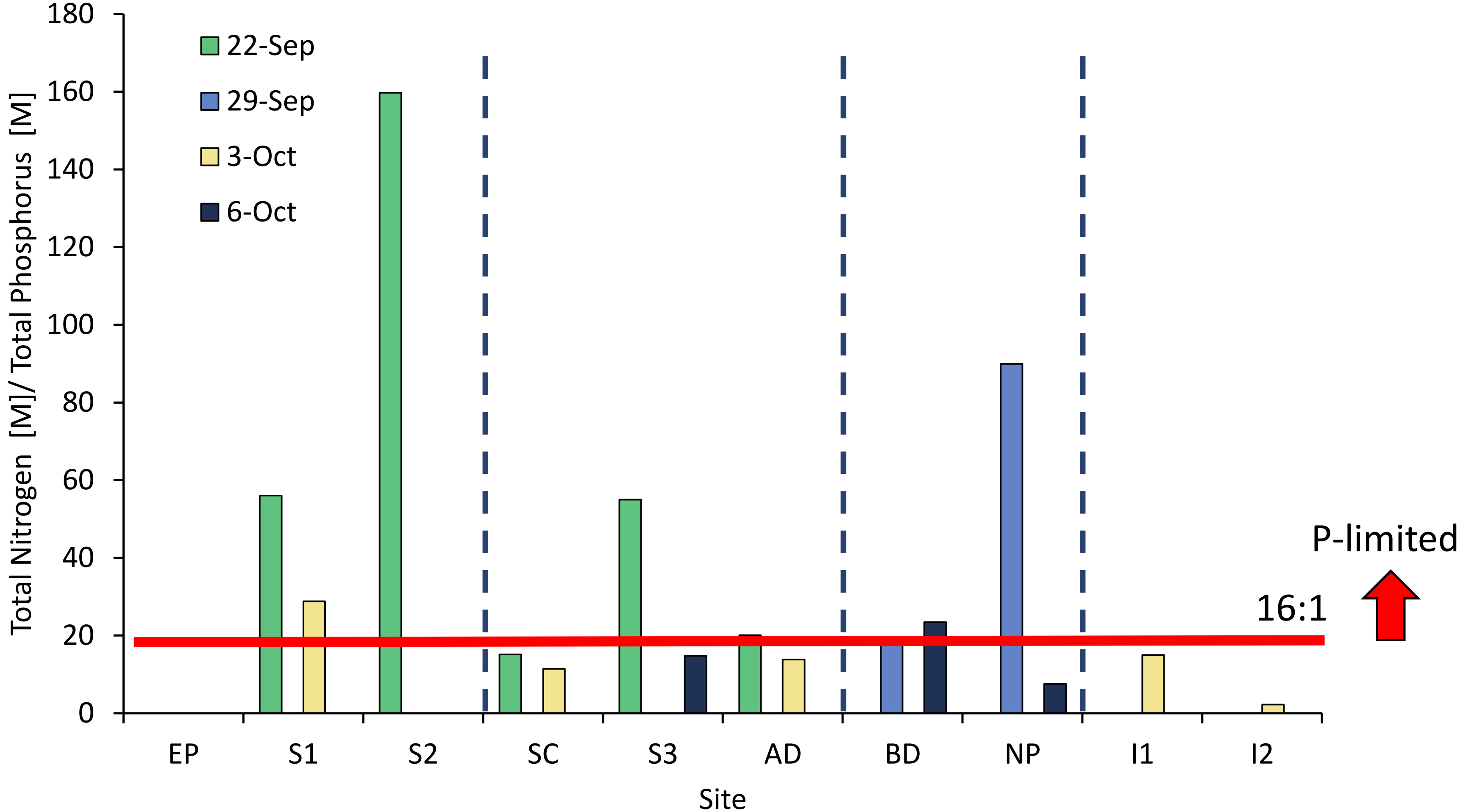
Total Phosphorus by Site by Day



Redfield Ratio & TN:TP Ratio

- The Redfield ratio is a total nitrogen to total phosphorus ratio
  - Defined as 16:1
- The point at which a system shifts from phosphorus limited to nitrogen limited

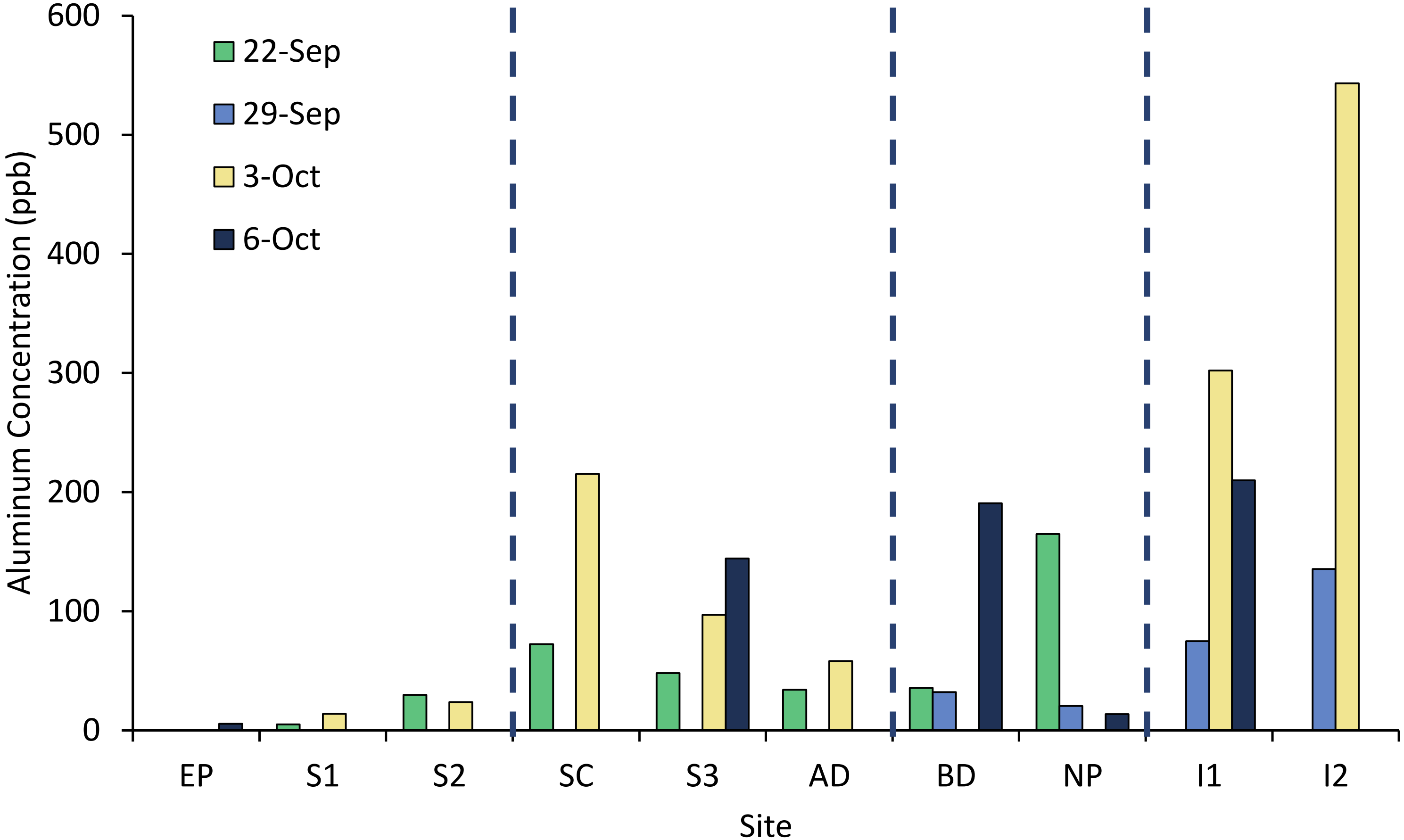
Total Nitrogen : Total Phosphorus ([M]:[M])



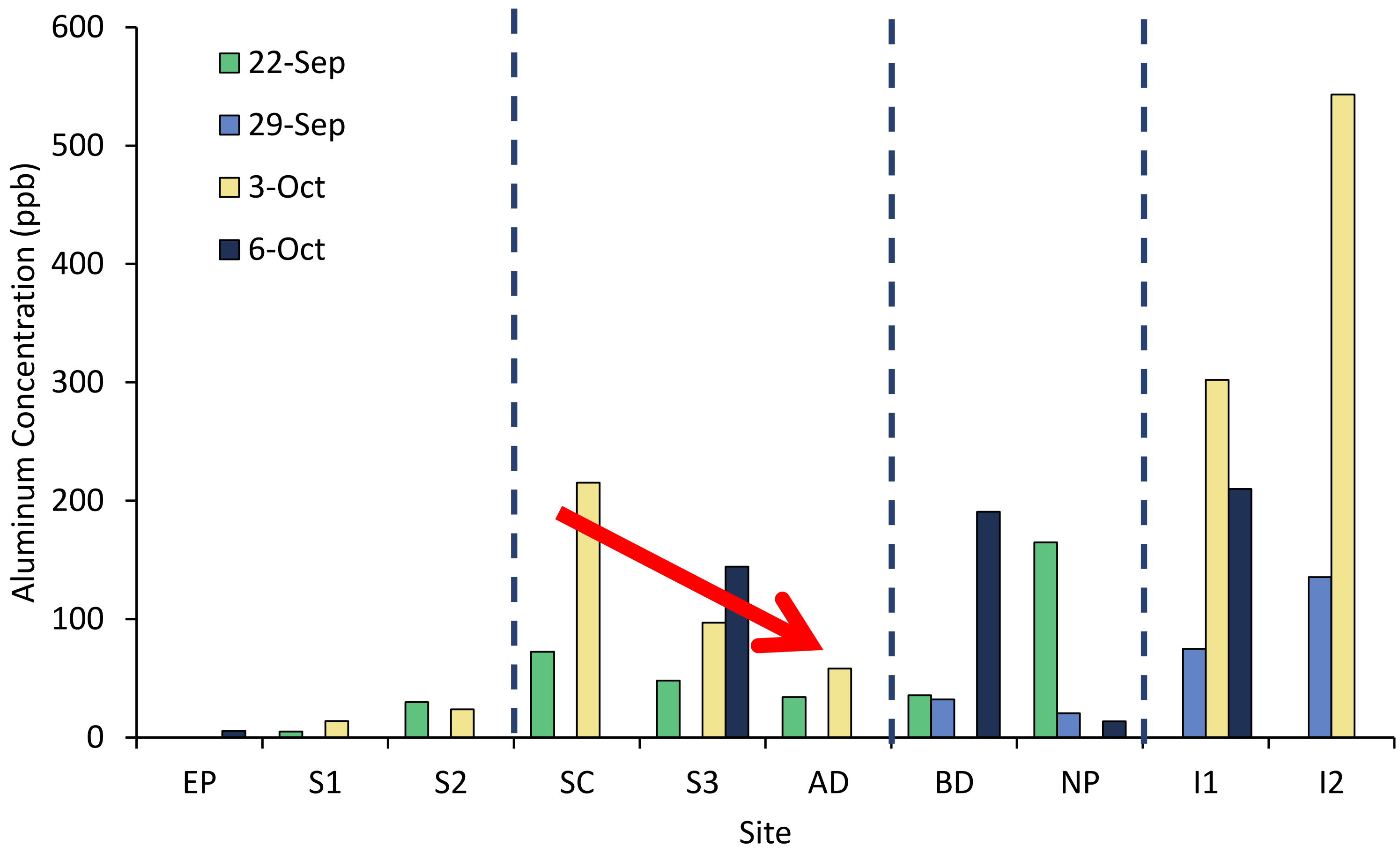
Aluminum

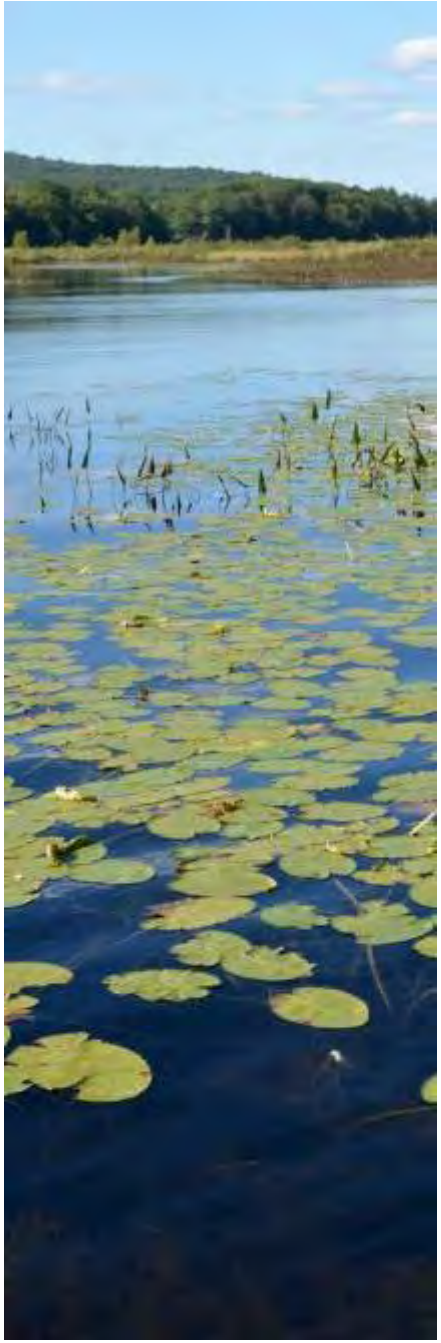
- An important metal which has the ability to permanently bind phosphorus
- Maine lakes had an average total aluminum concentration of 48 ppb (Brakke)
- Streams sampled in September and October averaged 150.5 ppb (Nelson and Johnson 2003)
- All sample sites averaged 112.01 ppb

Aluminum by Site by Day



Aluminum by Site by Day

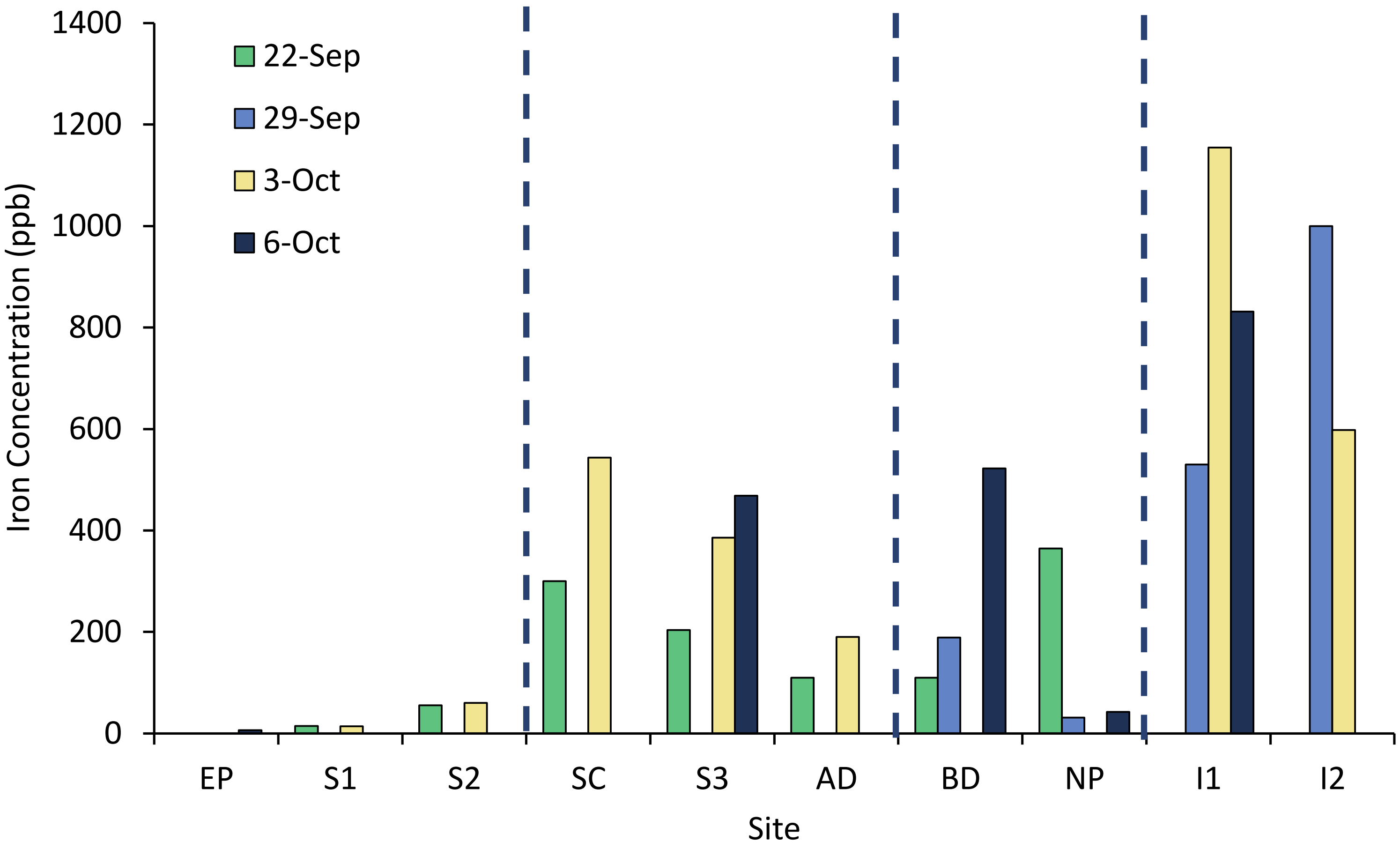




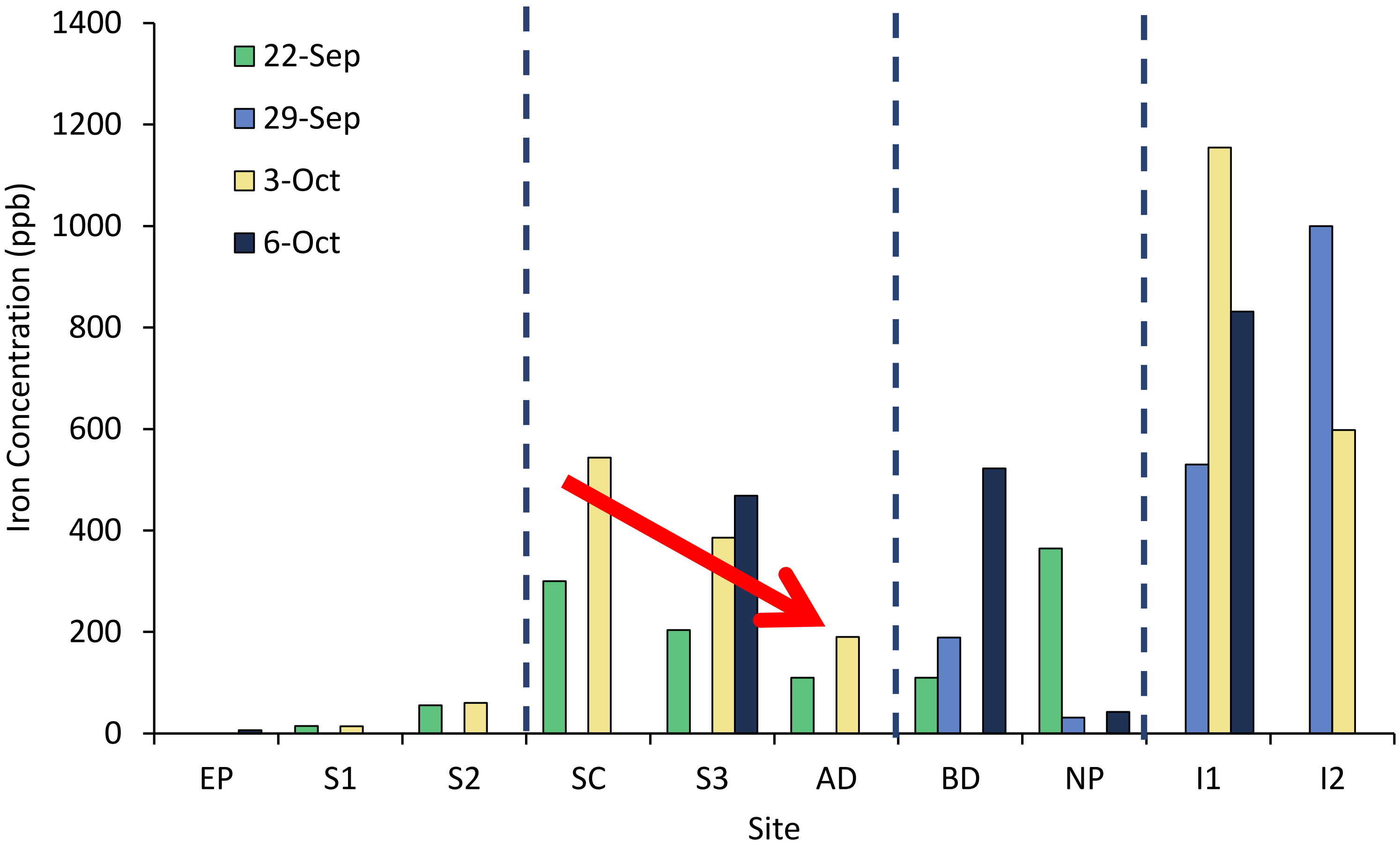
Iron

- An important element for phosphorus sequestration, however it can release phosphorus after binding, unlike aluminum
- Releases phosphorus during periods of hypoxia or anoxia
- Phosphorus is released due to use of iron as a reducing agent during anaerobic respiration
- Average of 40 ppb in Maine lakes (Brakke et al.)

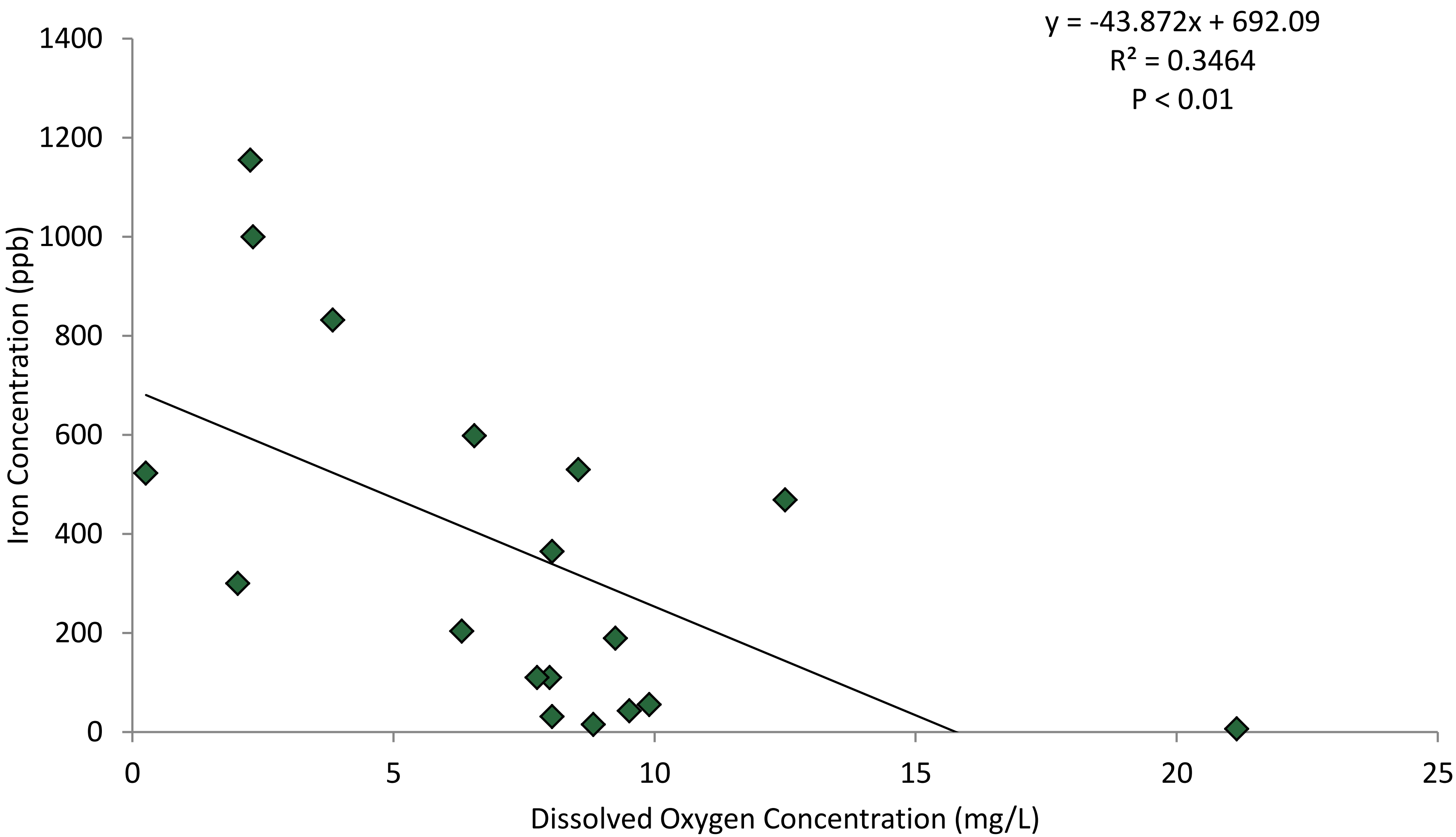
Iron by Site by Day



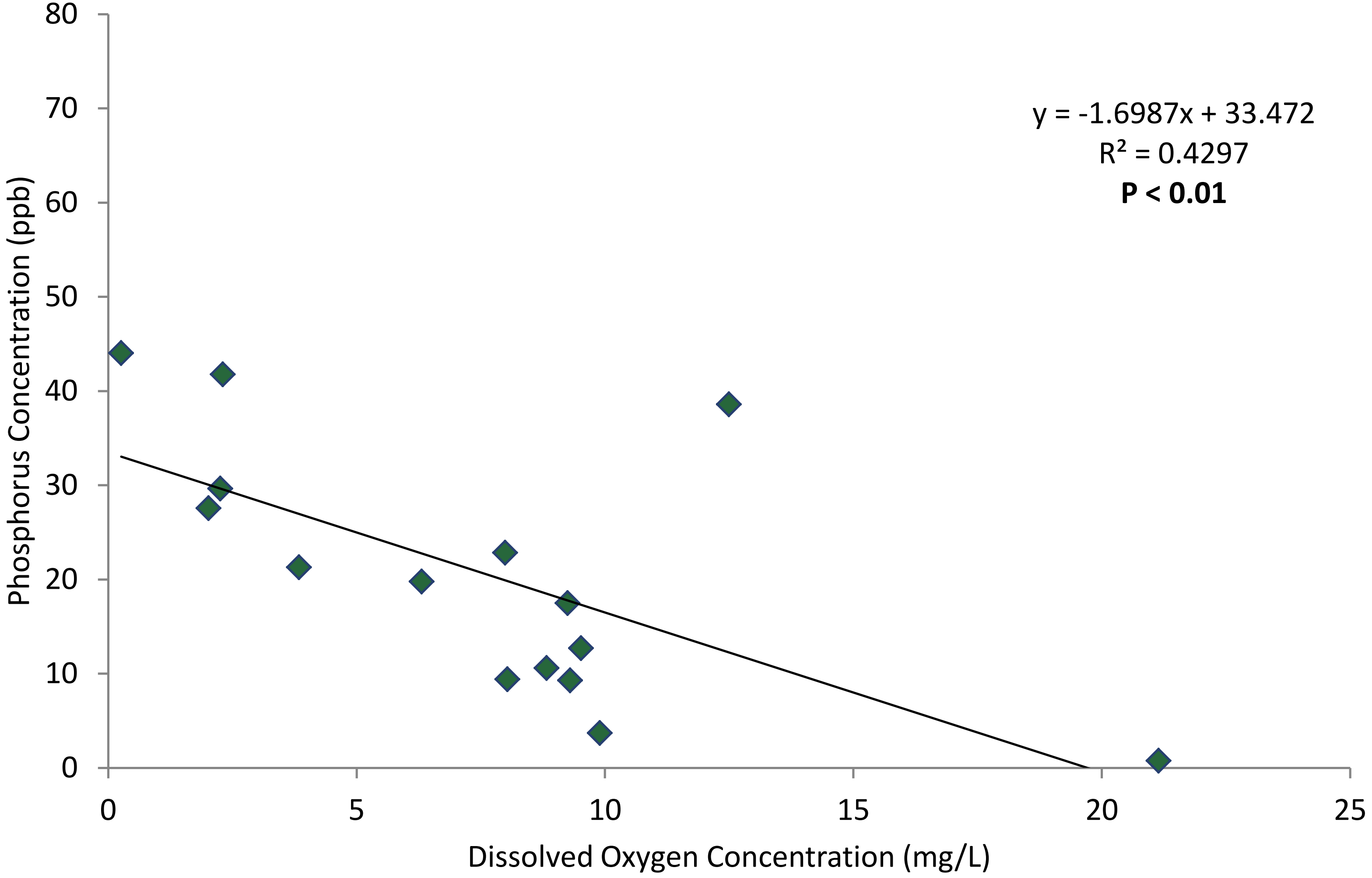
Iron by Site by Day



Iron vs. Dissolved Oxygen



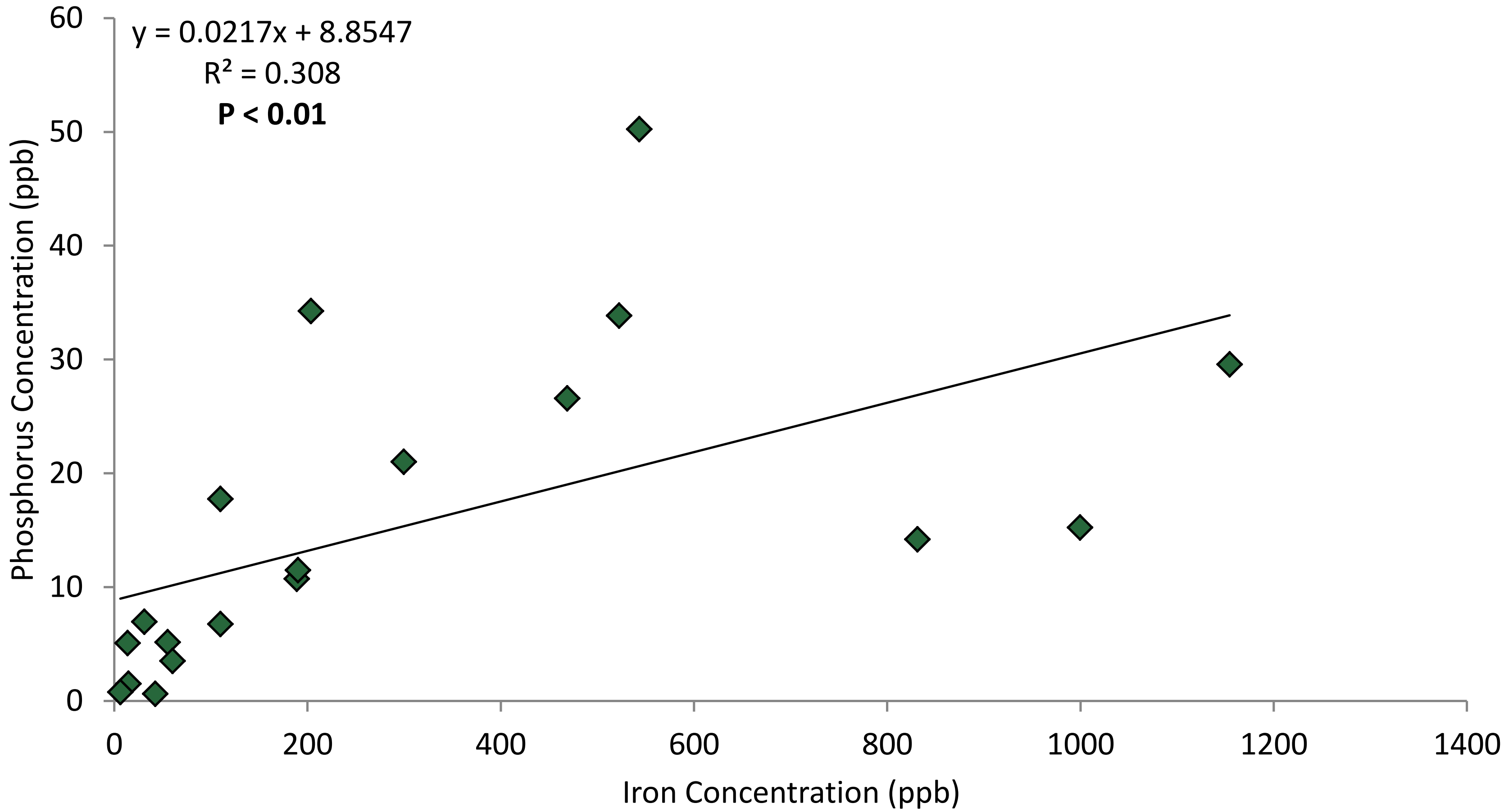
Phosphorus vs. Dissolved Oxygen



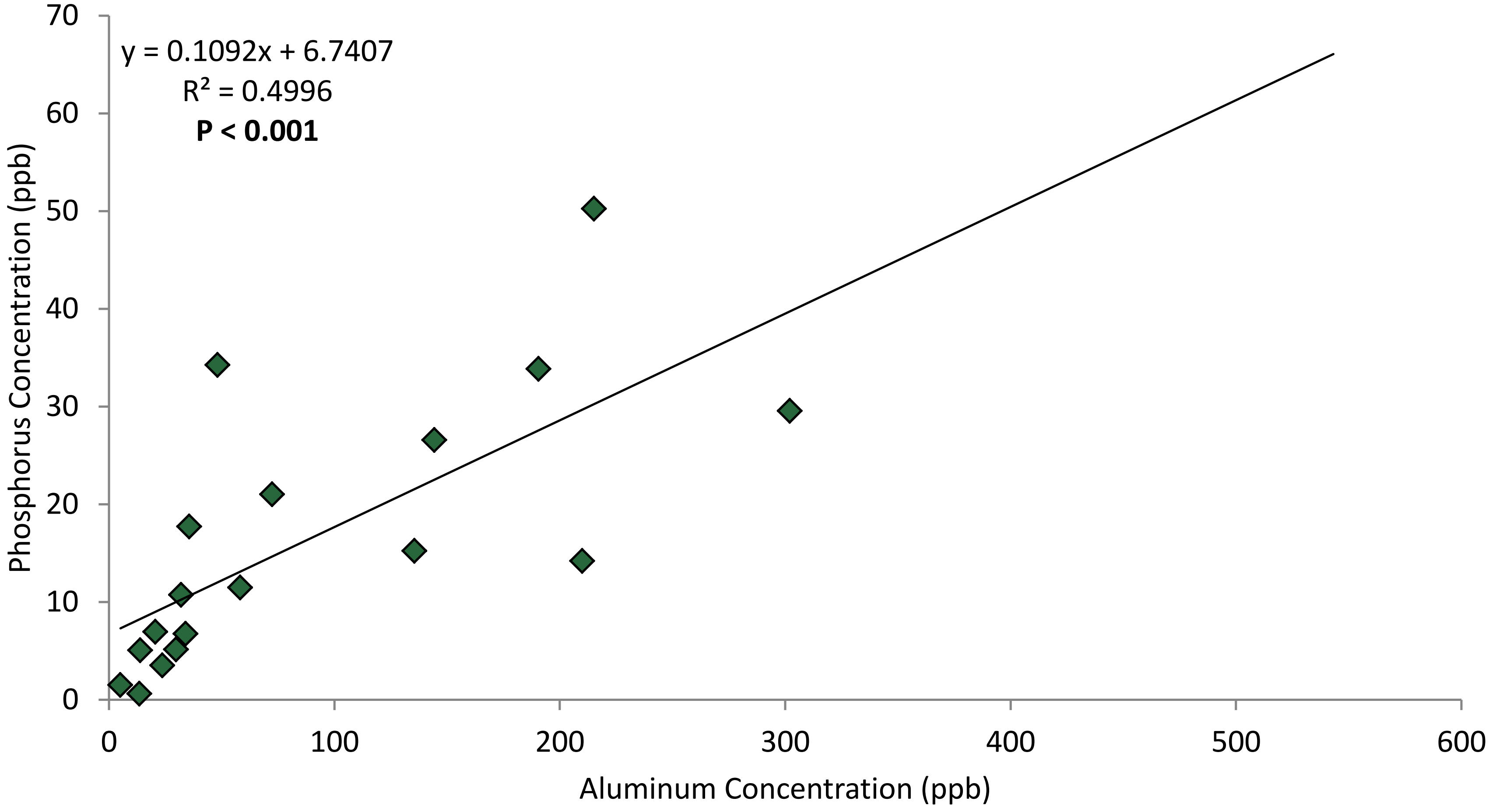
Phosphorus & the Metals

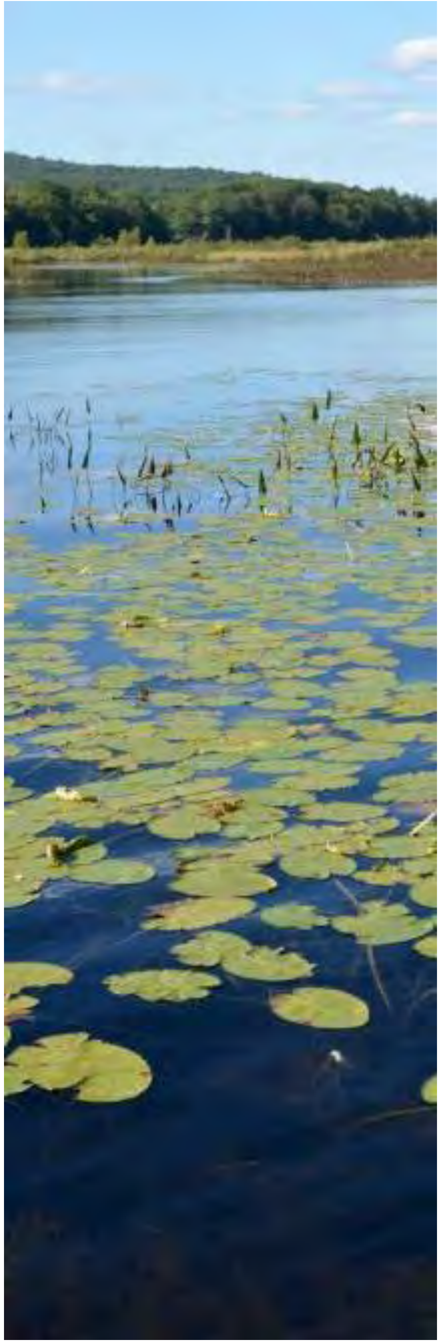
- As phosphorus binds to and is released by redox metals such as iron, we compared iron concentrations to phosphorus concentrations
- Conversely, aluminum binds phosphorus permanently
- Used linear regressions to determine correlation between metals and phosphorus

Iron vs. Phosphorus



Aluminum vs. Phosphorus





Take Home Messages

- The water chemistry in East Pond does not appear to be substantially influencing the water chemistry in the Serpentine beyond SC or North Pond

- The most substantial influx of nutrients from the input streams is seen after precipitation events

- Most nutrients seem to enter the Serpentine via the input streams
  - However, those nutrient levels are substantially diminished in North Pond
    - H1: biological uptake
    - H2: binding with Fe or Al
    - H3: dilution

Future Research

- Determine if other inputs contribute substantially to nutrient levels in North Pond
  - Importance of input streams?
- Further investigate three potential hypotheses
  - Does one process reduce nutrients more than others?
  - How might these processes change over time?
- Collect data over a longer time scale
- Determine the impacts of flow on nutrient levels

Algal Sampling

Why do algal blooms occur frequently in East Pond but not North Pond?

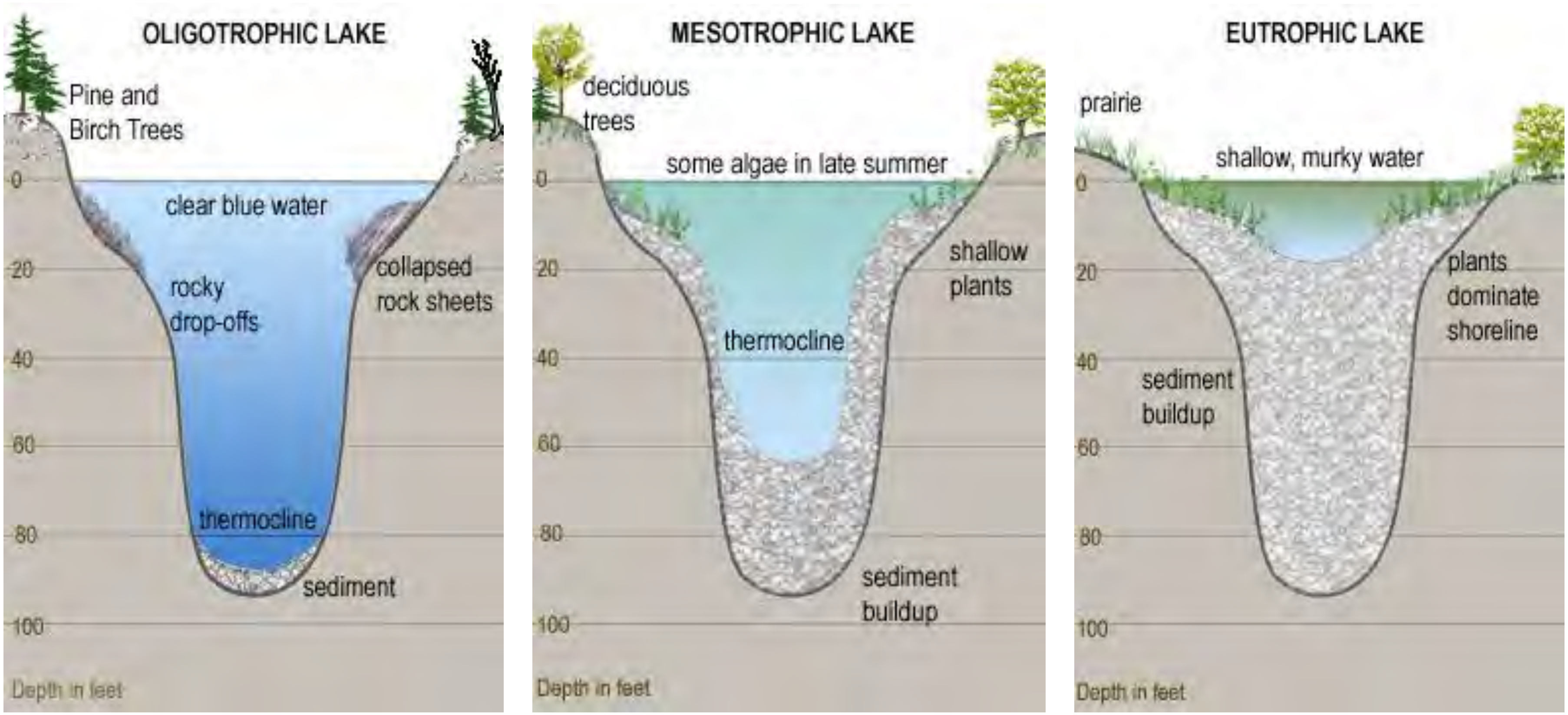
Our objectives:

- Establish a baseline for algal species found in the Serpentine, East and North Ponds
- Record algae species that can be bioindicators
  - Can track change in the system over time

Algae as Bioindicators

- Different types of algae grow best in different conditions
  - Water nutrient levels (phosphorus, nitrogen)
  - Water temperatures
- Classified the algae by phylum

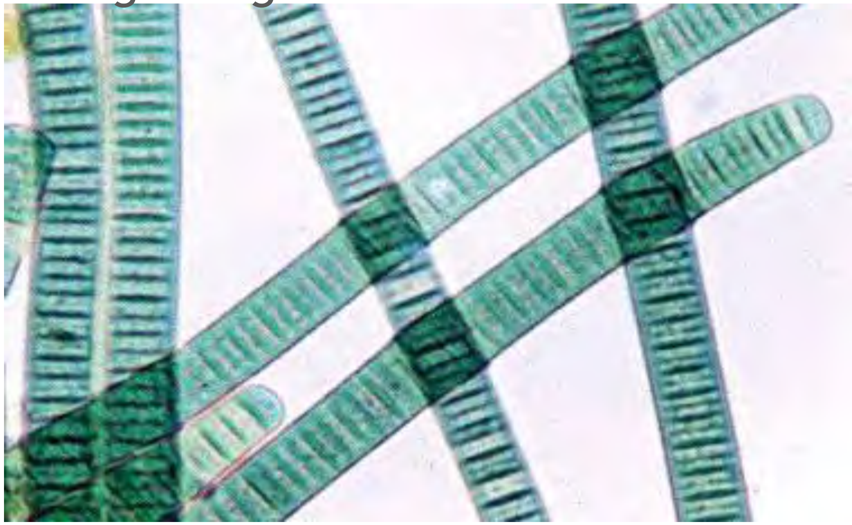
Review: Nutrient Loading



Algal Types (I)

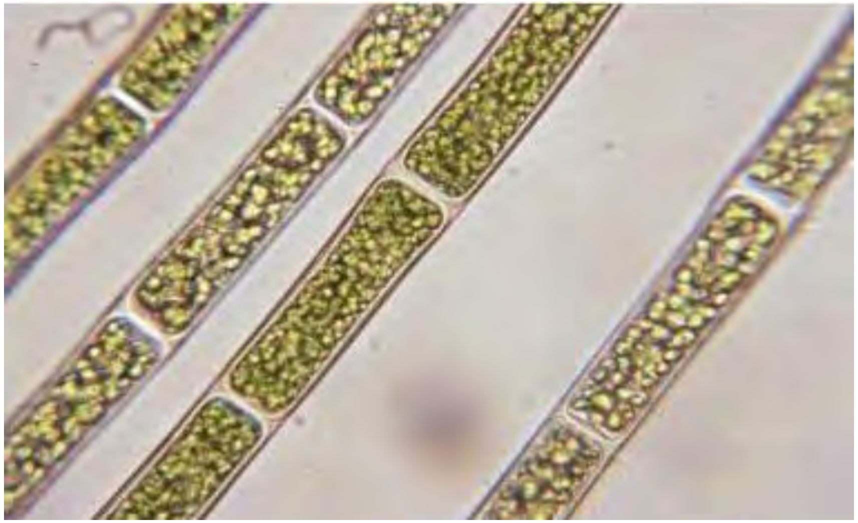
Cyanophyta

- Blue-green algae
- Eutrophic systems—high phosphorus
- Large blooms in late summer (warm water)
- Resistant to zooplankton grazing



Chlorophyta

- Green algae
- Mesotrophic and eutrophic environments
- Not dominant when phosphorus levels are high
- Early summer



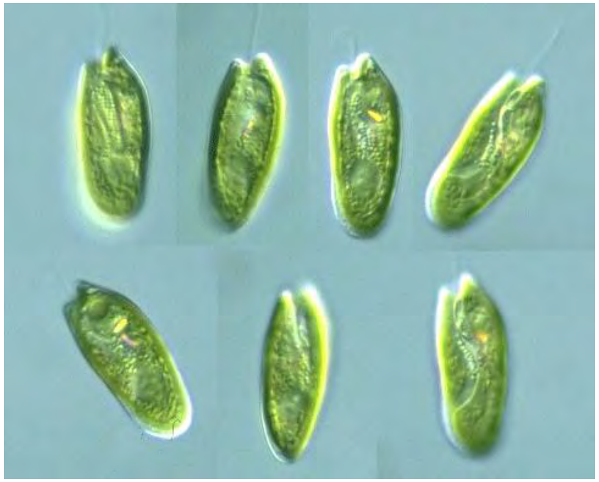
Algal Types (II)

Bacillariophyta

- Diatoms
- Mesotrophic systems
- Mid-level phosphorus concentrations
- Bloom in spring and fall
- Cooler water temperature

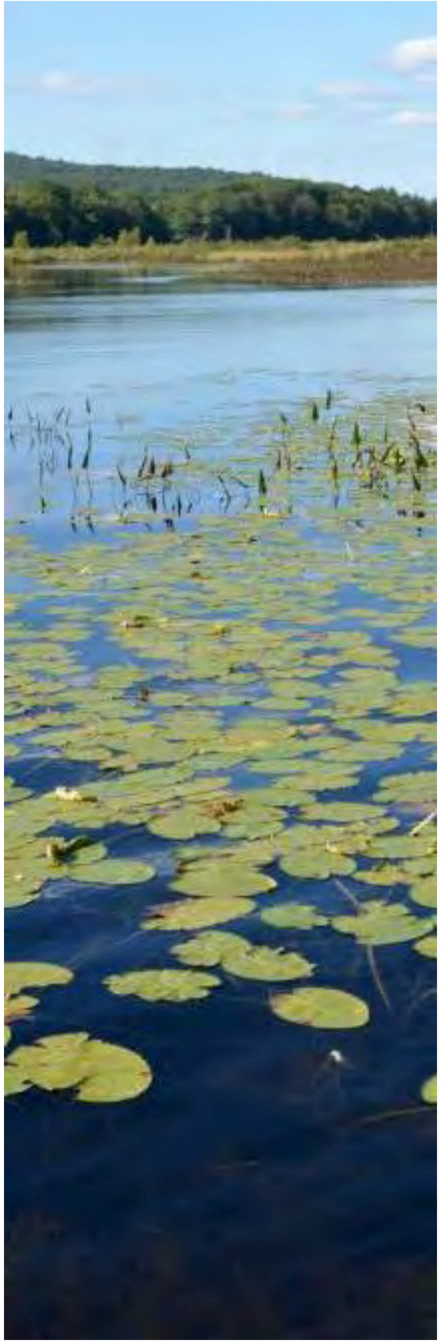
Cryptophyta

- Oligotrophic and mesotrophic systems
- Cold water
- Spring blooms

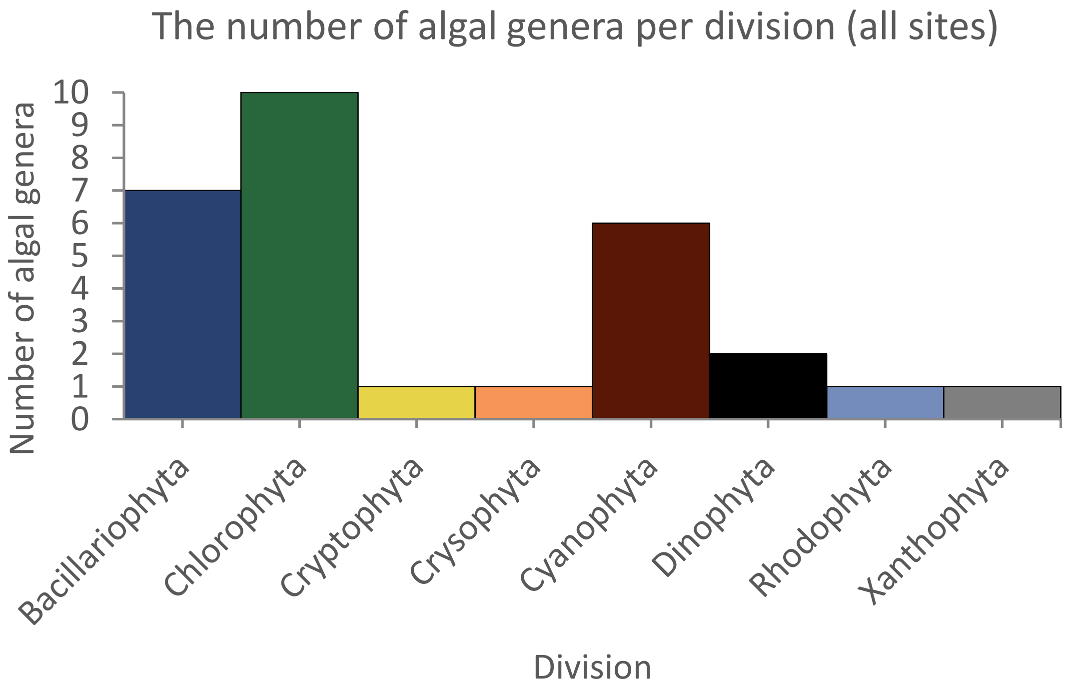


Methods

- 5 study sites
- One day of sampling (October 6th, 2011)
- Plankton tow net
- Preserved in ethanol
- Examined 5 slides from each sample through a microscope
- Identified each different specimen

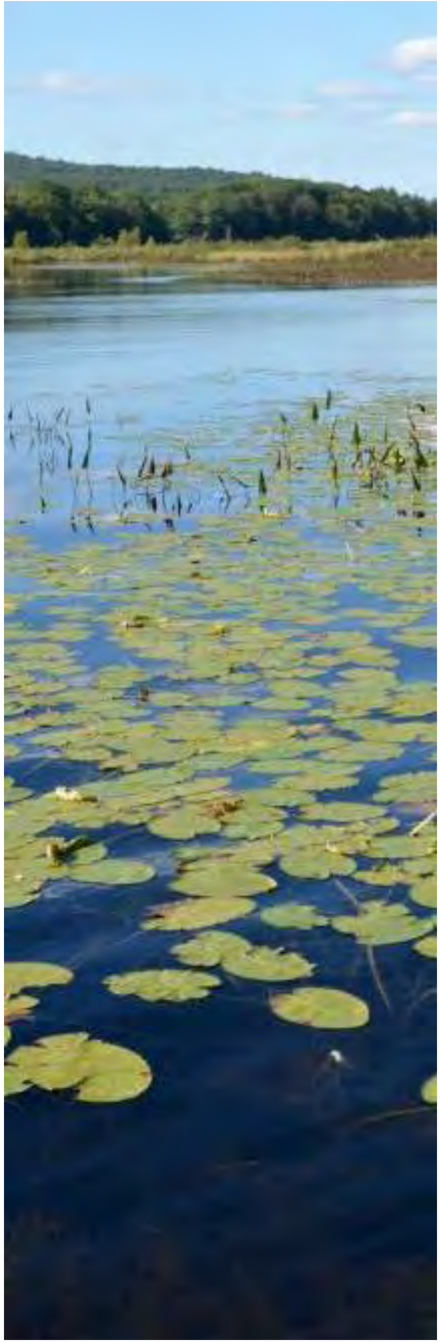


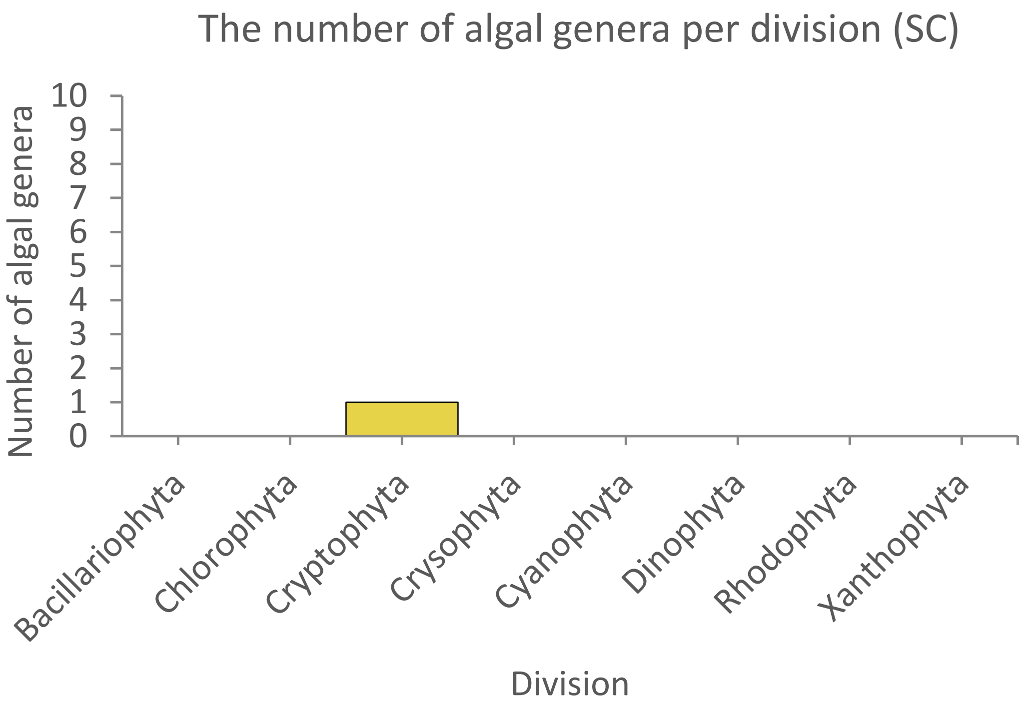
Combined Results



- 62 different genera in 8 phyla
- Chlorophyta, Bacillariophyta, and Cyanophyta were best represented

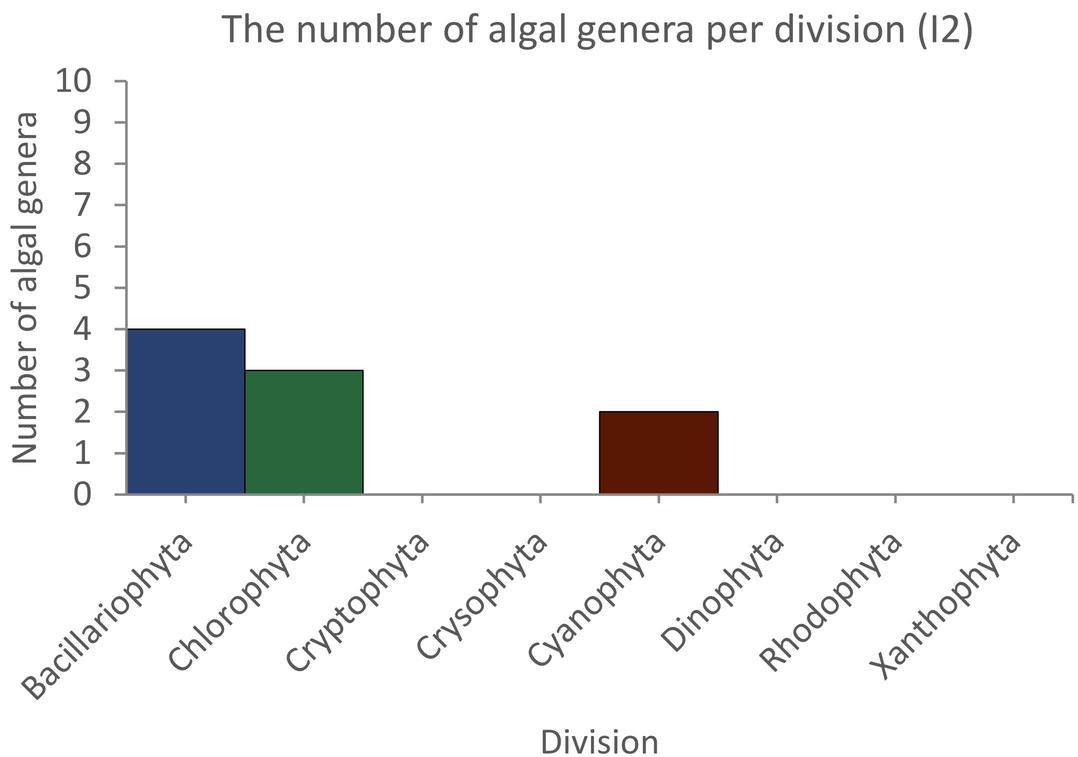
Serpentine Stream



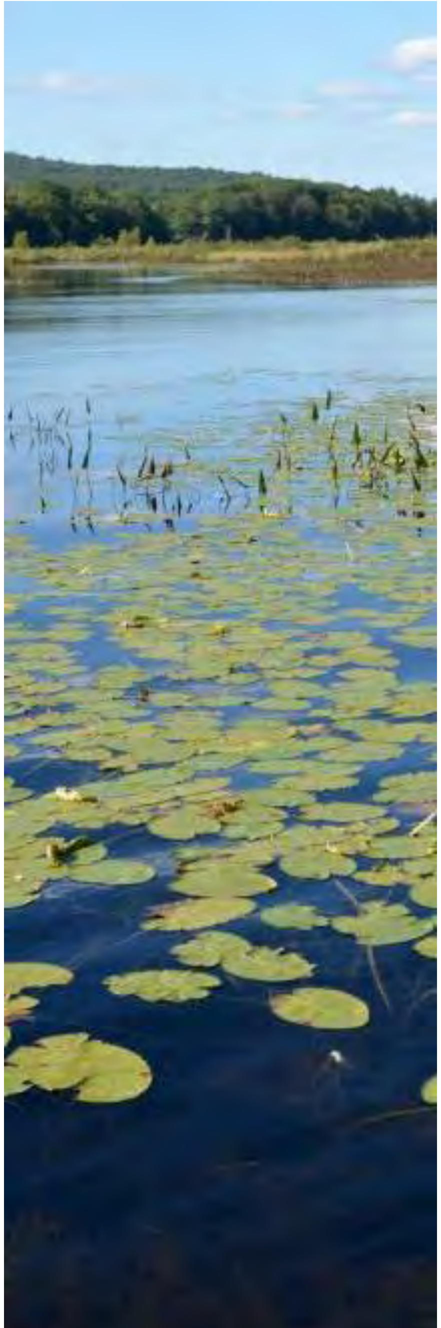


- Only one specimen spotted in five slides
- Cryptophyta—cold water species

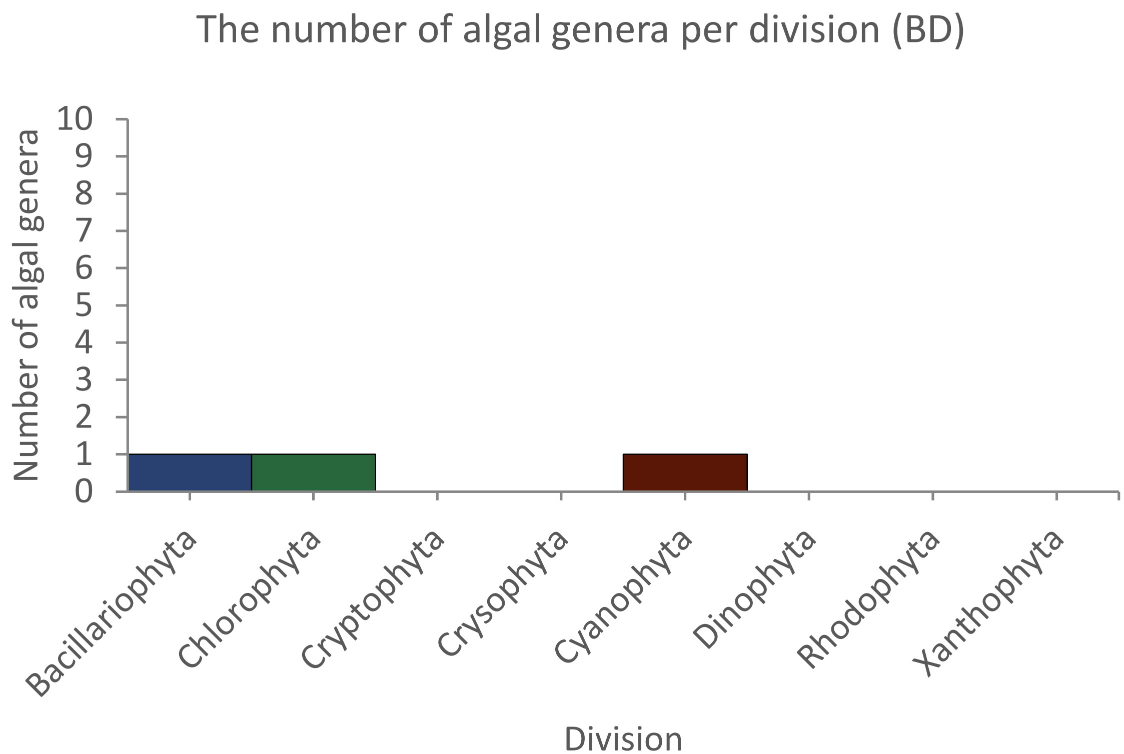
Input Stream



- Bacillariophyta, Chlorophyta, and Cyanophyta
- More Bacillariophytes as a result of cool temperatures?

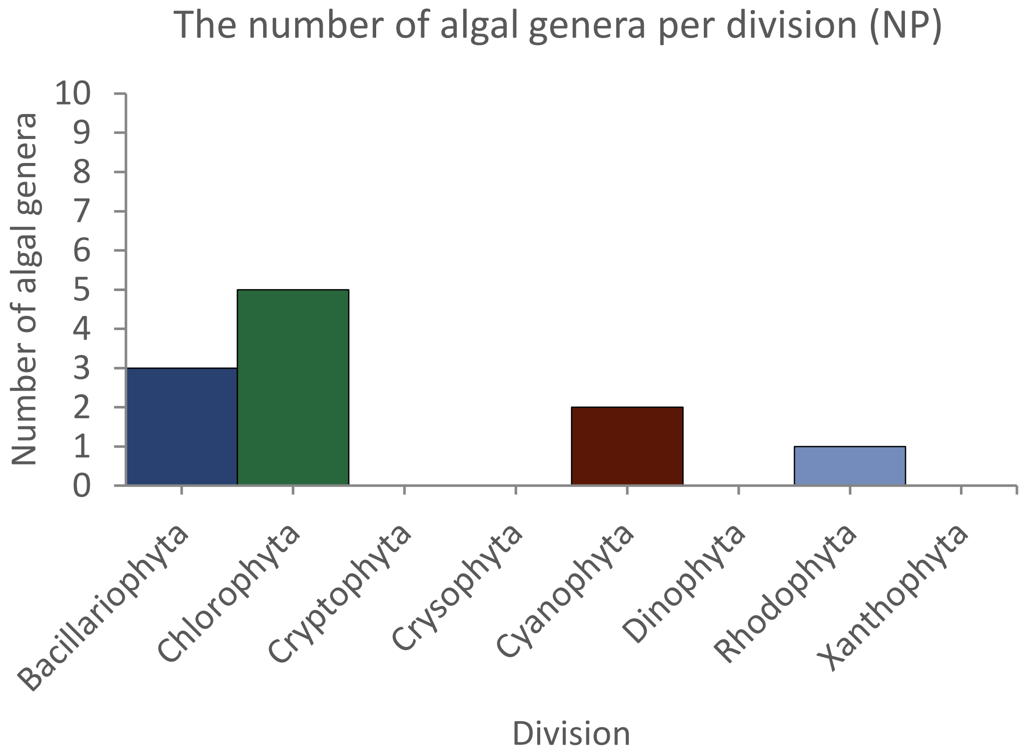


North Pond, Below Dam

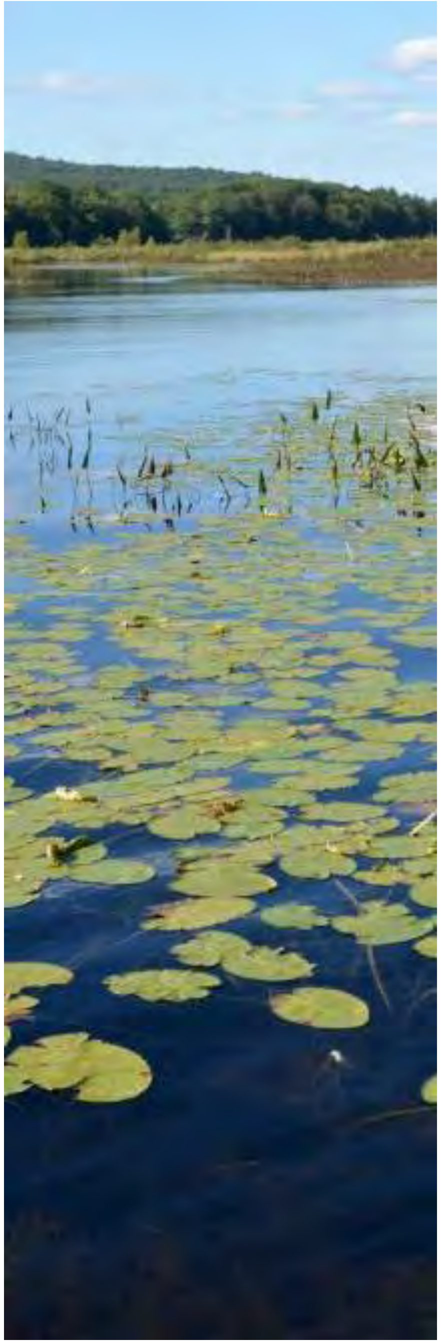


- Bacillariophyta, Chlorophyta, and Cyanophyta

North Pond



- Bacillariophyta, Chlorophyta, and Cyanophyta
- 11 genera in 14 phyla



Implications

- Chlorophyta, Bacillariophyta and Cyanophyta most represented
- Cold water species (Bacillariophyta, Cryptophyta)
- Can indicate:
  A. System is mesotrophic
  B. System is eutrophic, but cold water limits Cyanophytes

Future Research

- Limits of sampling method
  - Count abundance of the algal specimens
- Data collected over the whole ice-free season would better represent the system
  - Cyanophyta may dominate late summer algal blooms (warm water)
  - Biomanipulation not effective against Cyanophytes

Fish

Our objectives:

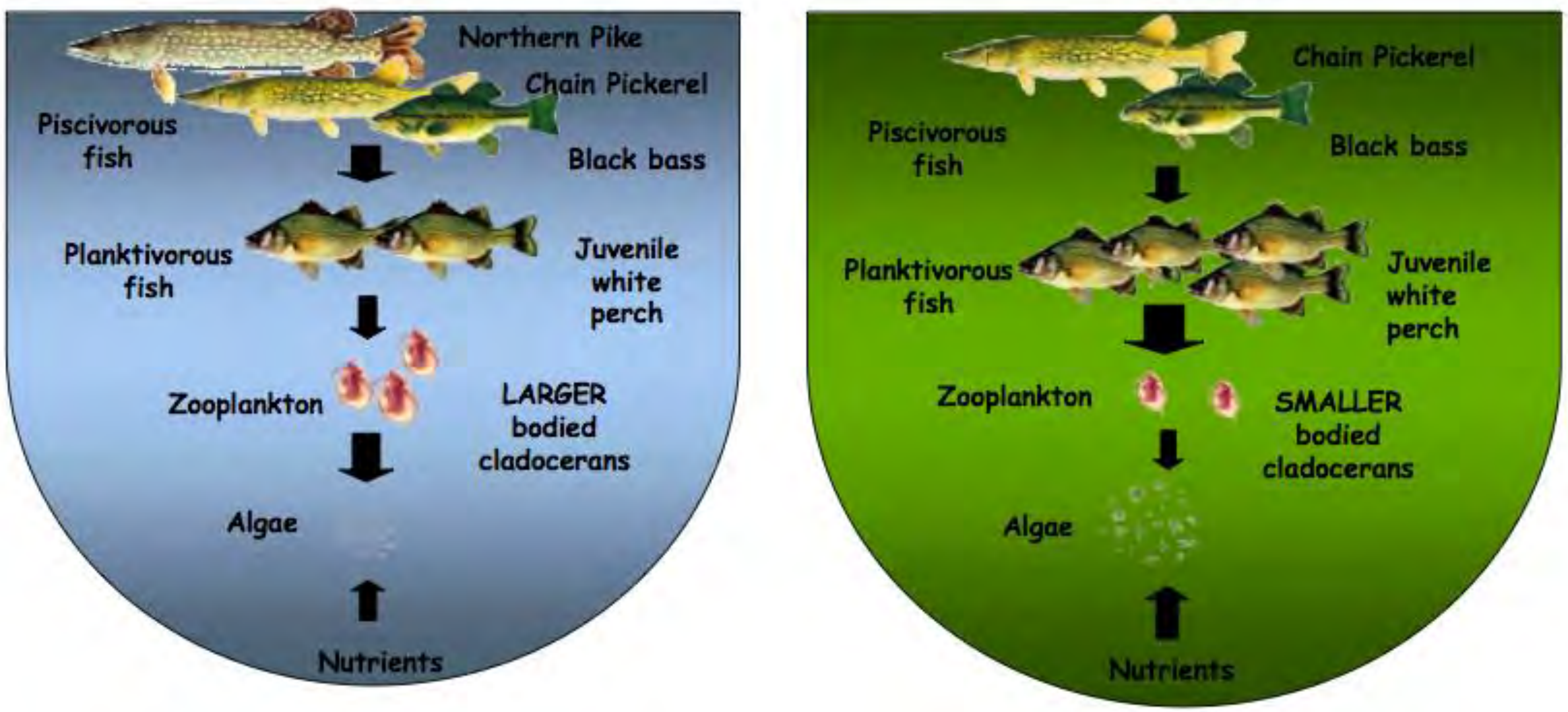
- Determine which fish species may be present in the Serpentine
- Understand how these fish may be affecting trophic relationships in the Serpentine
- Understand the influence of fish in East pond algal blooms
- Develop potential explanations for the mixed results of the 2008 East pond biomanipulation project

Ecological Role of Fish in Aquatic Ecosystems

Warmwater Shallow Lake Trophic Cascade

North Pond

East Pond

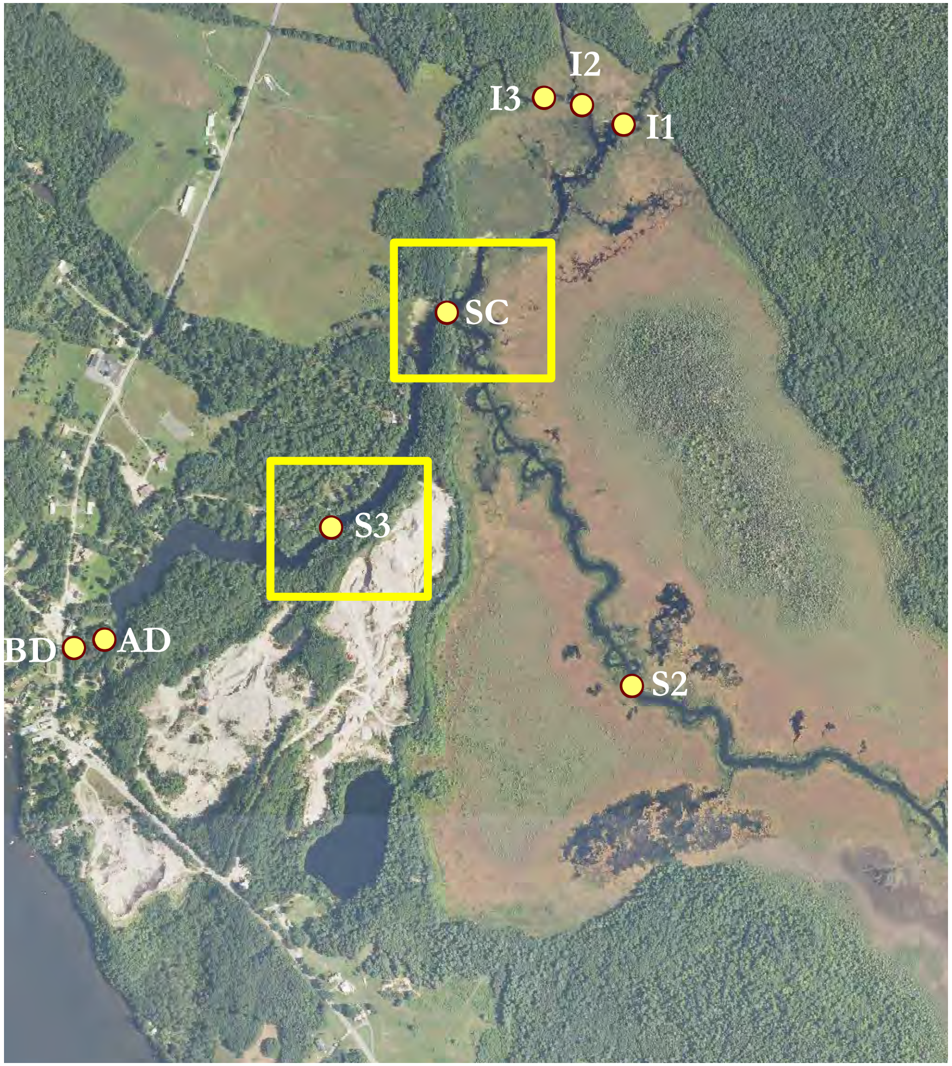


Source: Halliwell & Evers (2008)

Comparison of East & North Pond Fish Stocks

East Pond	Shared	North Pond
Rainbow Smelt	**Brown Trout**	Northern Pike
Black Crappie	**Smallmouth Bass**	Banded Killfish
	Largemouth Bass	
	White Perch	
	Yellow Perch	
	Chain Pickerel	
	Golden Shiner	
	White Sucker	
	Hornpout	
	Pumpkinseed Sunfish	

Field Methods



- Angling survey
  - Catch per unit effort
- Diet analysis
  - Species identification
- Fisherman Survey
  - Presence/absence

Results & Discussion

Present	Absent
Yellow Perch	**Brown Trout**
White Perch	Rainbow Smelt
Chain Pickerel	
Smallmouth Bass	
Largemouth Bass	
Black Crappie	
Bullhead	
White Sucker	
Pumpkinseed Sunfish	

Results & Discussion

- Presence and absence conclusions supported by interviews with fishermen and catch from angling
- Yellow perch dominance and trophic implications

Implications for 2008 East Pond Biomanipulation Project

- Future biomanipulation projects should take into account the Serpentine's potential as a refuge for zooplanktivorous fish

Future Study

- Alternative survey techniques
  - Seine netting
  - Electrofishing
- Full year survey
  - Spawning season

Plants

Our objectives:

- Determine species composition and distribution along length of Serpentine
- Classify types of habitats along Serpentine
- Investigate interactions of plants and sediment/water chemistry

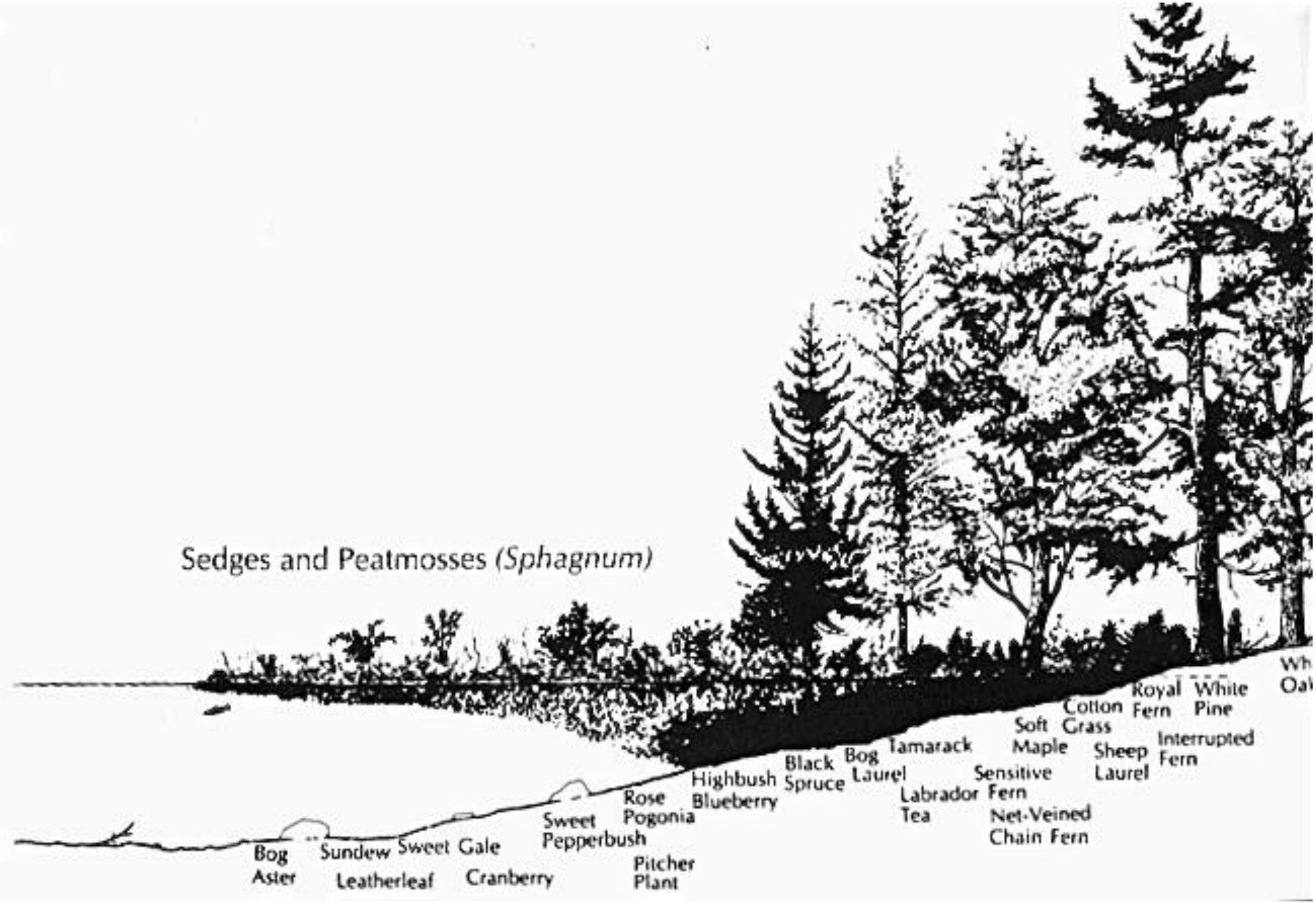
Watershed and Sample Sites

Study Area

Forest

Wetland

Fen Zonation



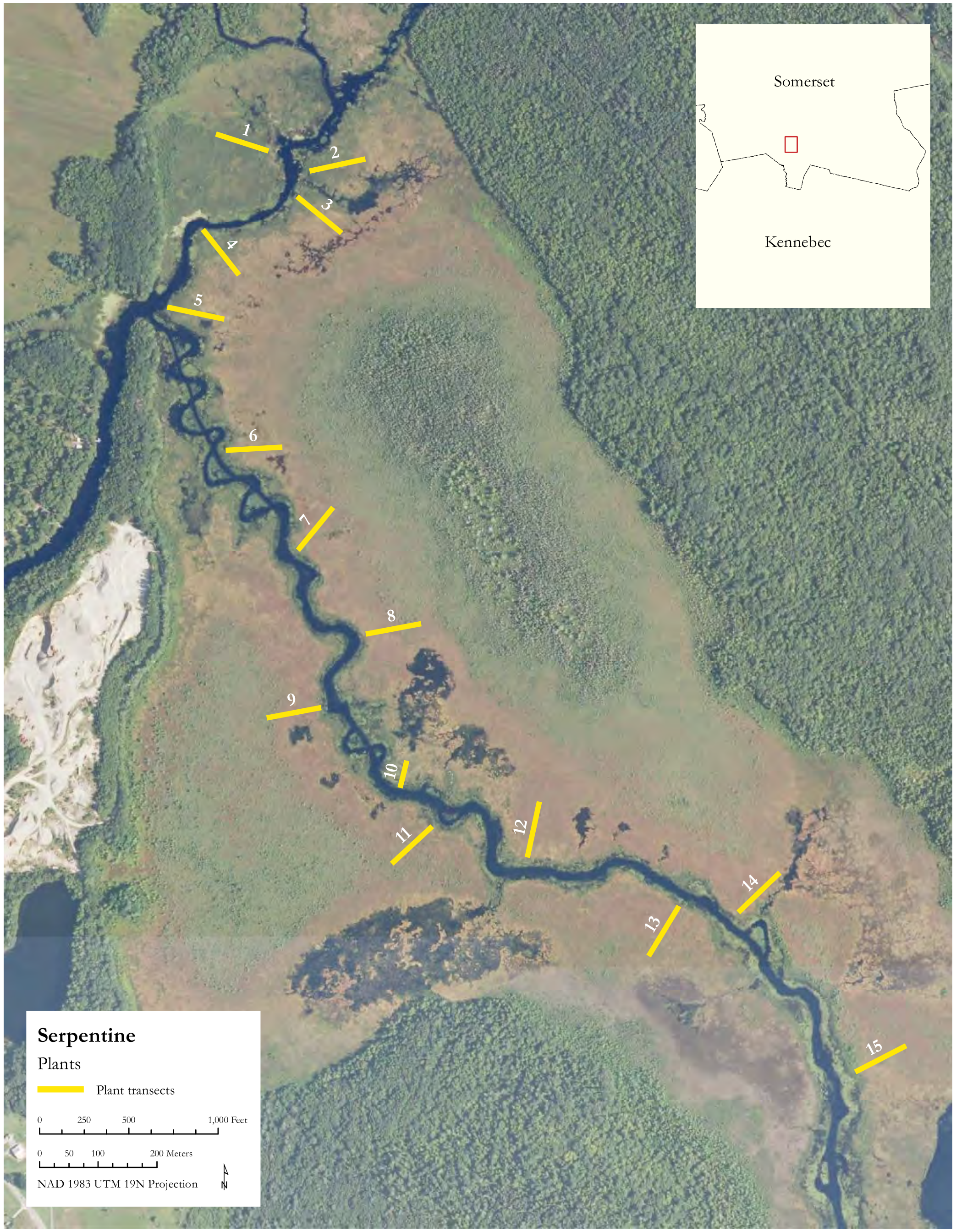
Methods

15 transects -- 9 quadrats each

0m • 5m • 10m • 15m • 20m • 25m • 50m • 75m • 100m

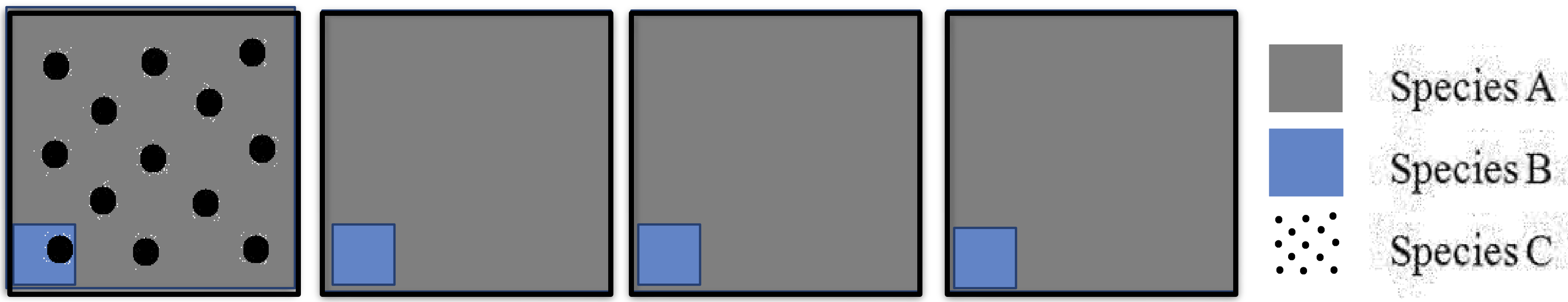




Somerset
Kennebec
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Serpentine
Plants
Plant transects
0 250 500 1,000 Feet
0 50 100 200 Meters
NAD 1983 UTM 19N Projection
N

Methods: Plant Importance Index



Site 1
A 100%
B 4%
C 100%

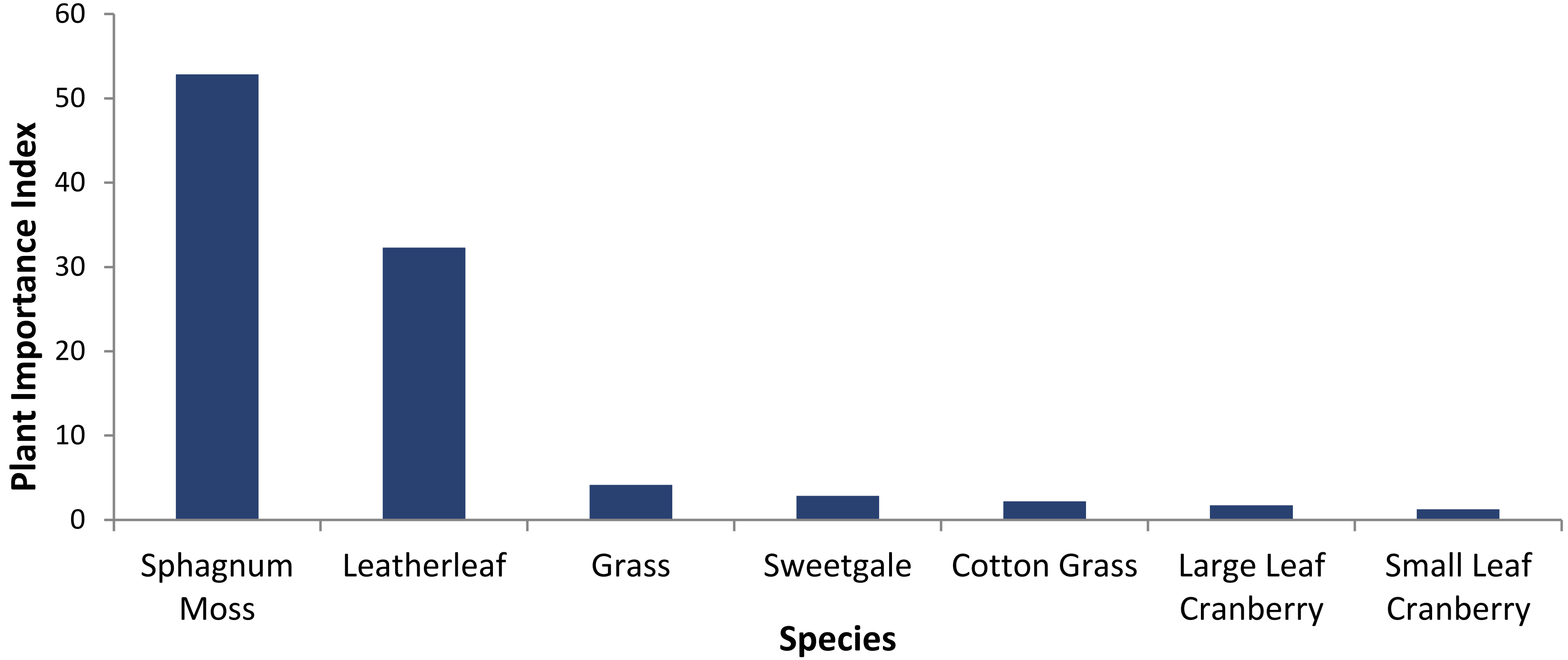
Site 2
A 100%
B 4%
C 0%

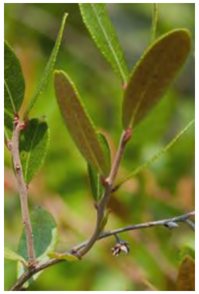
Site3
A 100%
B 4%
C 0%

Site 4
A 100%
B 4%
C 0%

Species	Normalized Cover		Normalized Frequency		Plant Importance Index
A	0.7752	x	1	=	0.7752
B	0.0310	x	1	=	0.0310
C	0.1938	x	.25	=	0.0485

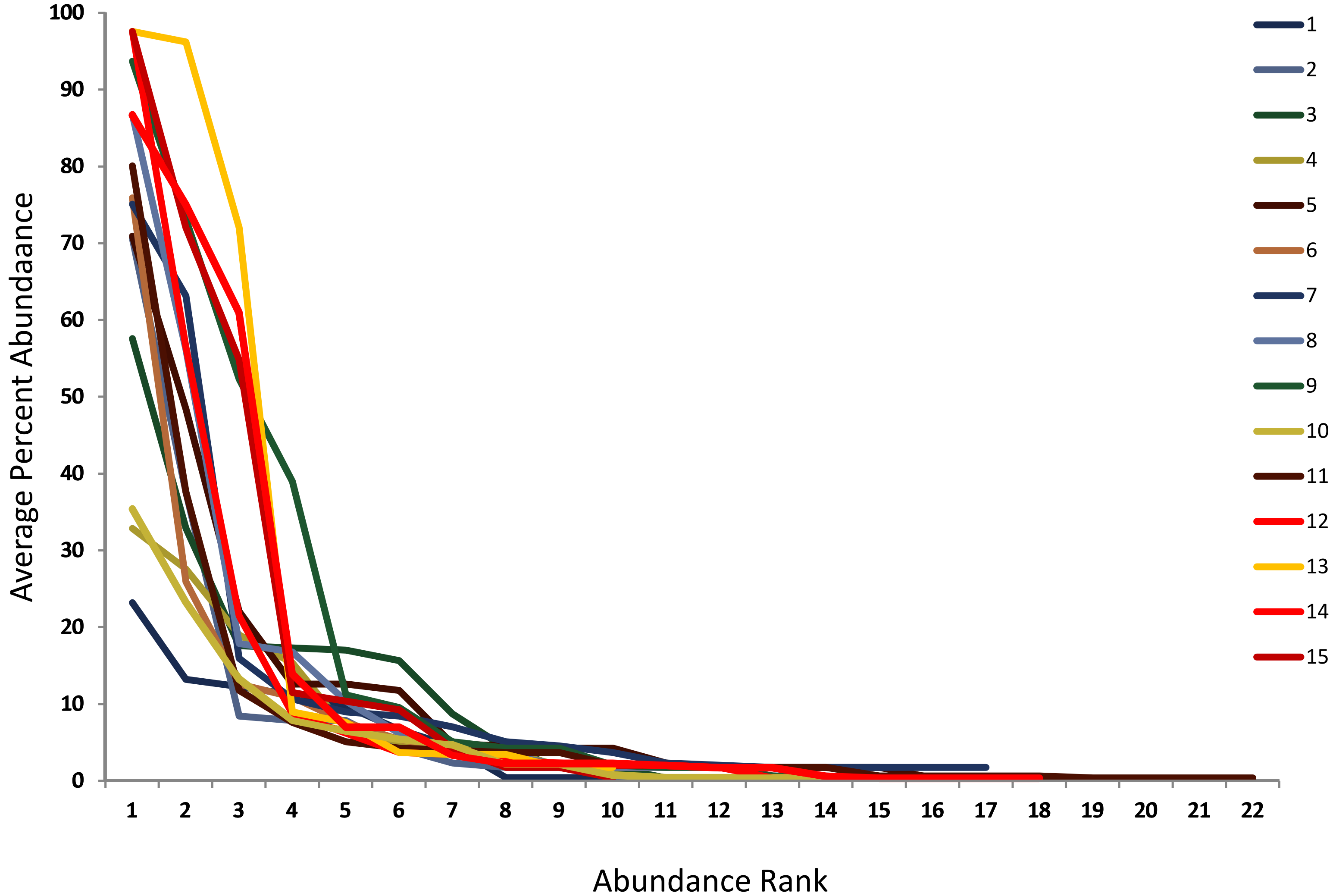
Results: Plant Importance Index






Results: Rank Abundance



Results: Shannon Weiner Index

Inputs → *East Pond*

Conclusions: Sphagnum Moss

- Sphagnol
  - Build up of peat
  - Low decomposition
- Peat as a carbon sink

Conclusions

- Input of nutrients lowers species diversity from inputs into serpentine
- Few dominant species, many uncommon species (typical for fens)
- Importance of biodiversity

Future Research

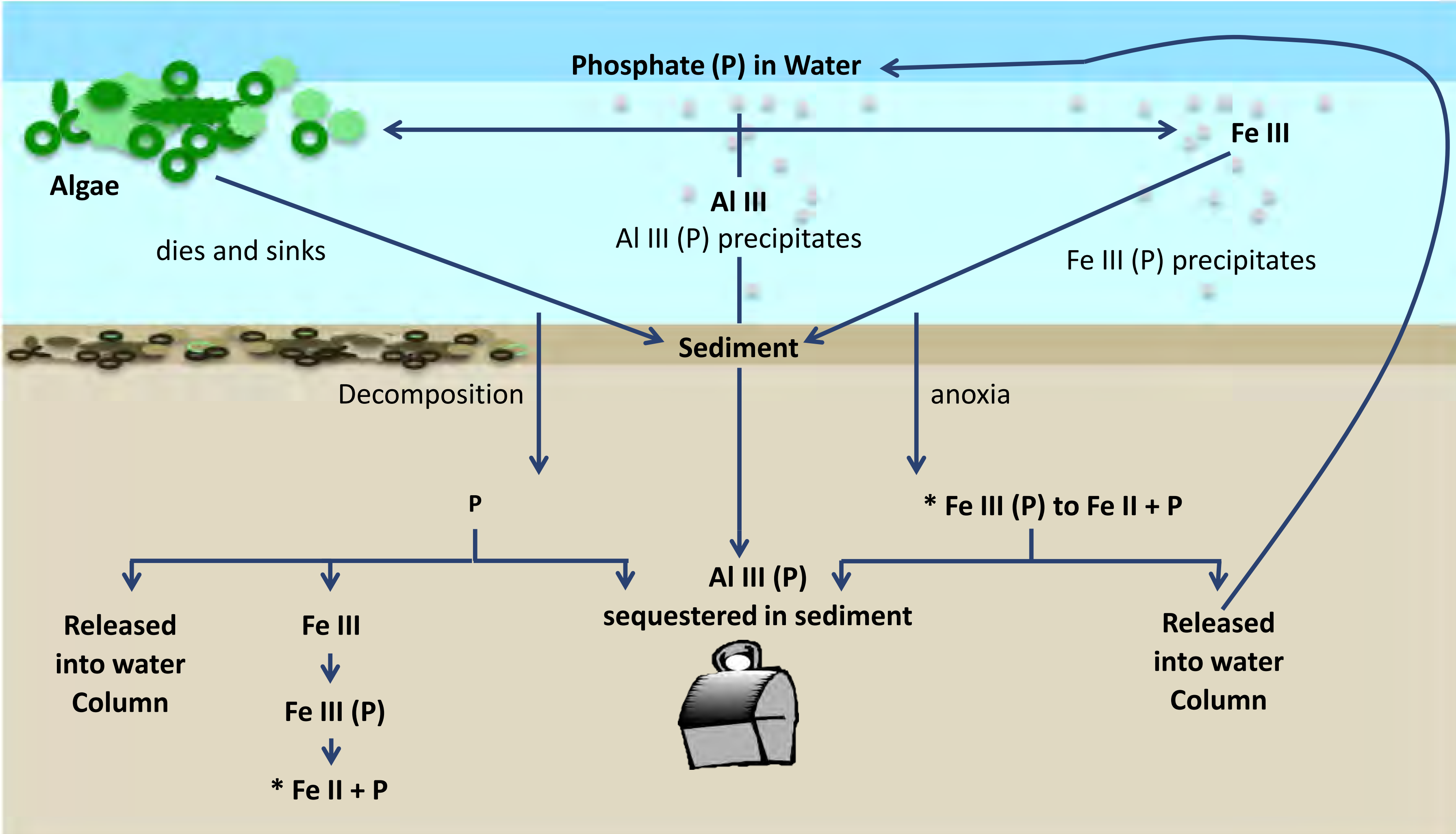
- Peat as a nutrient sink?
- Water flow through fen (cores)

Sediment Chemistry

Objective:

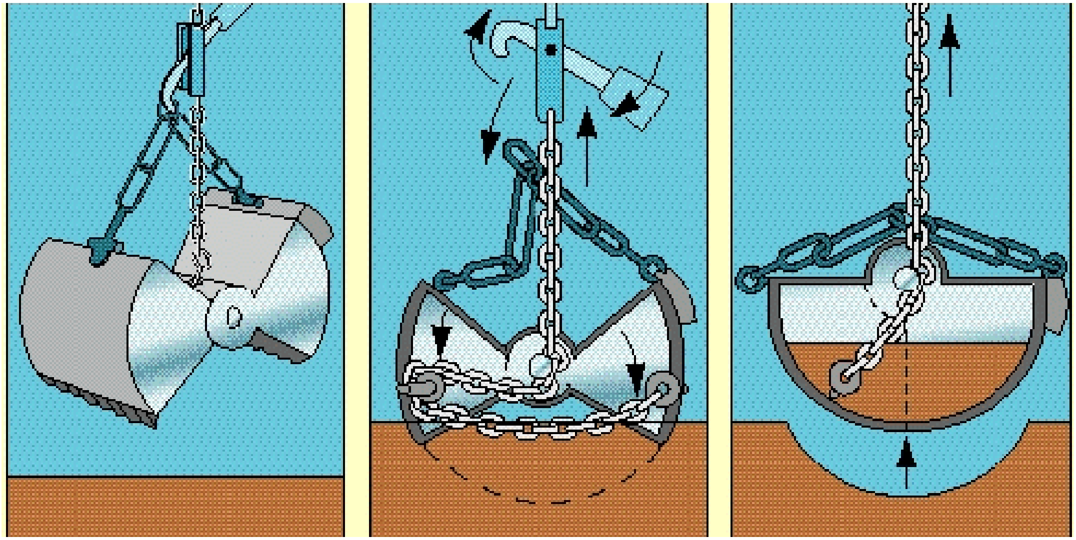
To understand the nutrient cycling in the Serpentine by measuring P, Al, and Fe in the sediment.

The Phosphorous Cycle



Al *sequesters* **P** **Fe** *releases* **P** from sediment in ANOXIC environments **P** causes algal bloom

Methods



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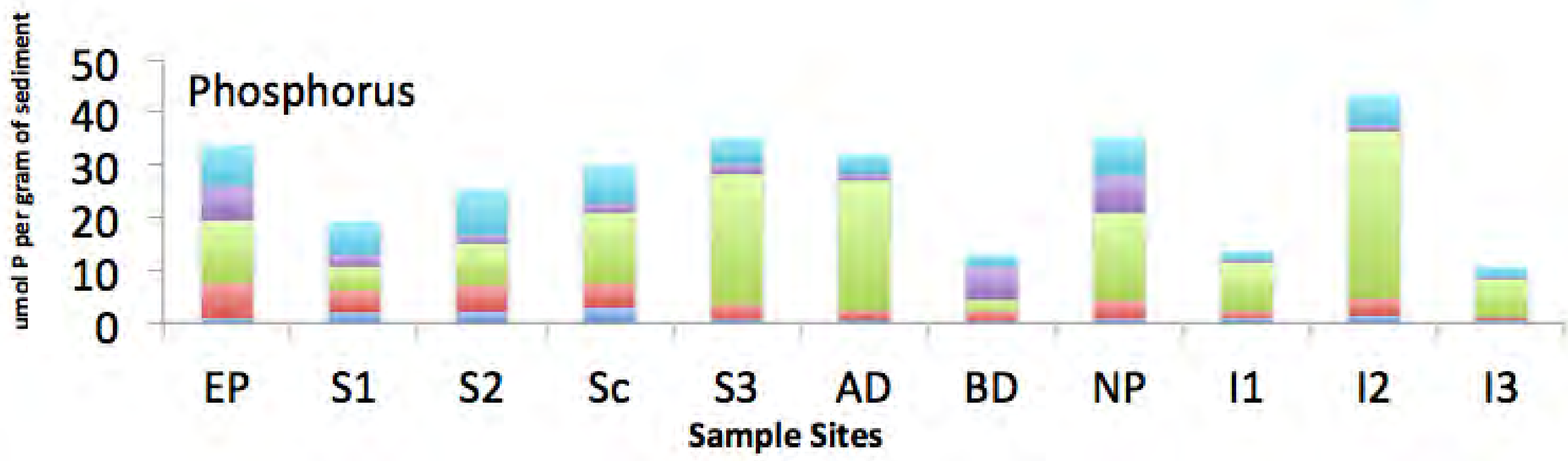
Sequential Extraction



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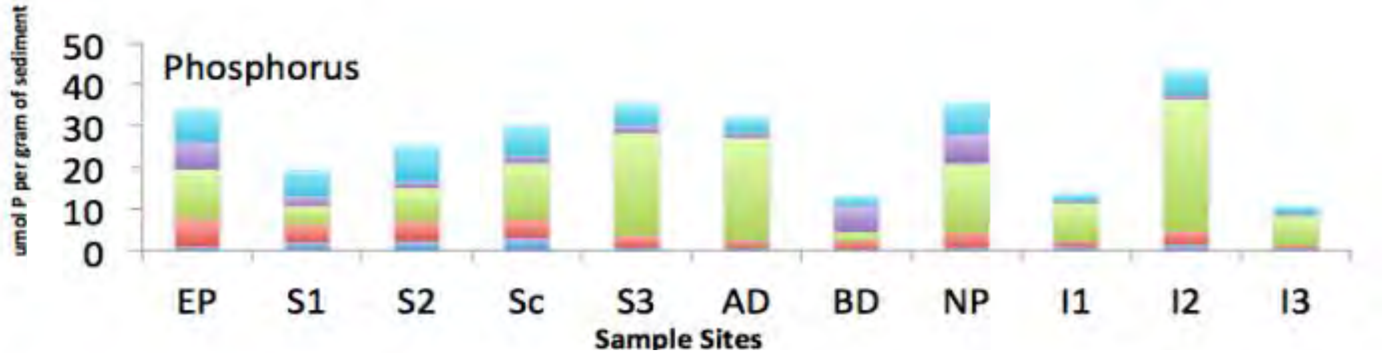

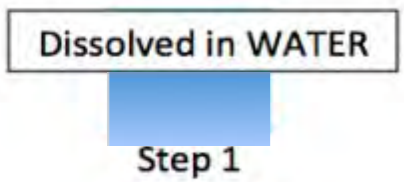

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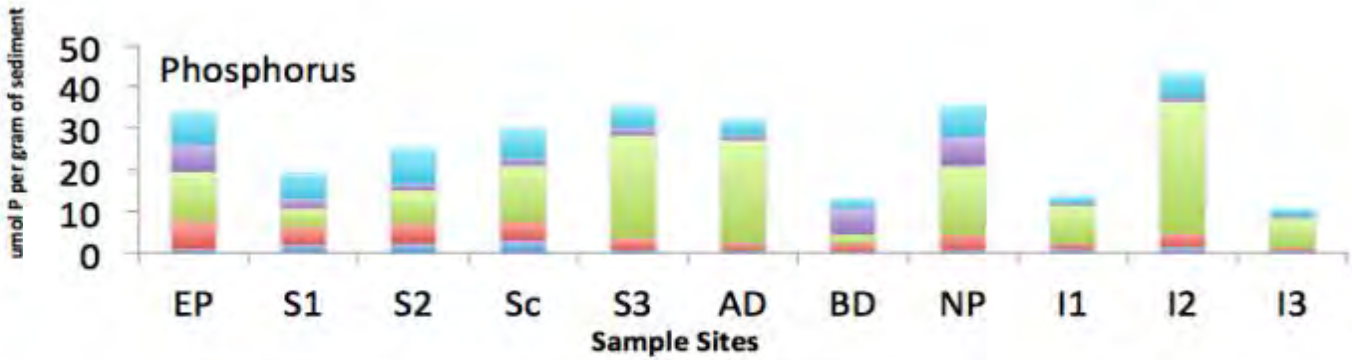


Dissolved in WATER

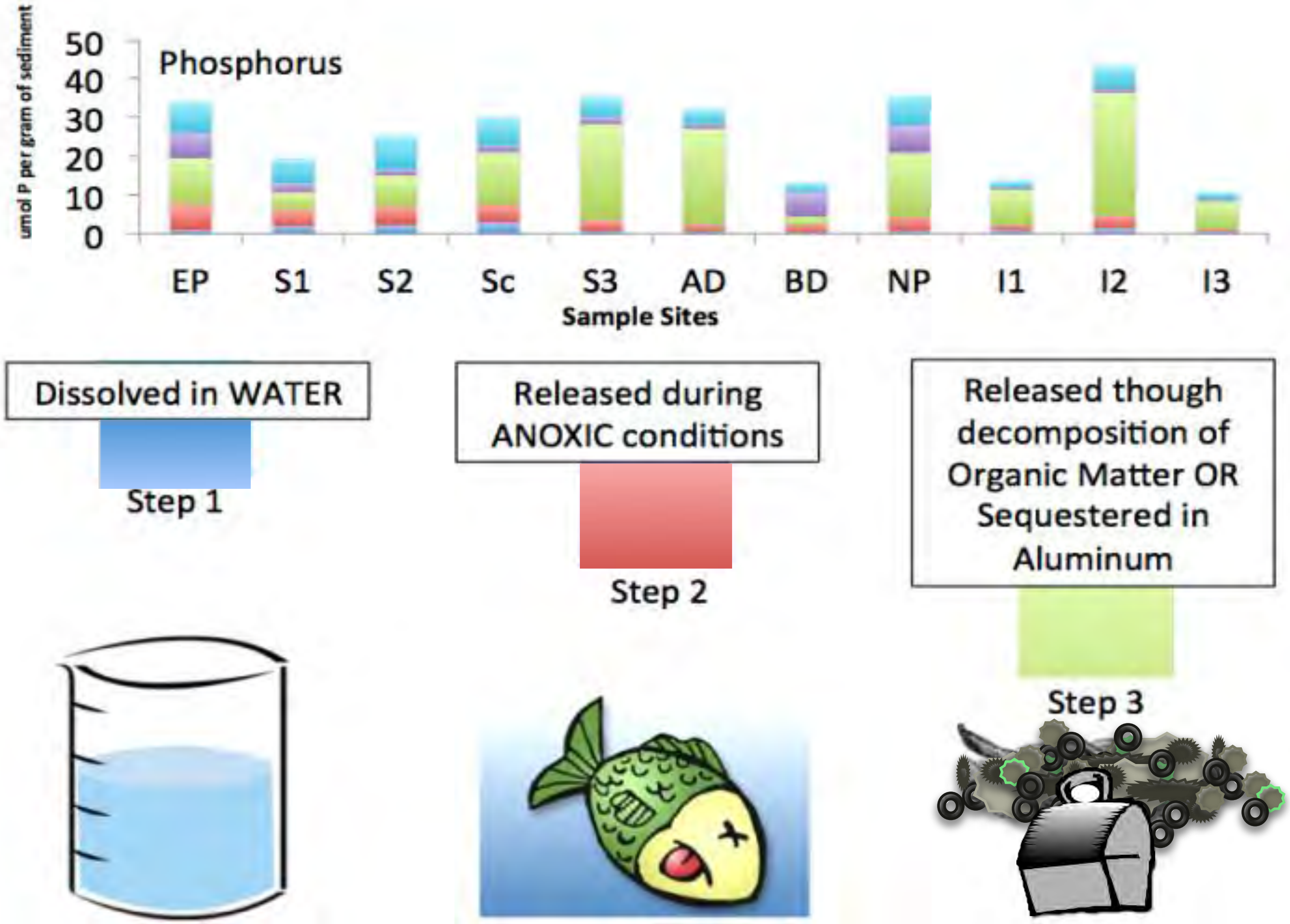
Step 1

Released during ANOXIC conditions

Step 2

Al *sequesters* **P** **Fe** *releases* **P** from sediment in ANOXIC environments **P** causes algal blooms

Sequential Extraction



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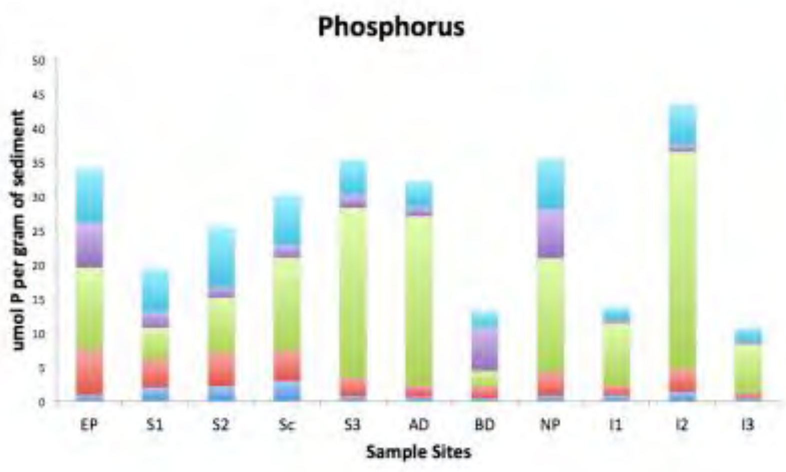
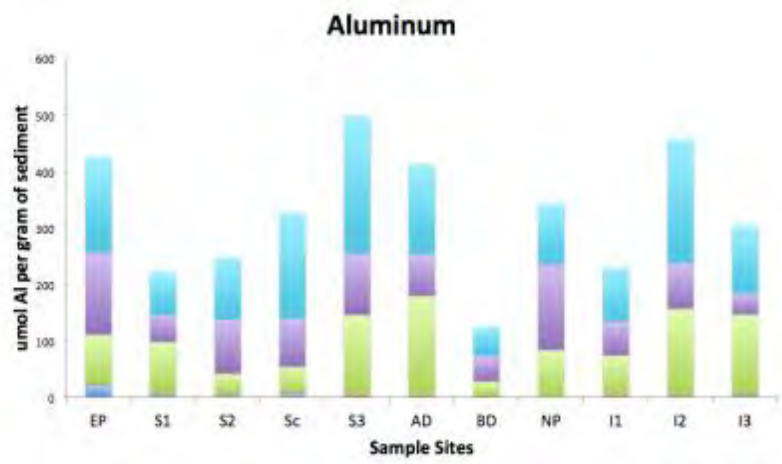
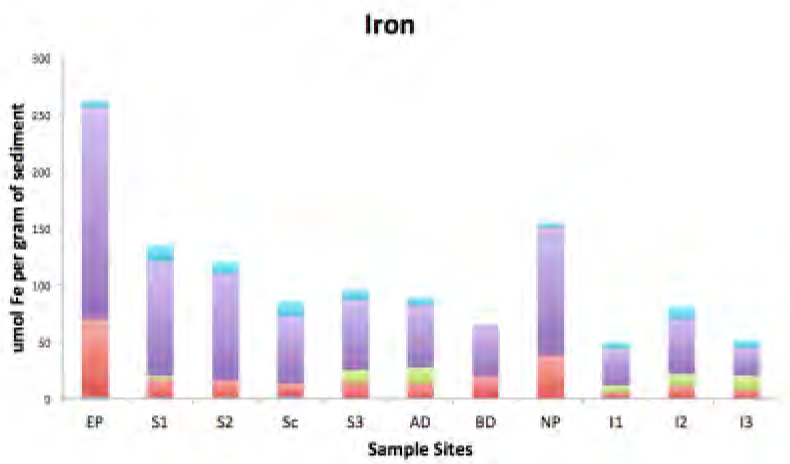
Results

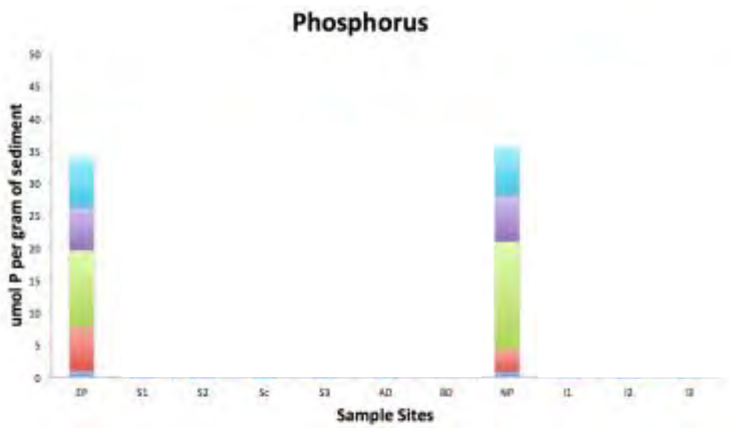


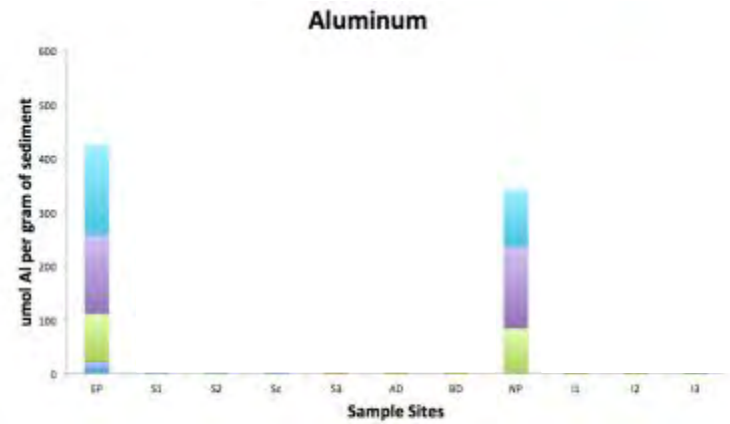


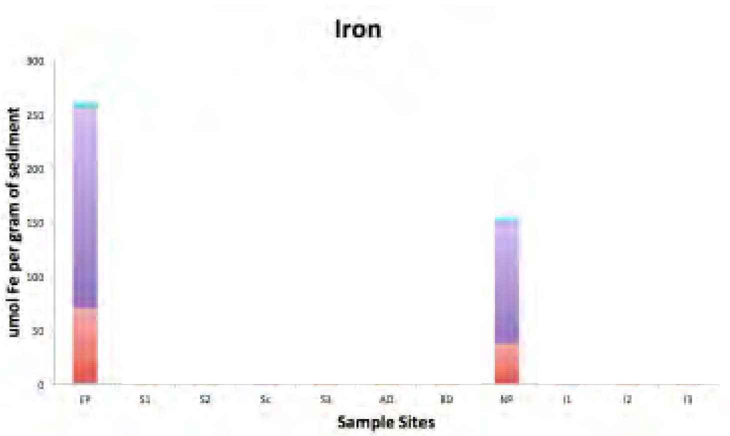


Step 5 Step 4 Step 3 Step 2 Step 1

East Pond vs North Pond

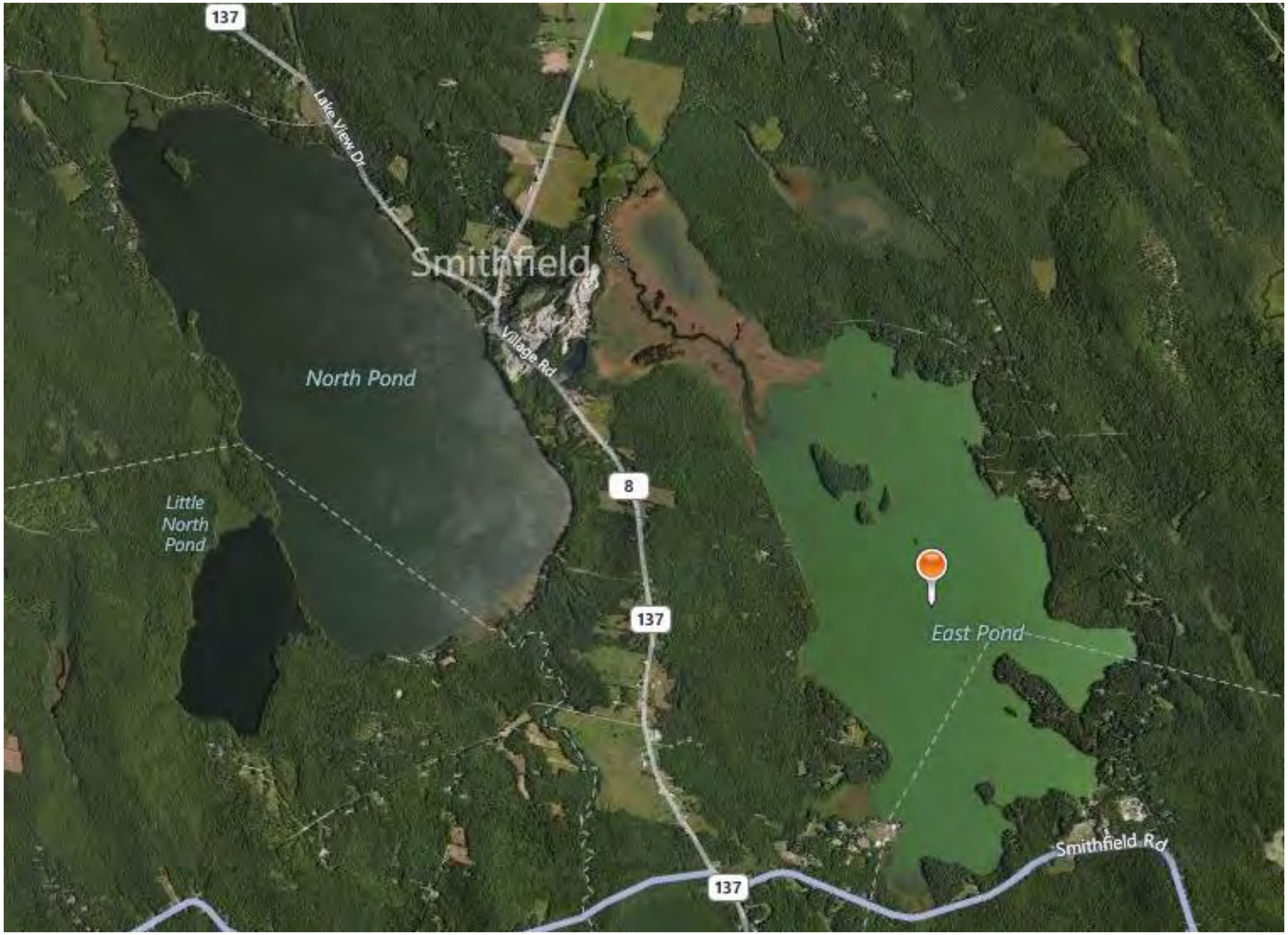






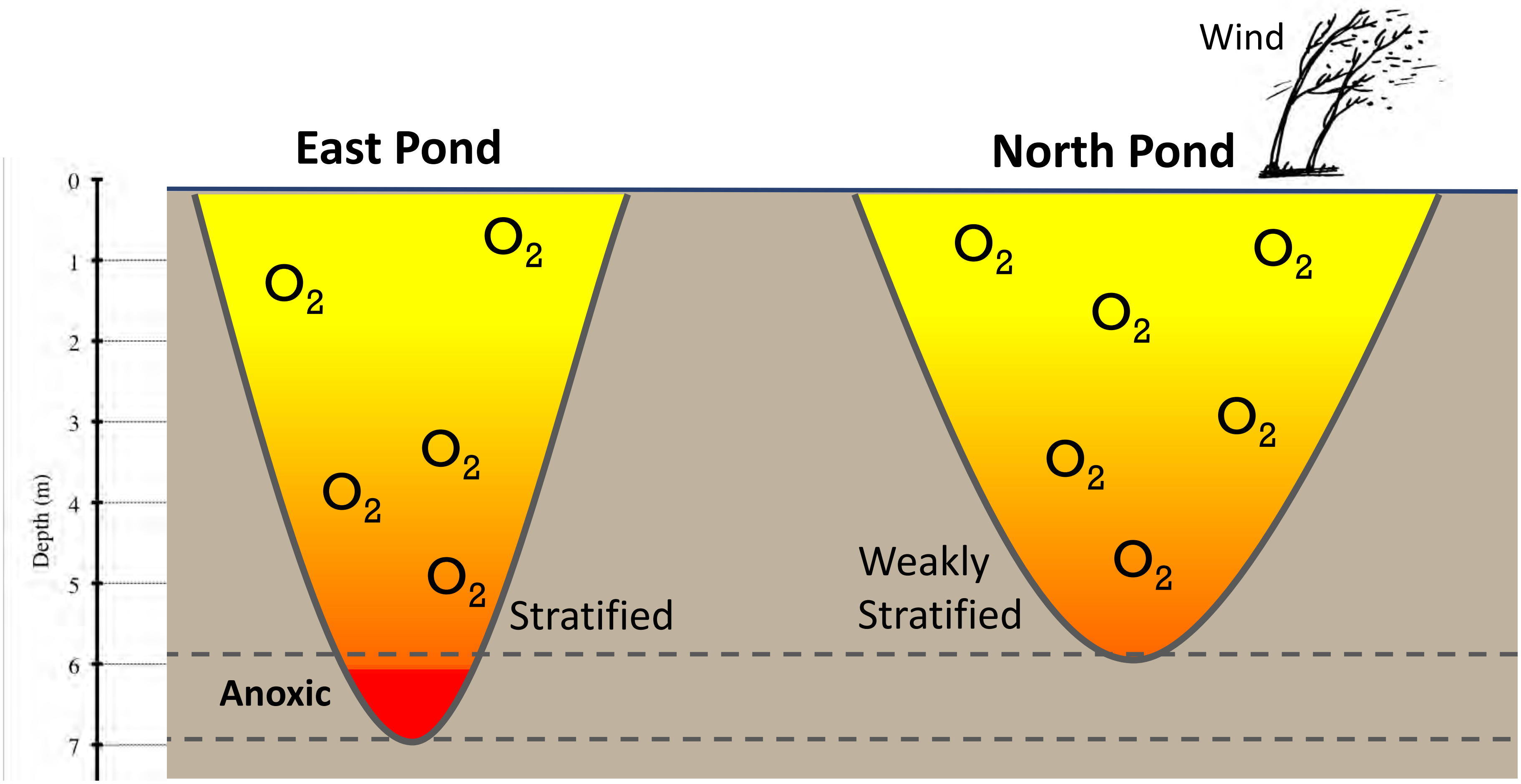
Step 5 Step 4 Step 3 Step 2 Step 1

Why does East Pond bloom?



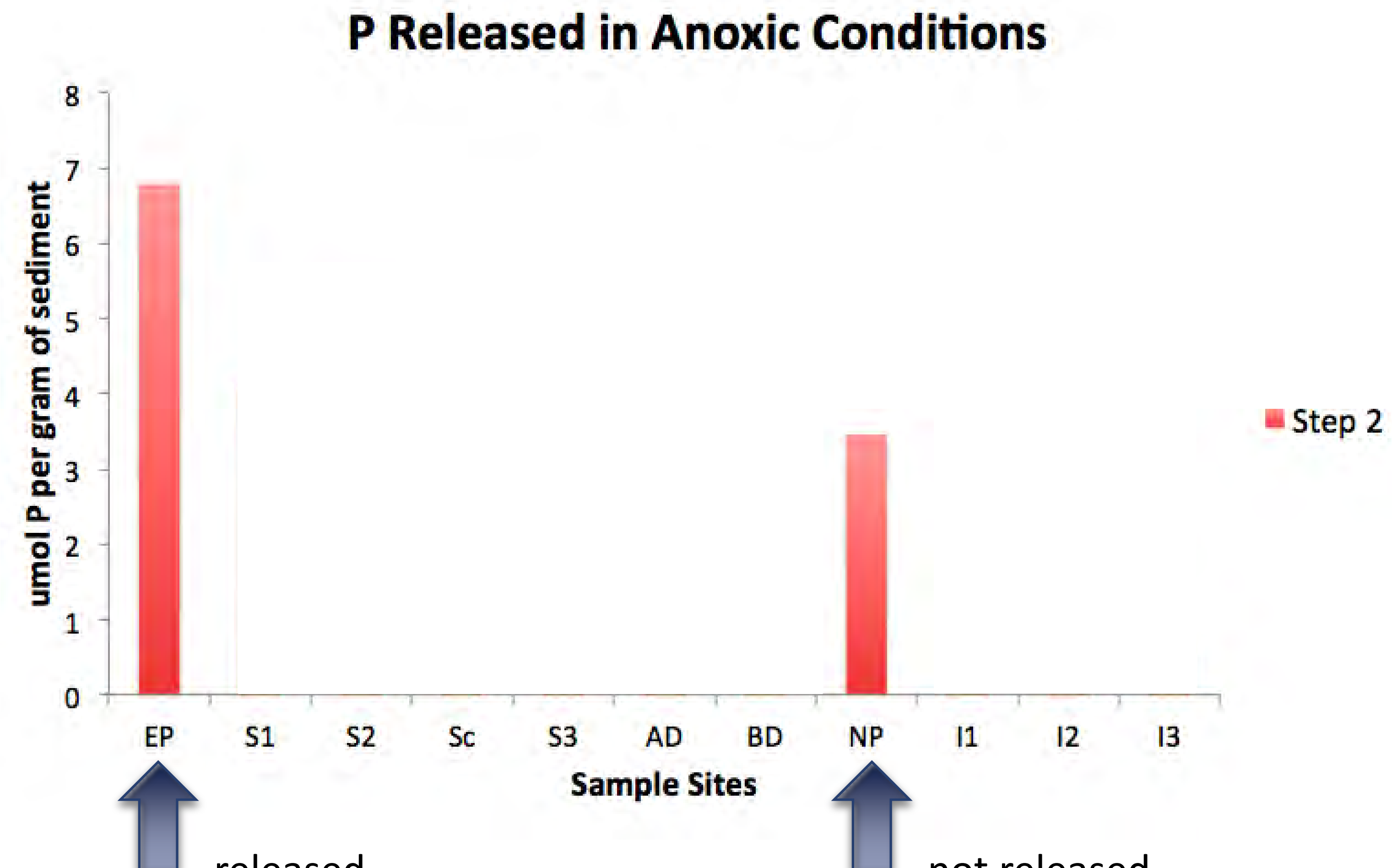
Al *sequesters* **P** **Fe** *releases* **P** from sediment in ANOXIC environments **P** causes algal blooms

Lake Stratification



Al *sequesters* **P** **Fe** *releases* **P** from sediment in ANOXIC environments **P** causes algal blooms

How much more is being released?

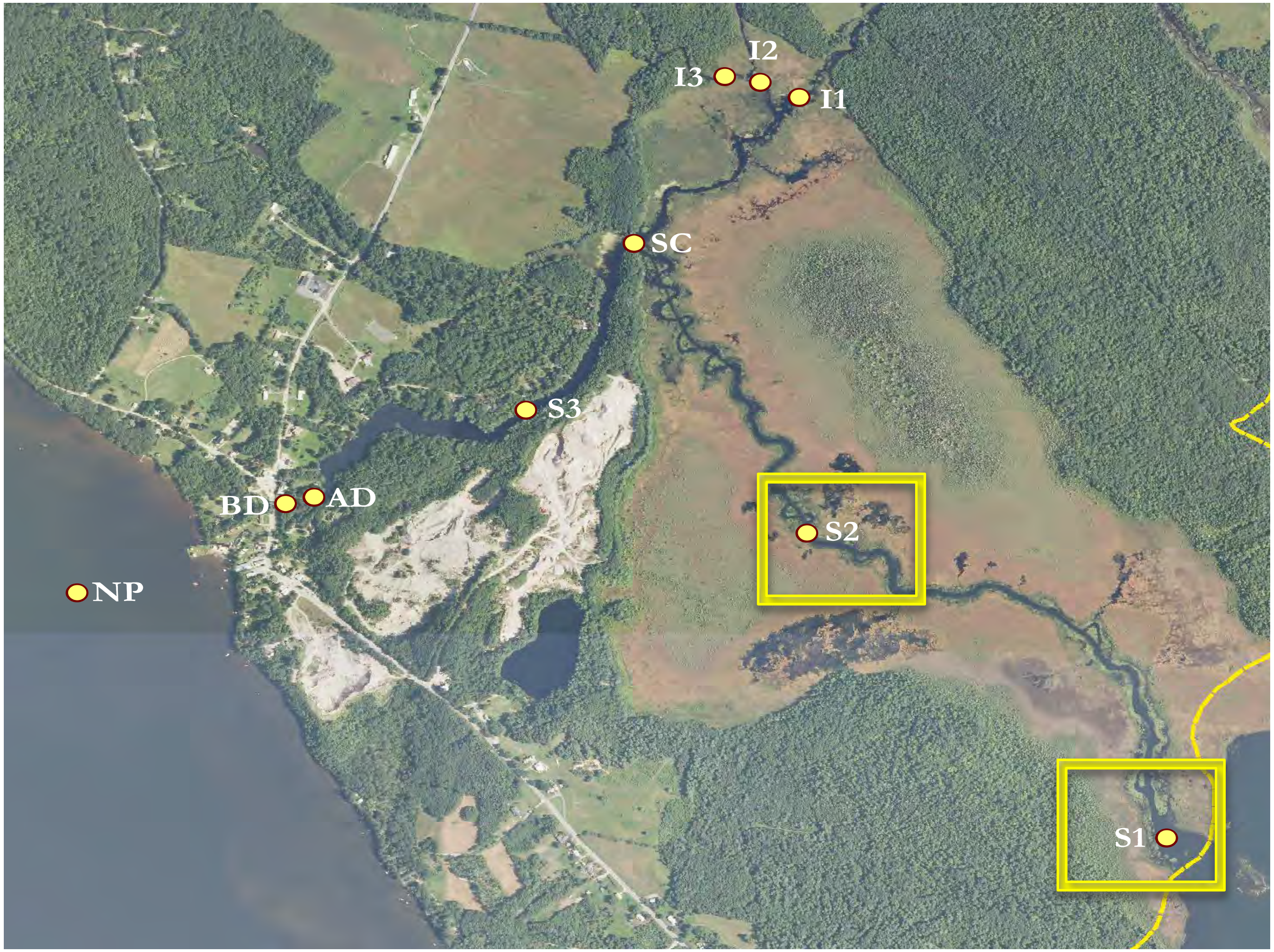


released

not released

Al *sequesters* **P** **Fe** *releases* **P** from sediment in ANOXIC environments **P** causes algal blooms

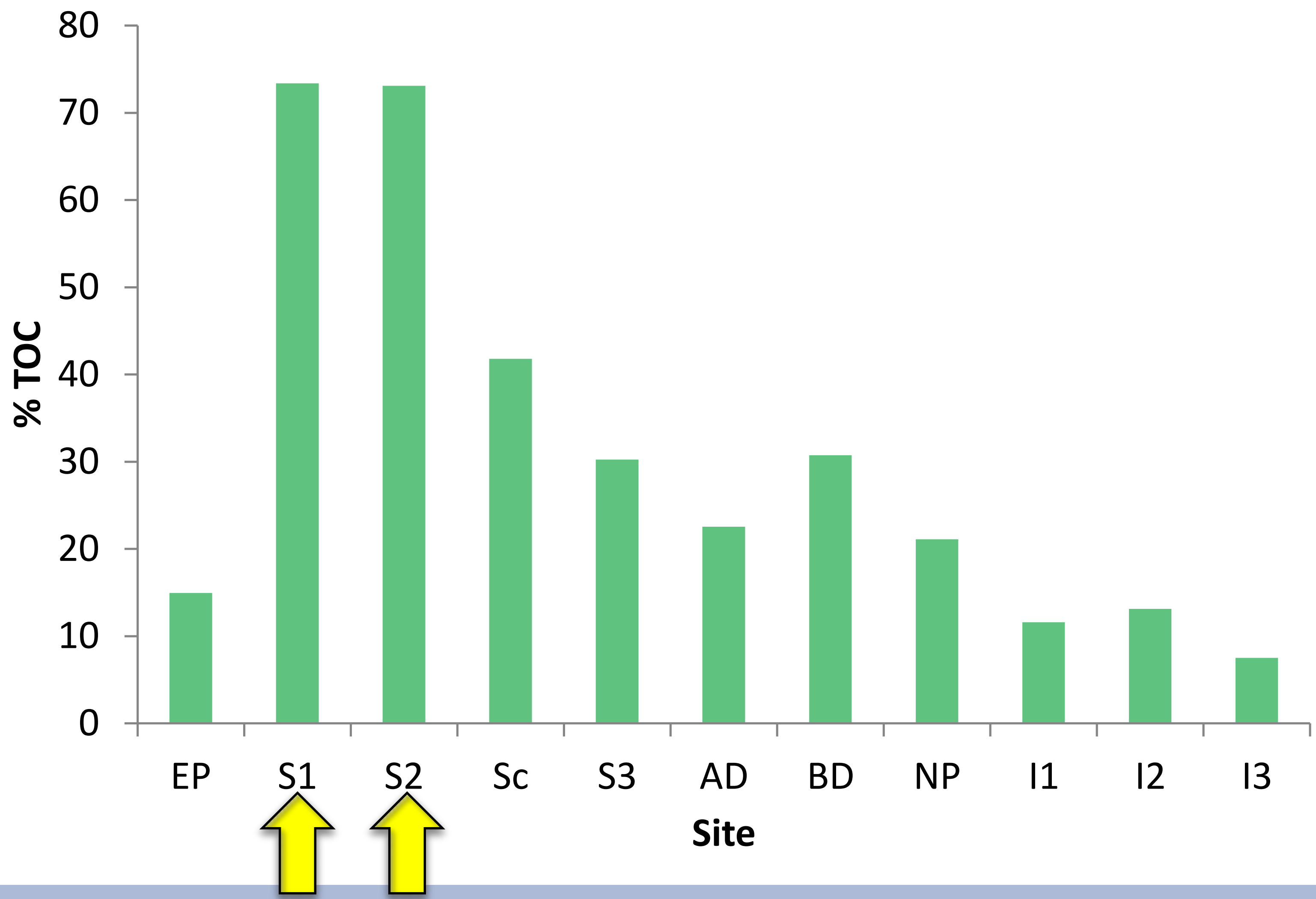
Discussion: S1 and S2



- High total organic carbon
- High dissolved oxygen
- High sphagnum moss presence
- Sphagnol implies low rates of decomposition

Al *sequesters* **P** **Fe** *releases* **P** from sediment in ANOXIC environments **P** causes algal blooms

Total Organic Carbon (TOC)



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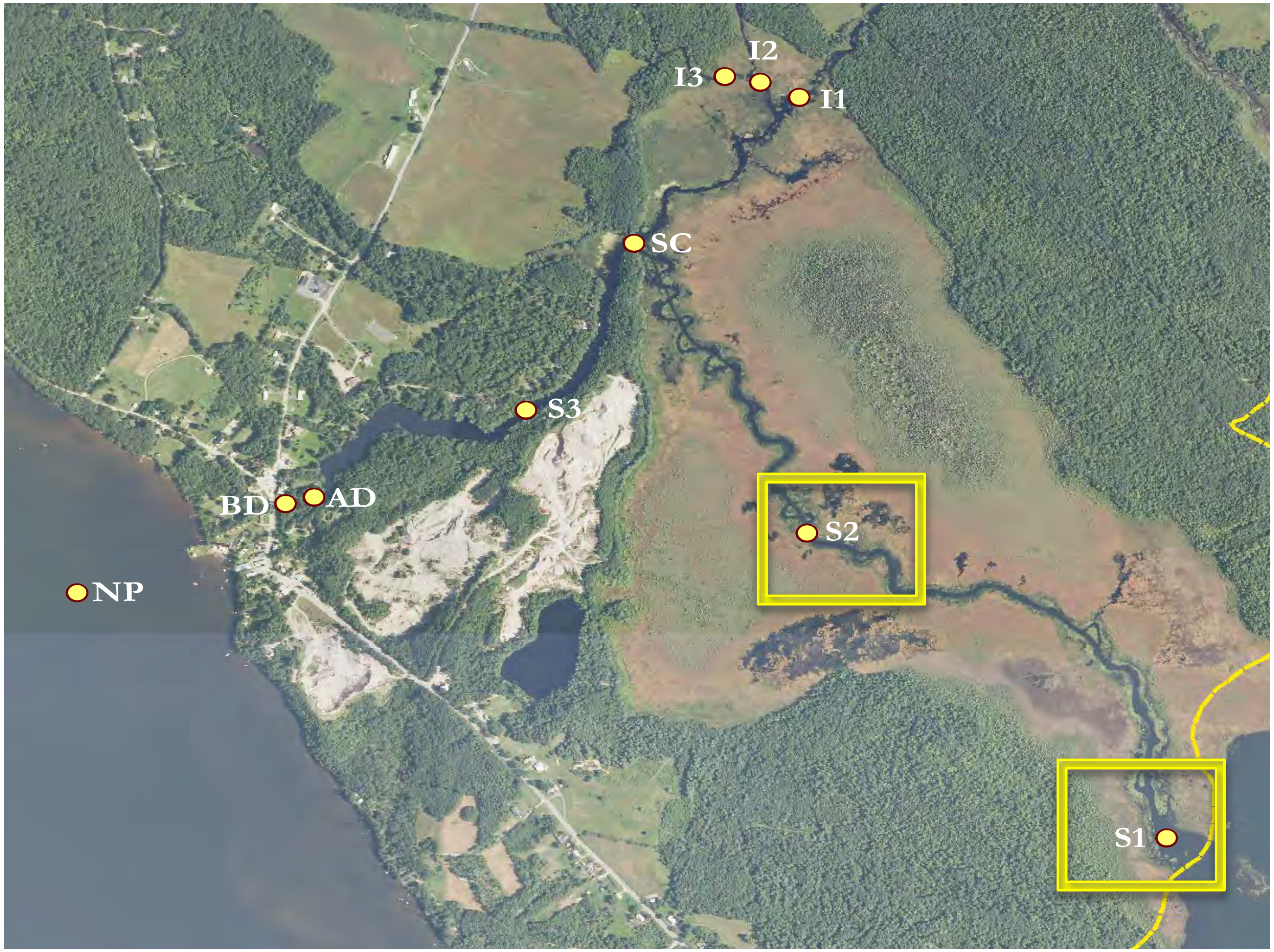

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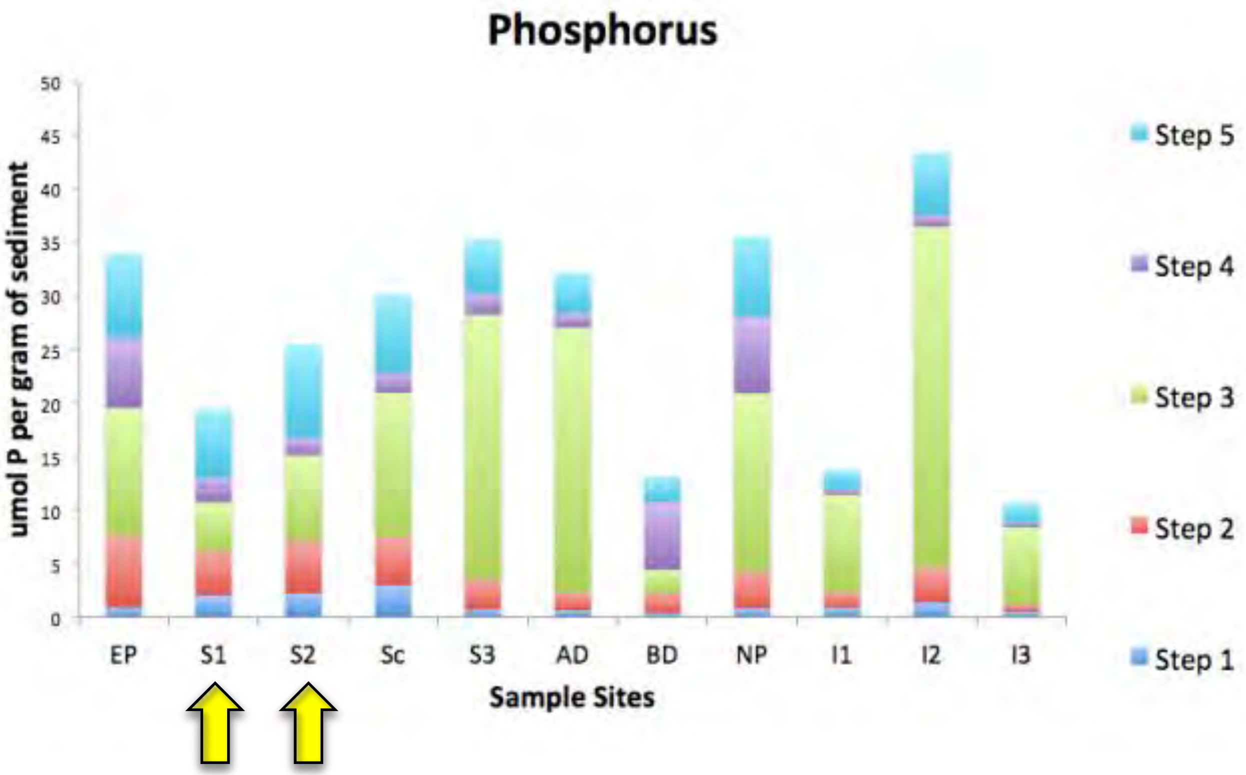


- High total organic carbon
- High sphagnum moss presence
- **Relatively low nutrients in the water and sediment**
- **Do not expect large nutrient release**

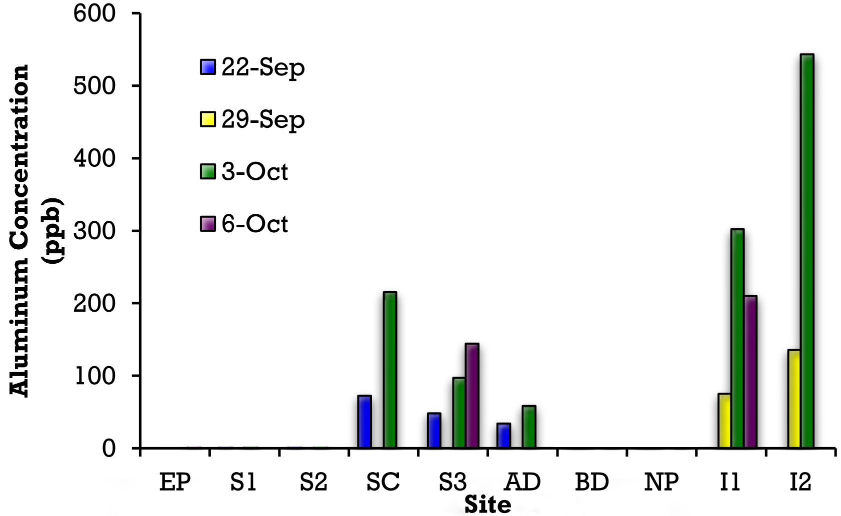
Al *sequesters* **P** **Fe** *releases* **P** from sediment in ANOXIC environments **P** causes algal blooms

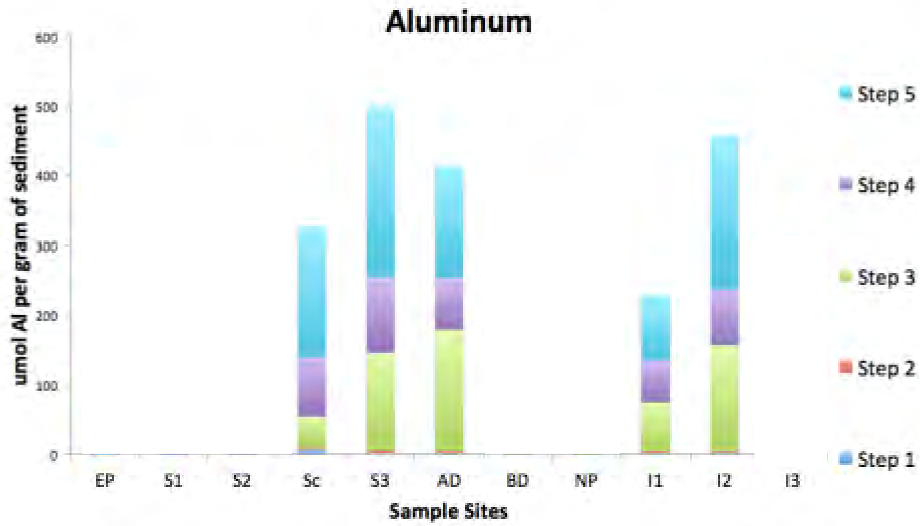
Discussion I2, SC, S3, AD

- **High P, Al, and Fe in water column at I2**
- Appears as though Al and P are precipitating out of water column
- Fe does not show this same correlation

Al *sequesters* **P** **Fe** *releases* **P** from sediment in ANOXIC environments **P** causes algal blooms

Discussion I2, SC, S3, AD





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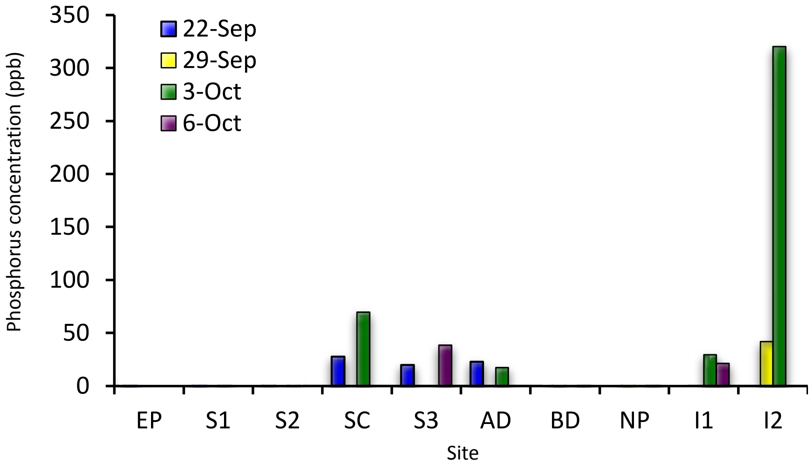

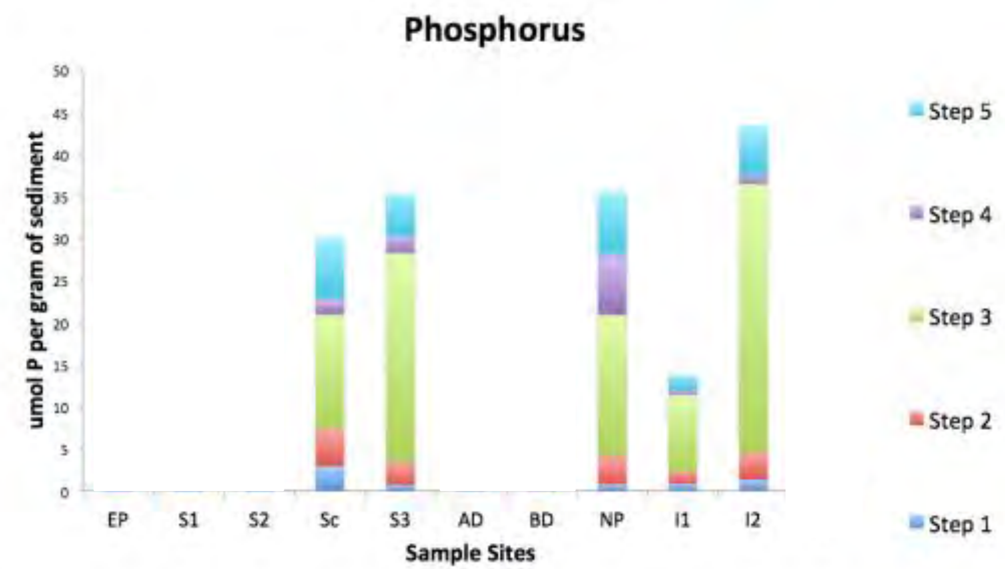

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Al *sequesters* **P** **Fe** *releases* **P** from sediment in ANOXIC environments **P** causes algal blooms

Discussion I2, SC, S3, AD

- Sediment appears to act as a nutrient sink

Al *sequesters* **P** **Fe** *releases* **P** from sediment in ANOXIC environments **P** causes algal blooms

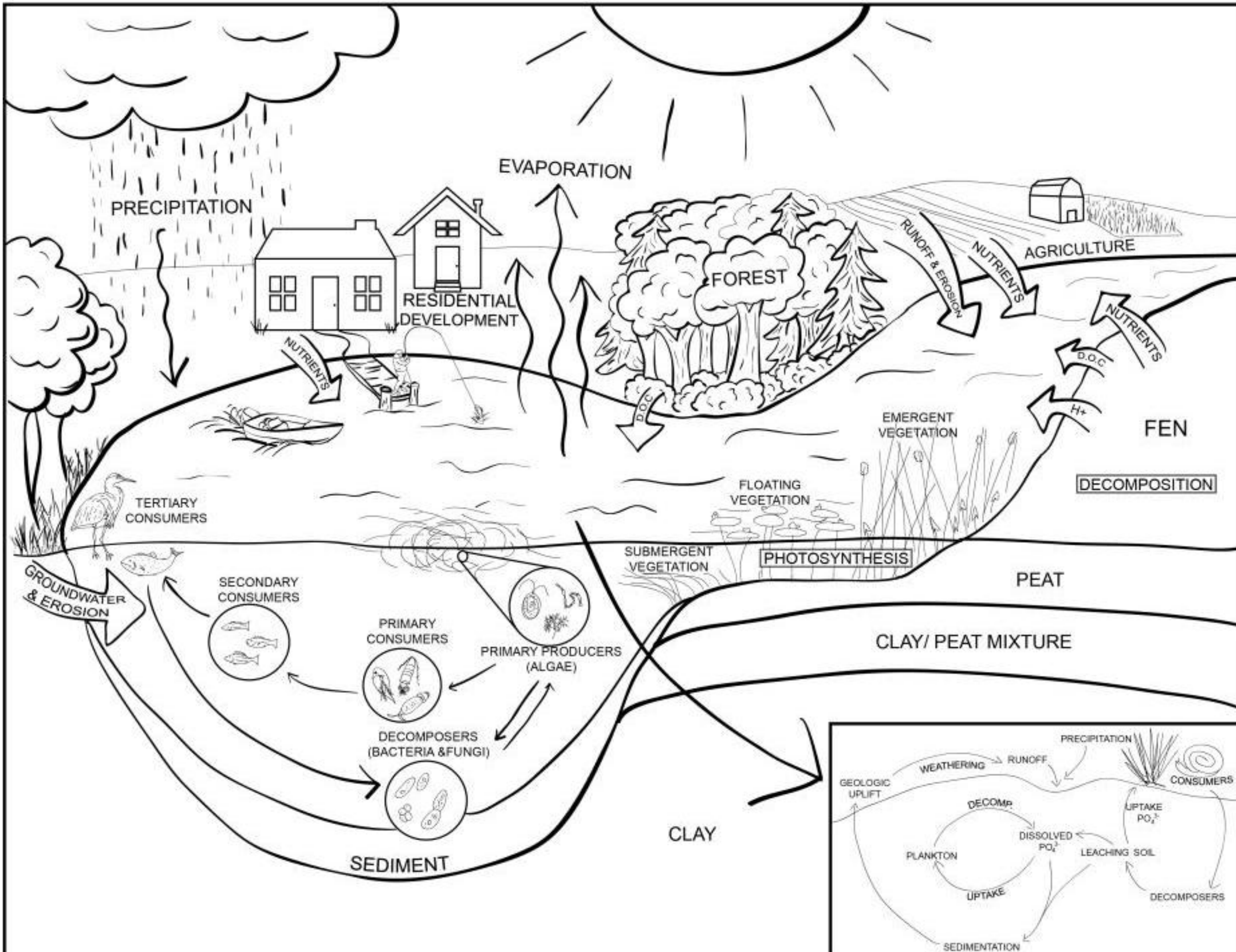
Sediment Take Home Messages

- East Pond blooms because it becomes anoxic
- Sediment is not a source of nutrients in the Serpentine
- The Serpentine may act more as a sink for nutrients than an input

Conclusions

Objective:

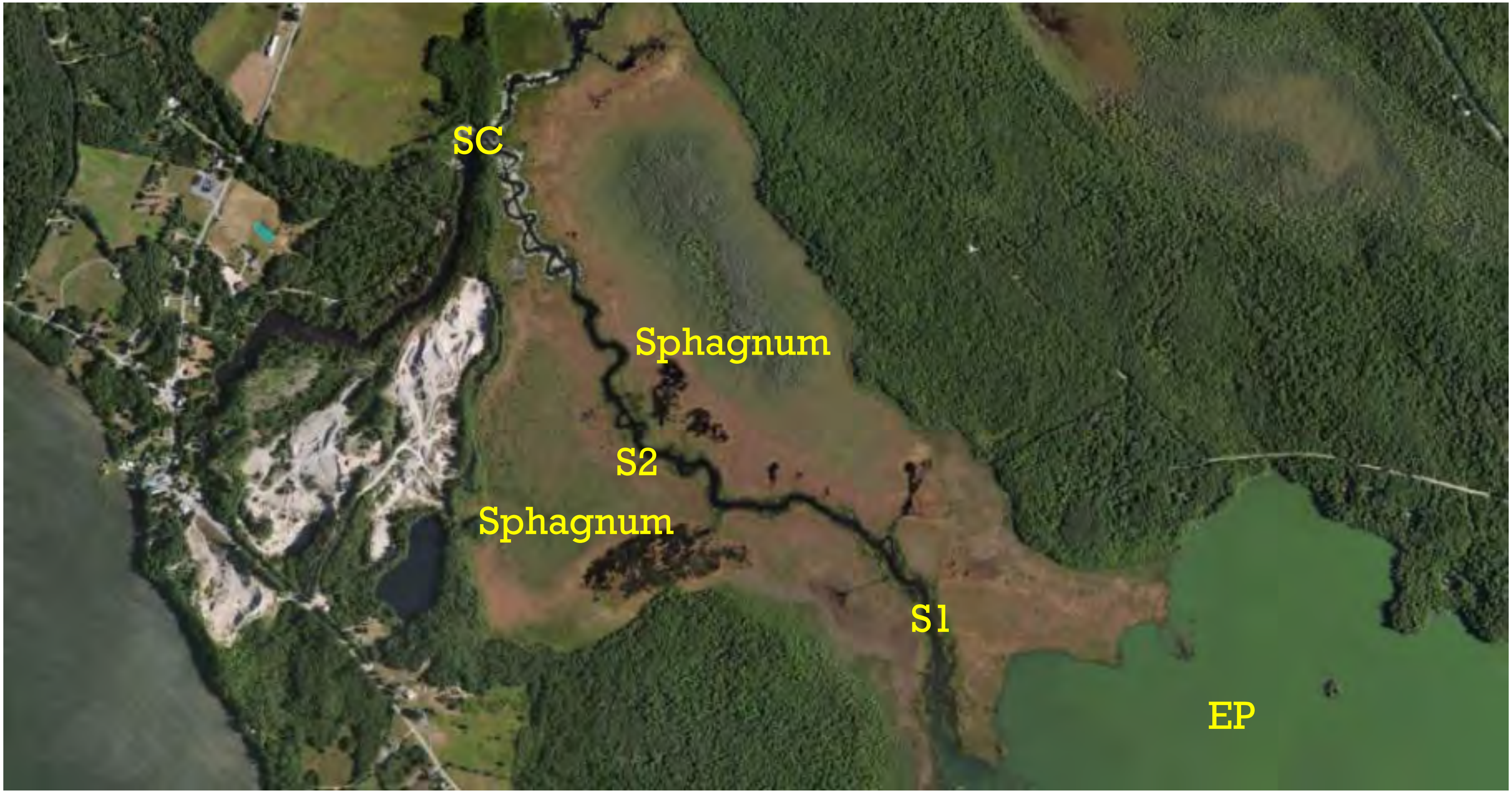
- Understand what effects the Serpentine has on East and North Ponds



PRECIPITATION
EVAPORATION
RESIDENTIAL DEVELOPMENT
FOREST
AGRICULTURE
RUNOFF & EROSION
NUTRIENTS
NUTRIENTS
NUTRIENTS
D.O.C
D.O.C
H+
FEN
EMERGENT VEGETATION
FLOATING VEGETATION
DECOMPOSITION
TERTIARY CONSUMERS
SUBMERGENT VEGETATION
PHOTOSYNTHESIS
PEAT
GROUNDWATER & EROSION
SECONDARY CONSUMERS
PRIMARY CONSUMERS
PRIMARY PRODUCERS (ALGAE)
CLAY/ PEAT MIXTURE
DECOMPOSERS (BACTERIA &FUNGI)
CLAY
SEDIMENT
PRECIPITATION
WEATHERING
RUNOFF
GEOLOGIC UPLIFT
CONSUMERS
DECOMP.
UPTAKE PO_4^{3-}
DISSOLVED PO_4^{3-}
PLANKTON
LEACHING SOIL
UPTAKE
DECOMPOSERS
SEDIMENTATION

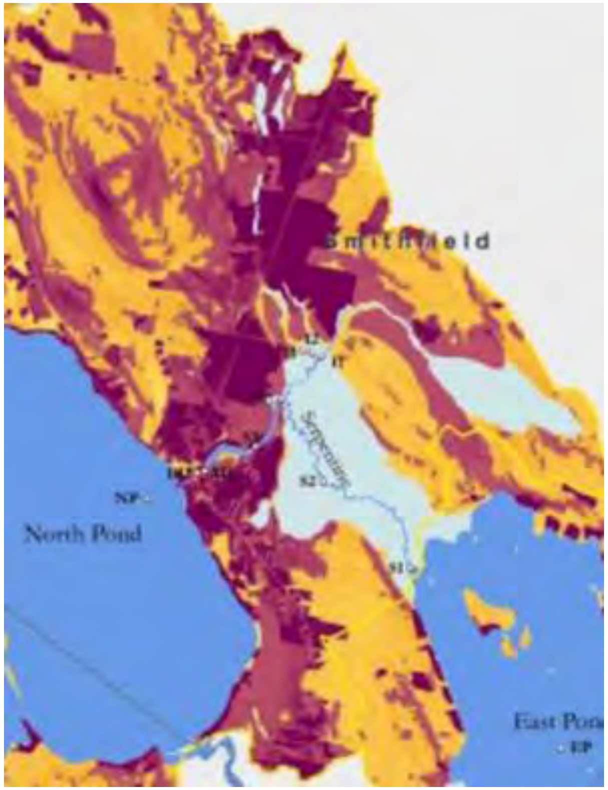
Conclusions

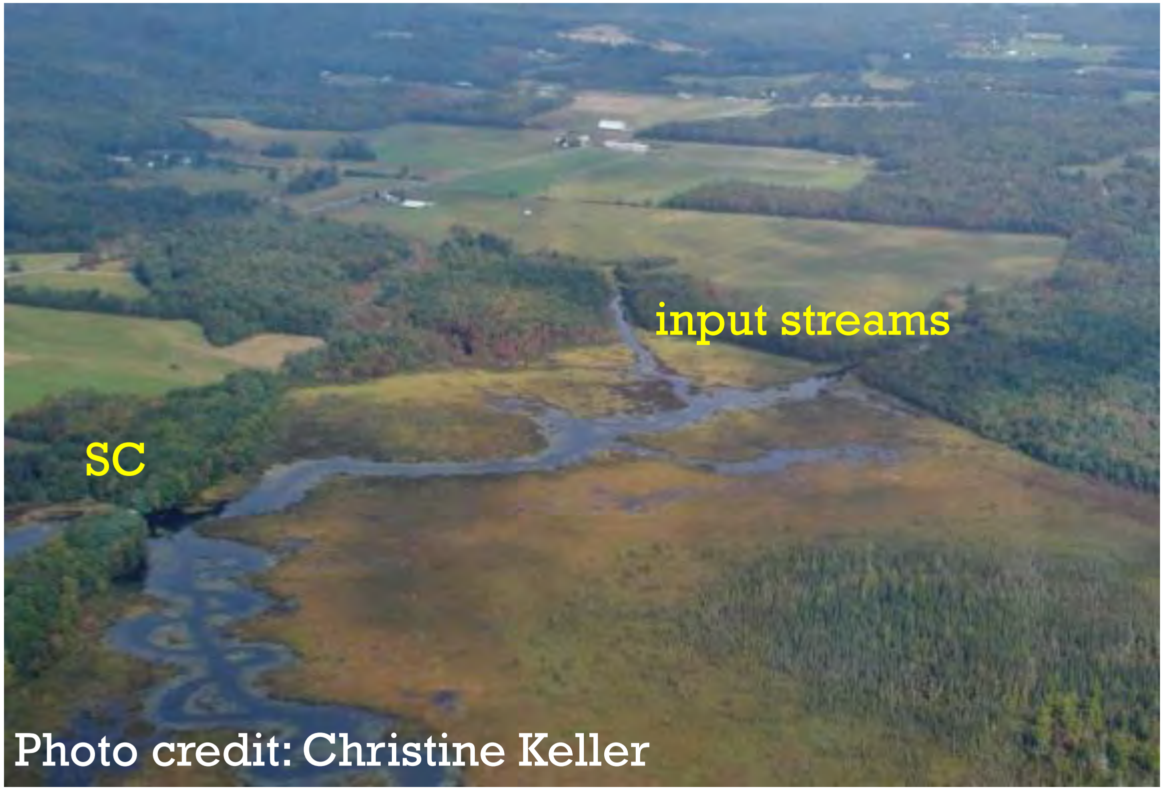
- Sphagnum acting as a decomposition inhibitor and subsequent nutrient sink



Conclusions

- Land-use: High erosion potential and high agricultural area near input streams
- High P, Al, Fe in surface water at input streams and Serpentine confluence (SC)





Conclusions

- Lower P, Al, Fe in surface water from SC down to dam and North Pond

Conclusions

- Lower P, Al, Fe in surface water from SC down to dam and North Pond
  - **H1: Biological uptake**
  - H2: P is binding with Al, Fe and precipitating out into the sediment
  - H3: Dilution

Conclusions

- Lower P, Al, Fe in surface water from SC down to dam and North Pond
  - H1: Biological uptake
  - **H2: P is binding with Al, Fe and precipitating out into the sediment**
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Conclusions

- Lower P, Al, Fe in surface water from SC down to dam and North Pond
  - H1: Biological uptake
  - H2: P is binding with Al, Fe and precipitating out into the sediment
  - **H3: Dilution**

The Take Home Message

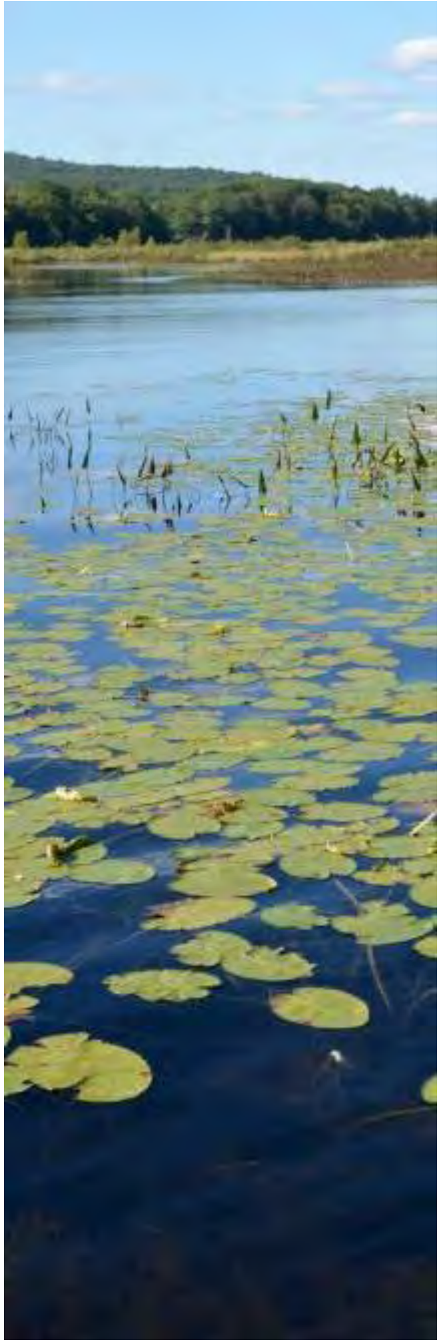
Serpentine acting as a sink, rather than a source for nutrients

Broader Implications

The Serpentine is a missing link …

- Important for mitigating nutrient loading from the input streams
- Maintaining health of the Serpentine will help maintain North Pond water quality
- To ensure informed management decisions input streams must be investigated at high resolution
- Collaboration between stakeholders will continue to be necessary in protecting the Belgrade Lake ecosystem


Photo credit: Christine Keller



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- Dr. Peter Kallin, BRCA
- Sean Boyd
- Bobby van Riper
- Colby College Environmental Studies Department
- Colby College Department of Geology
- Residents of the Serpentine


Questions?