Vermont EPSCoR

Experimental Program to Stimulate Competitive Research

Research on **A**daptation to **C**limate **C**hange
An Update on Question 1-2013

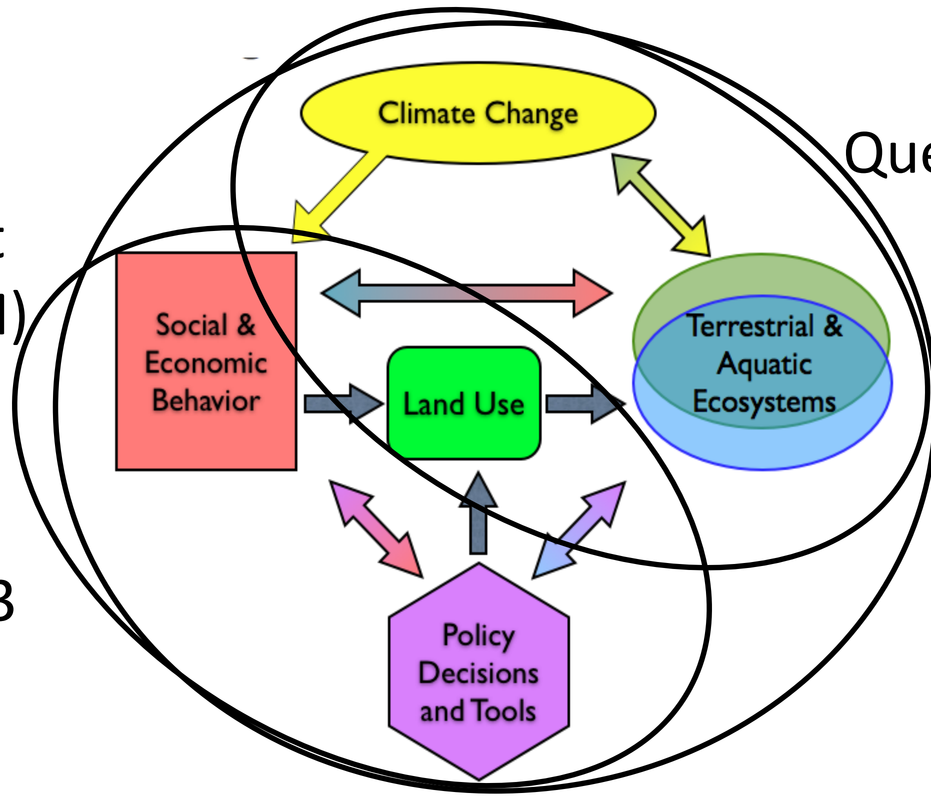
Andrew Schroth
Courtney Giles
Peter Isles

The Overarching RACC Question

How will the interactions of climate change and land use alter hydrological processes and nutrient transport from the landscape, internal processing and eutrophic state within Lake Champlain, and what are the implications for adaptive management strategies?

Integrated Assessment Model (IAM)

Questions 1 and 2



Question 3

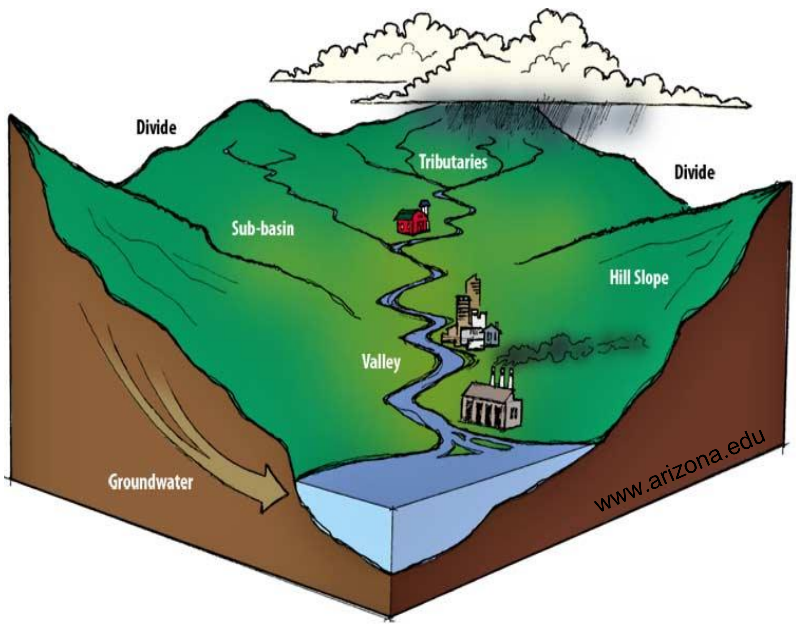
Question 1

- Q1: What is the relative importance of endogenous (in-lake) processes versus exogenous (to-lake) processes to eutrophication and harmful algal blooms?

Internal

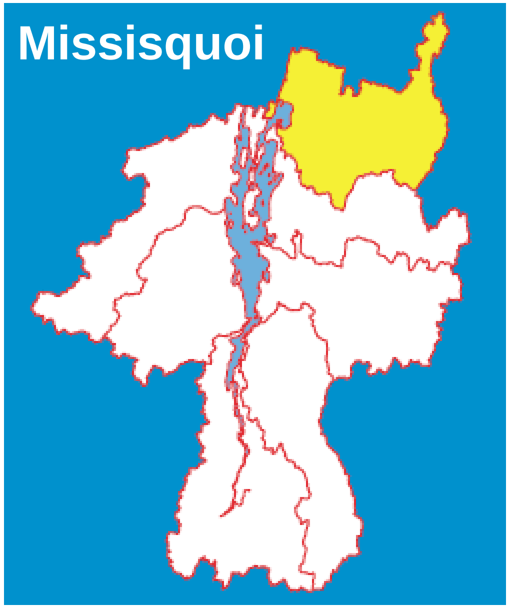
External

Approach to Question 1



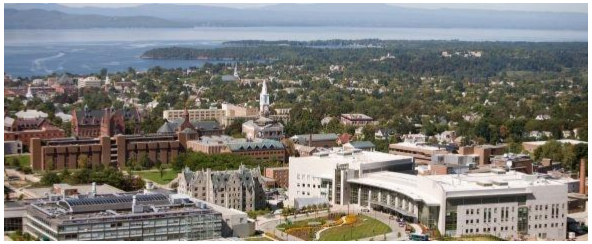
- What are the important sources of nutrients & sediment to the lake?
- How do land use and climate affect the nature and strength of these sources?
- How are nutrients and sediments transformed in transport to the lake and within the lake?
- How do the loadings of these materials affect lake processes?

Focus Watersheds



Agriculture: runoff, groundwater, soils, stream bank erosion

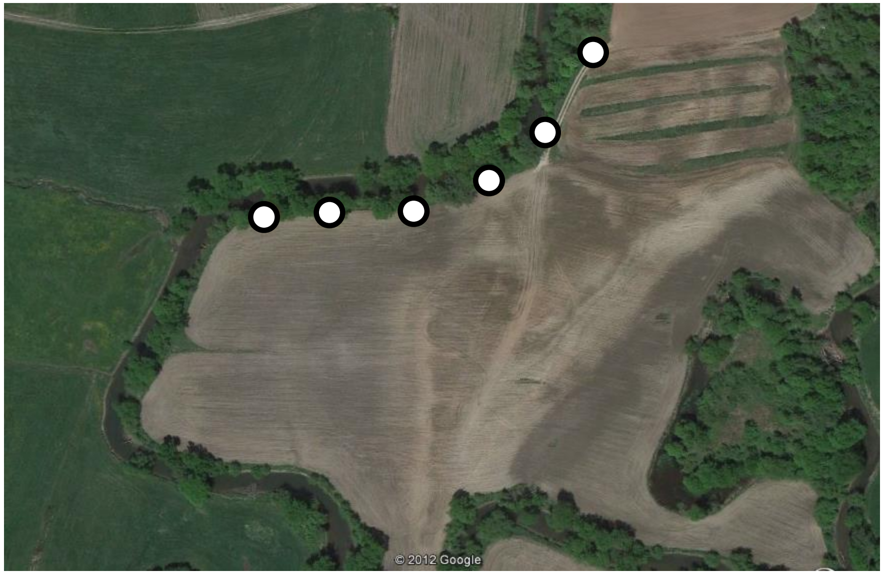
Forested: soils, groundwater, roads, channel migration, erosion



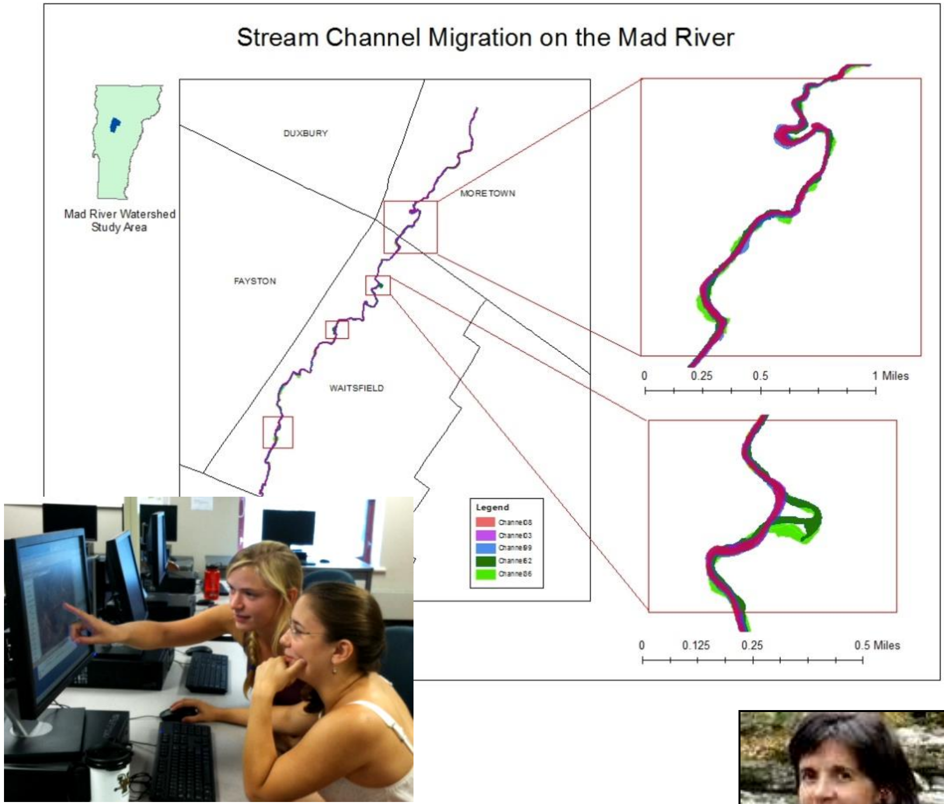
Urban: stormwater runoff, wastewater, stream erosion

What we have accomplished?

Source area characteristics



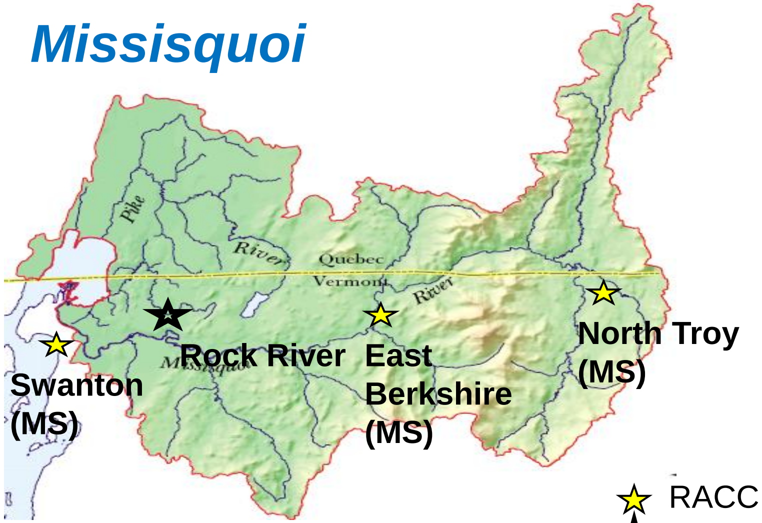
N/P Distribution across riparian zones



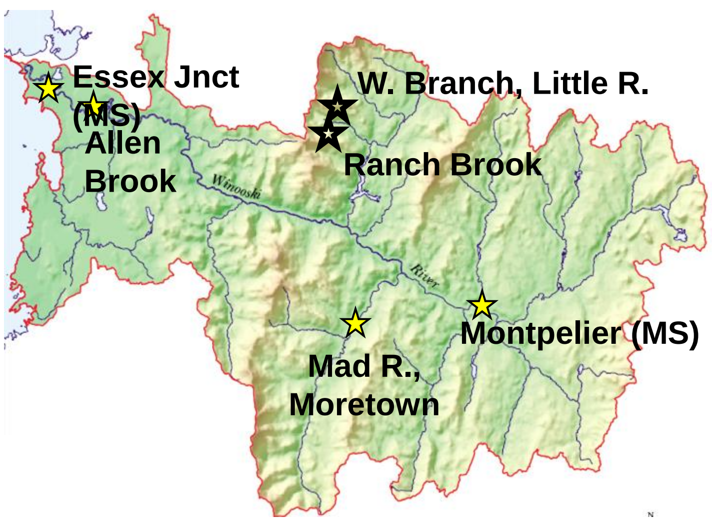
What we have accomplished?

Instrumented key sub-watersheds

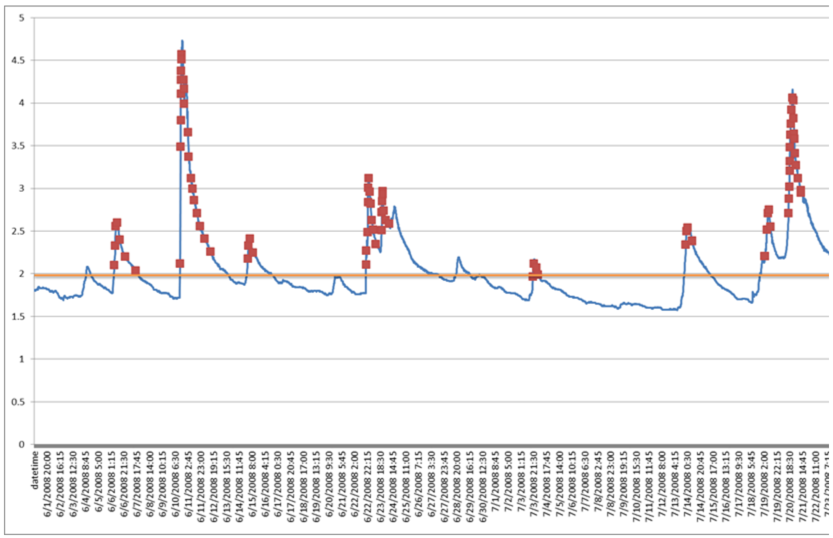
Missisquoi



Winooski



Capture Storm Event Biogeochemical Evolution with Automated Sampling



Modify ISCO Programs for 2013 Effort

What we have accomplished?

Integrated water sampling & analysis network

Johnson State College

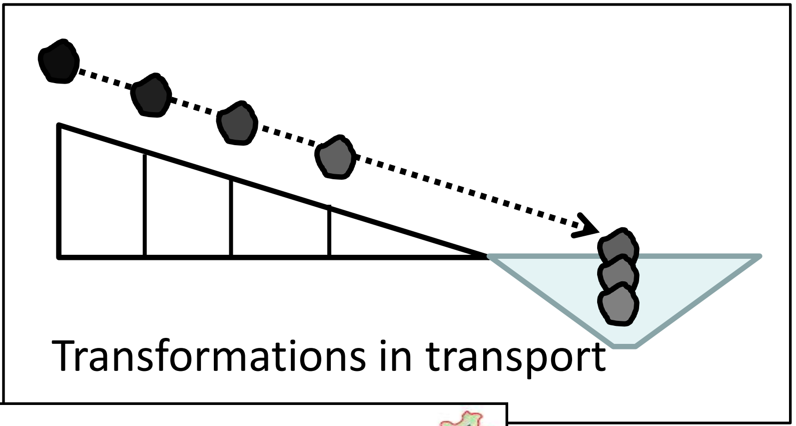
St. Michael's College

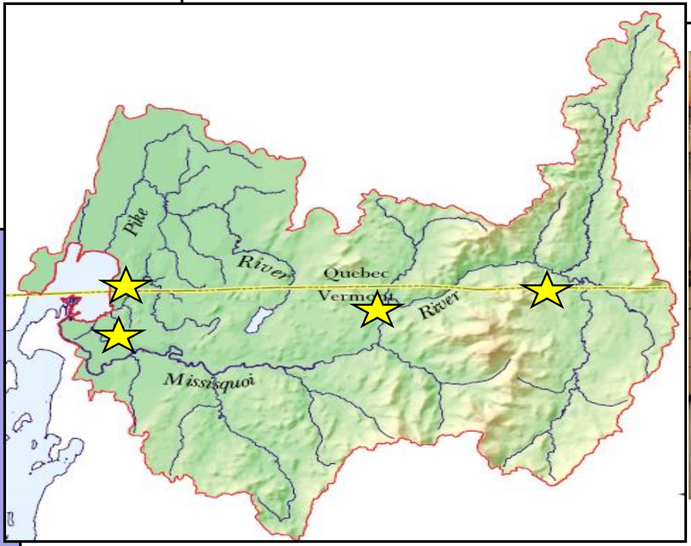
Undergraduate and graduate students have been directly involved in installation, maintenance, sampling, analysis, and data management.

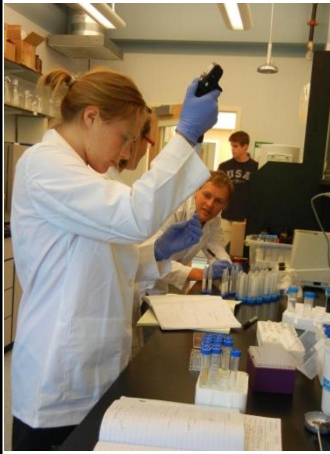
What we have accomplished?

Characterization of P transformations in watershed and lake

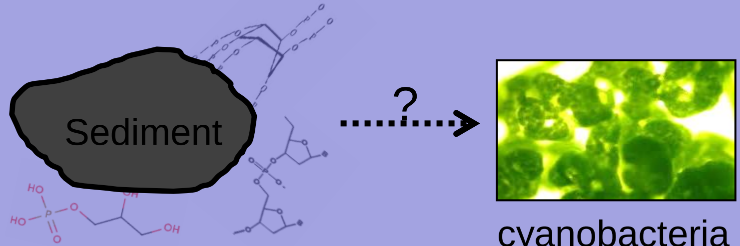
- What are the primary forms of P transported to Lake Champlain via *external sediment loading*?
- How algal-available are these sediment-bound-P forms?
- How do redox processes influence P cycling and *internal loading* from lake sediments?







Sediment-Bound-P
Species Analysis



cyanobacteria

ENZYME HYDROLYSIS
Solution ^{31} P NMR Spectroscopy




Partitioning P Sources

Small Watershed and Time-Series Analyses

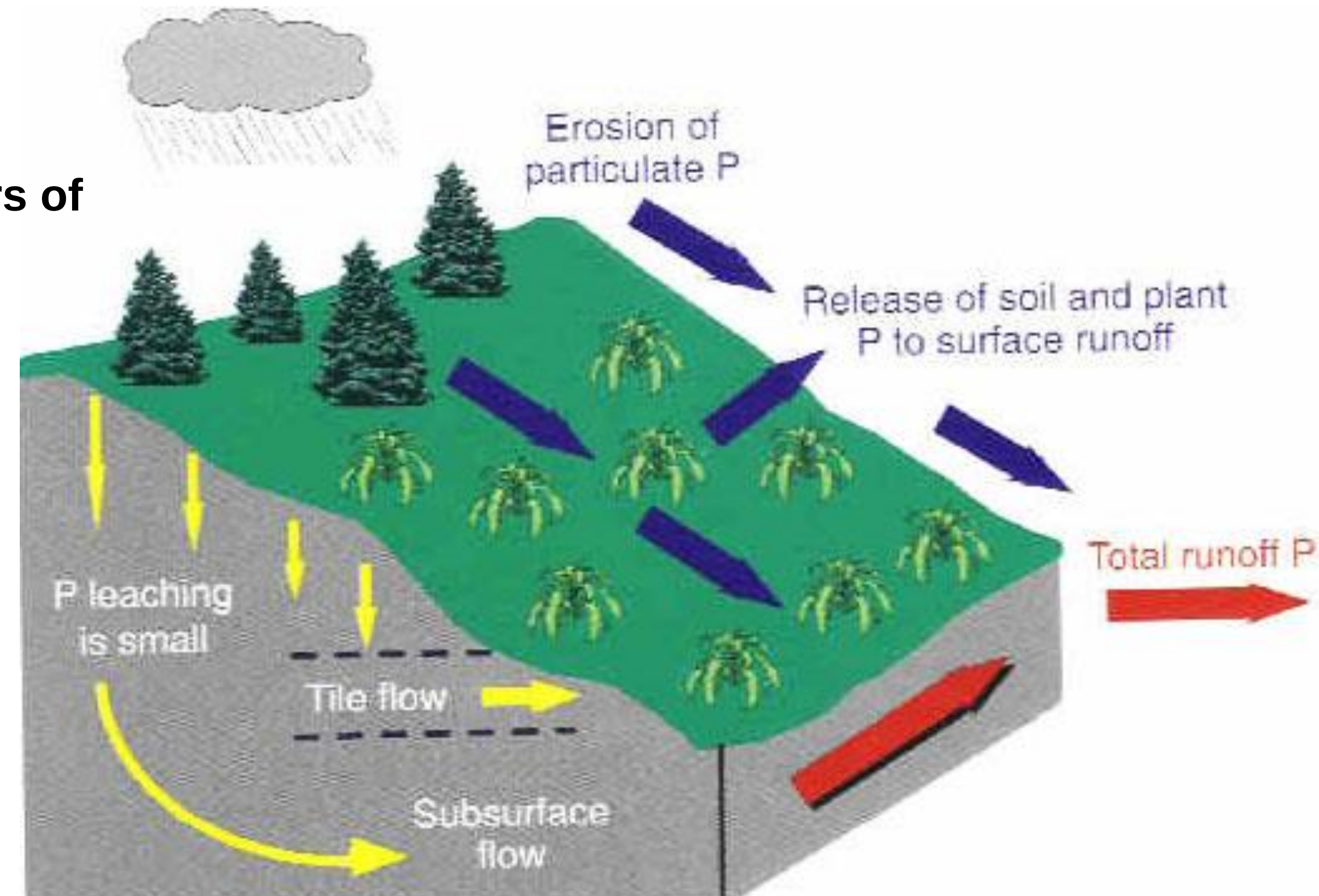
Employ Novel Tracers of Process and Source

Short-Lived Isotopes

PO_4 Isotopes

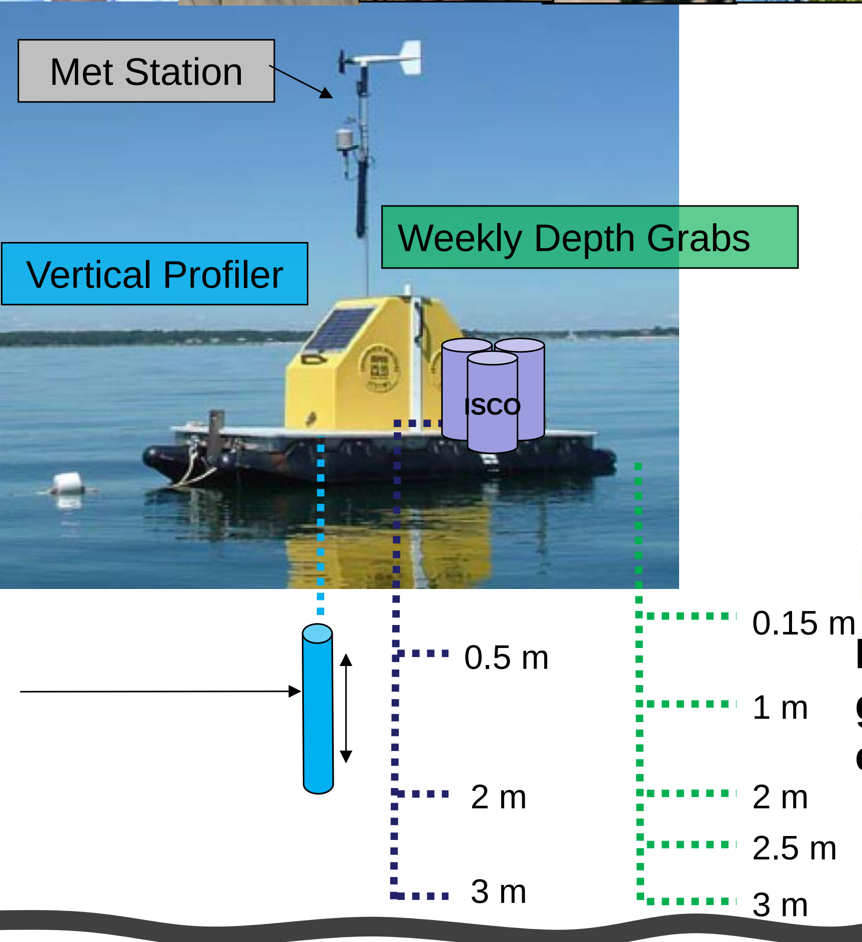
P-Speciation

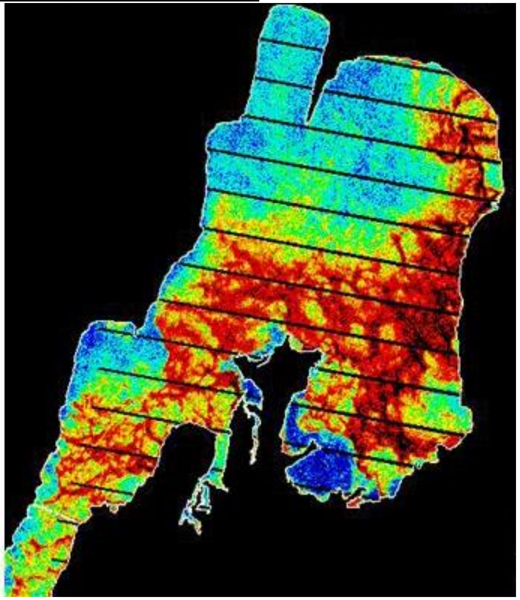
Metal Partitioning and Speciation



What we have accomplished?

Missisquoi Bay Advanced Environmental Monitoring Systems

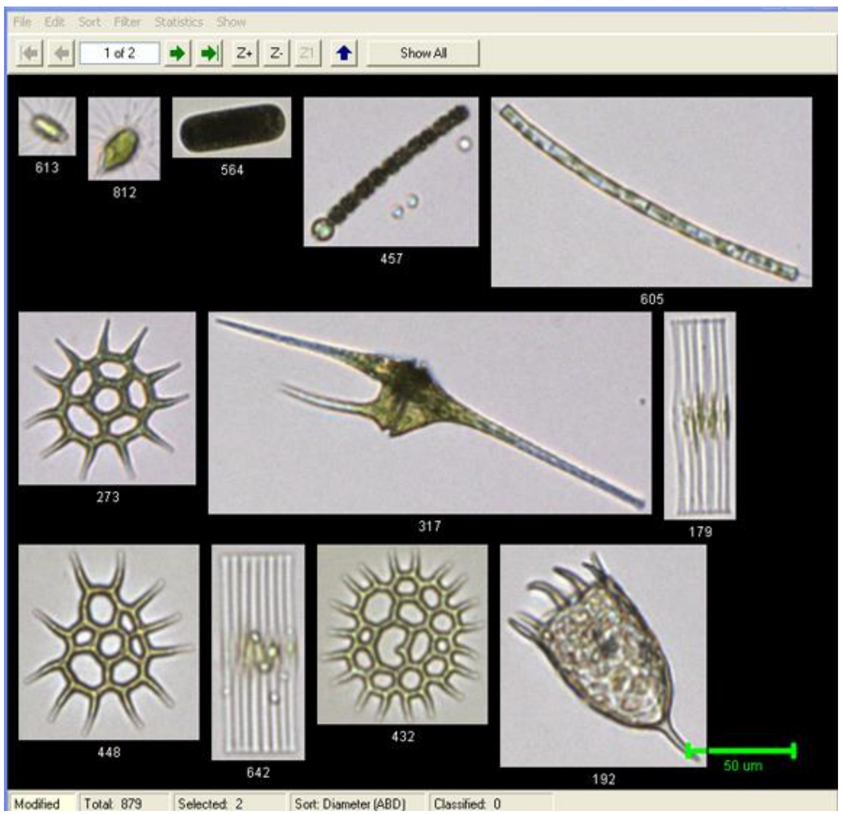




Linking climate, hydrodynamics, geochemistry and ecology to explain bloom dynamics

What are we working on?

Bioindicators to explore the effects of nutrient dynamics on aquatic food web structure



Sampling & identification

Phytoplankton

Zooplanton

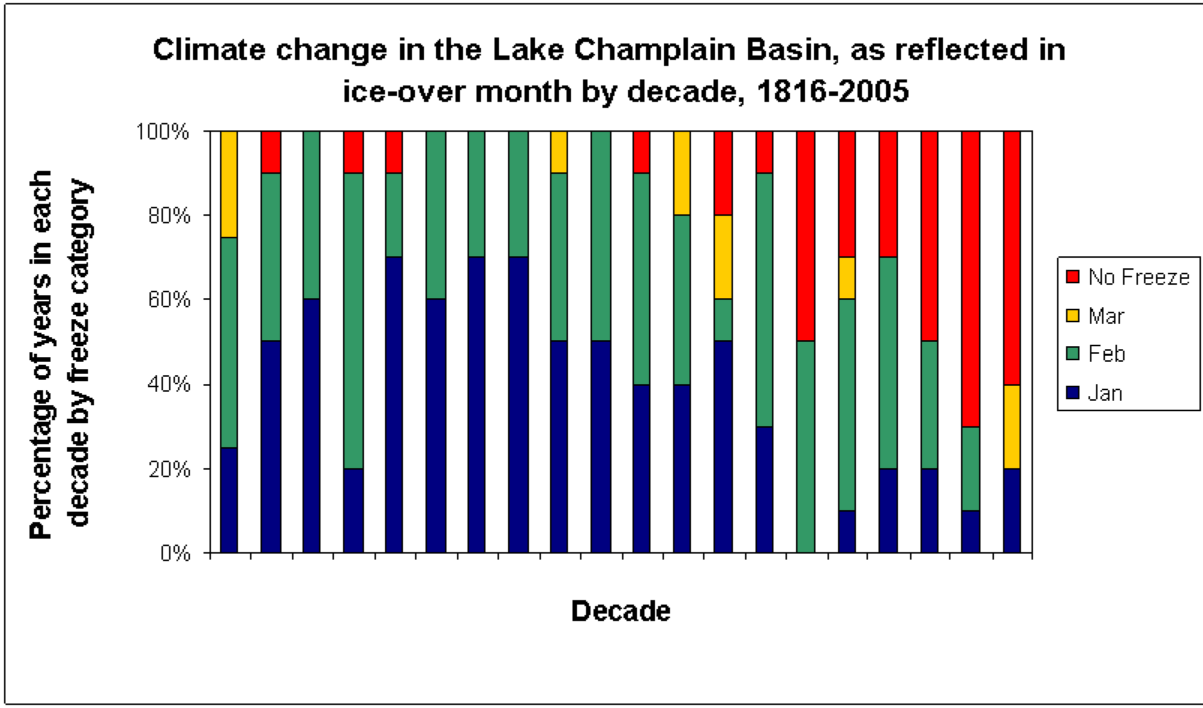
Benthic invertebrates

Aquatic plants

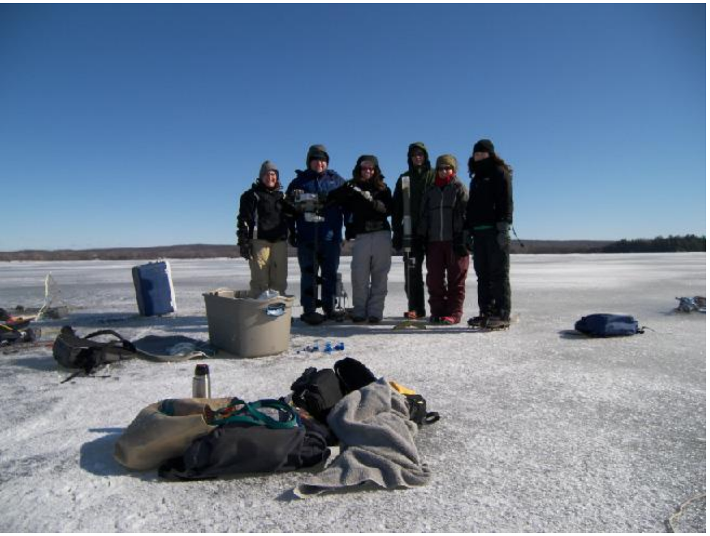
Fish

What have we accomplished?

Winter Through Ice Sampling



Duration and extent of ice cover is decreasing!



How does ice cover affect lake biology, physics and chemistry?

Winter grab sampling of water profile chemistry/biology and sediment cores

Hydrodynamic array under ice

New Lake Efforts for 2013 Field Season

Increased spatial sampling at different bloom stages

Time series sediment cores

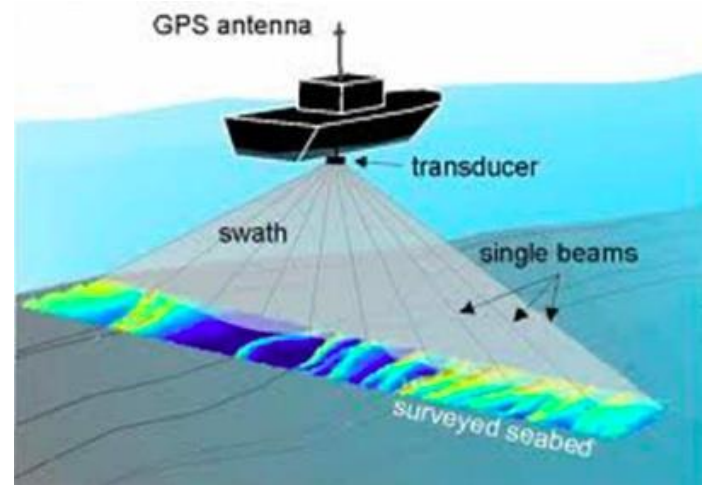
Redox chemistry micro-observatory deployment

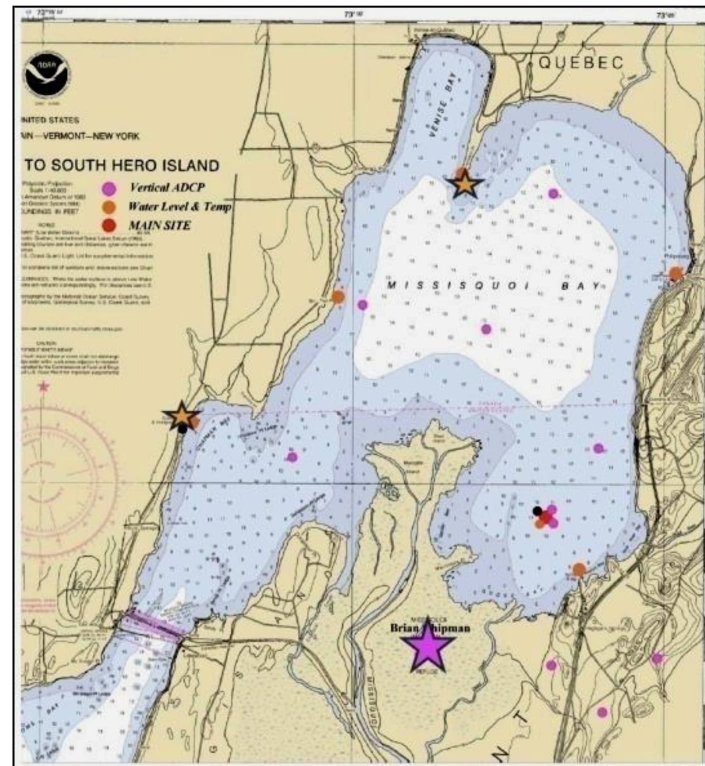
Diel nutrient/metal cycling studies during peak bloom

Bay wide sediment transport analyses

Bathymetric mapping of Missisquoi Bay

Lake model development





Phytoplankton Nutrient Limitation During a Dry Summer

Peter Isles, Courtney Giles, Andrew Schroth, Yaoyang Xu, Elissa Schuett, Saul Blocher, Trevor Gearhart, Jason Stockwell, Greg Druschel

RACC
Research on Adaptation to Climate Change

Vermont EPSCoR

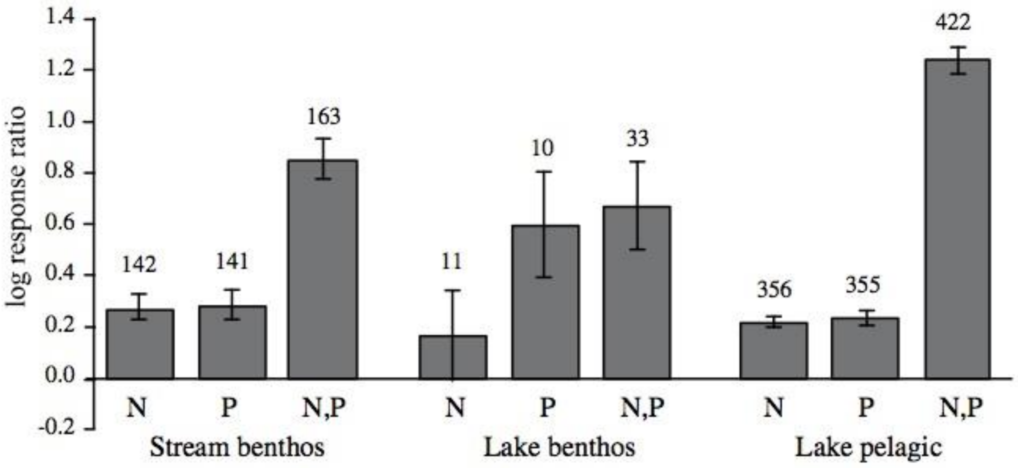
Outline

- Background
- Goals
- Picture of the Season
- Nutrient limitation
- Light Limitation
- Conclusions

Please Ask Questions!

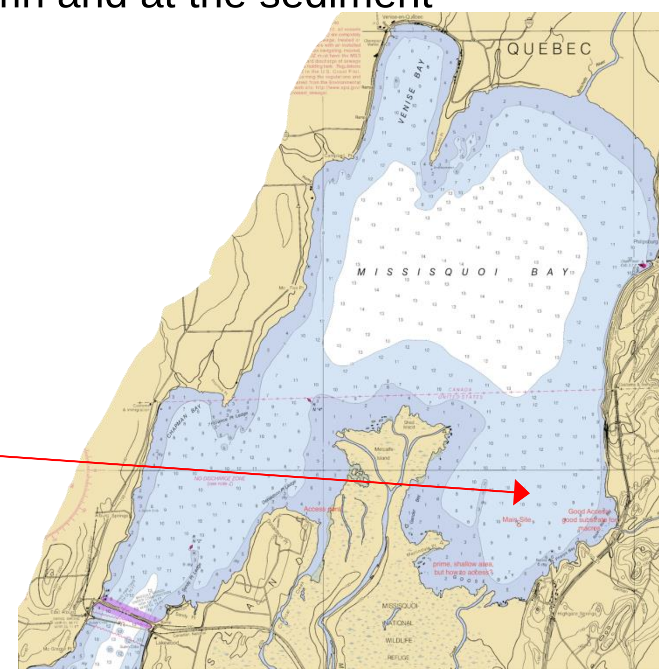
Background: Nutrient Limitation in Lakes

- Redfield Ratio
  - Alfred C. Redfield, 1934
  - C:N:P ≈ 106:16:1
- Schindler 1977 (and others)
  - Phosphorus is the key limiting nutrient in lakes
- Recent results: Co-Limitation
  - Elser 2007, Sterner 2008



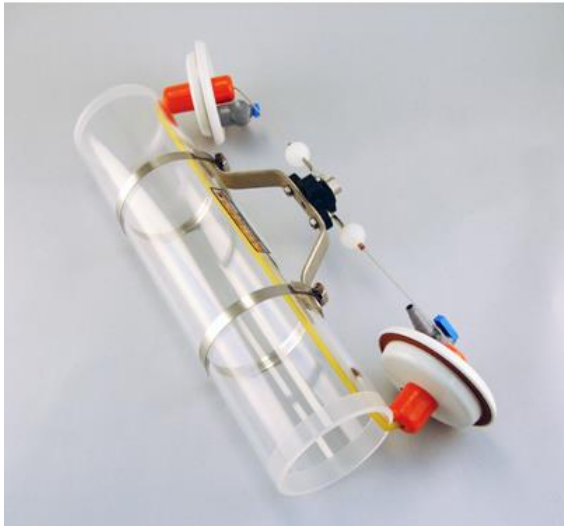
Goal: Identify drivers of cyanobacteria blooms

- Identify periods of N, P, and light limitation
- Identify sources of N and P to phytoplankton
  - Importance of internal v. external nutrient inputs
- Identify multiple-timescale processes controlling nutrient supply
  - Mechanisms driving release of benthic nutrients
  - Remineralization of nutrients in the water column and at the sediment surface

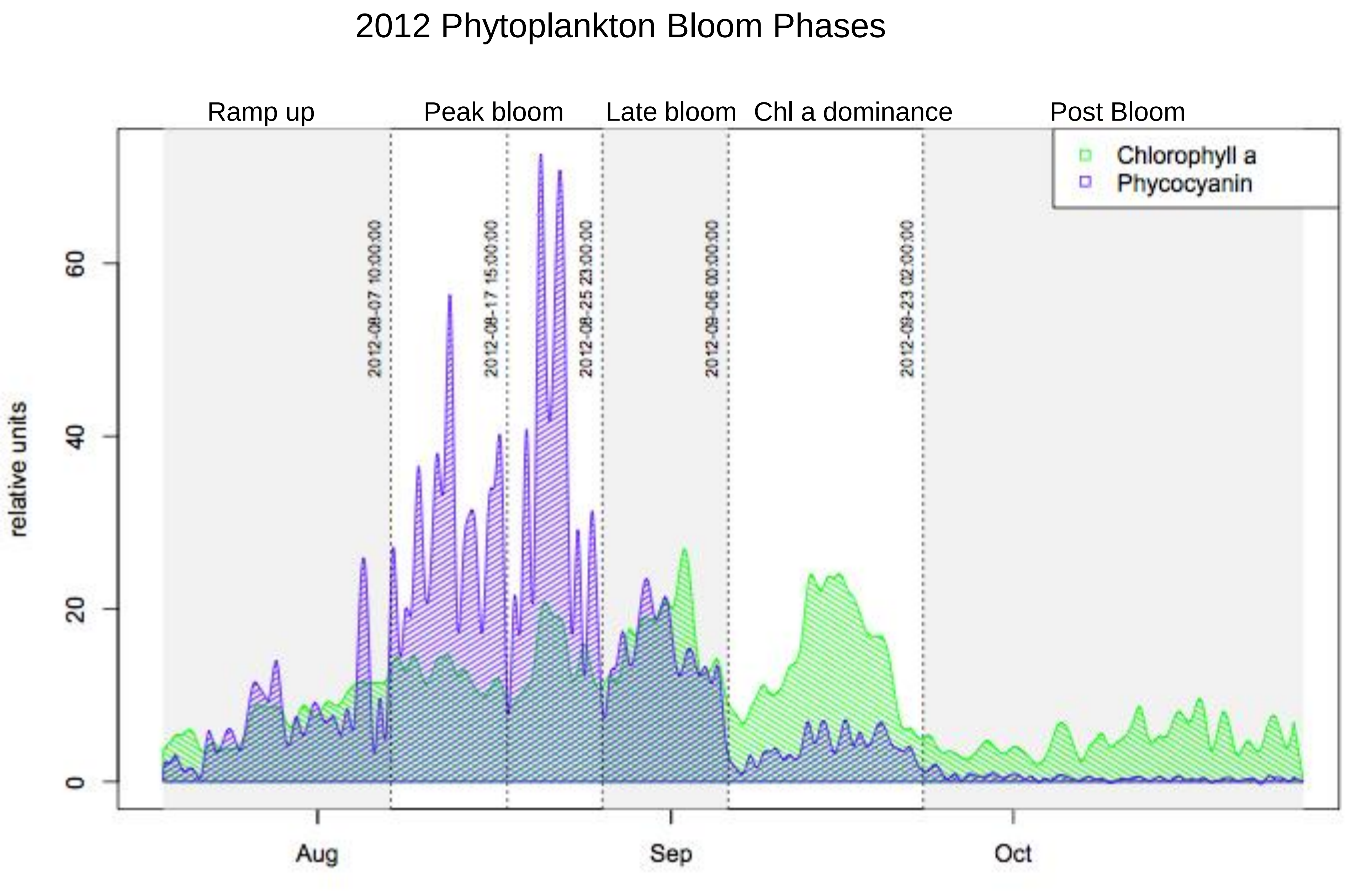


Sampling Strategy:

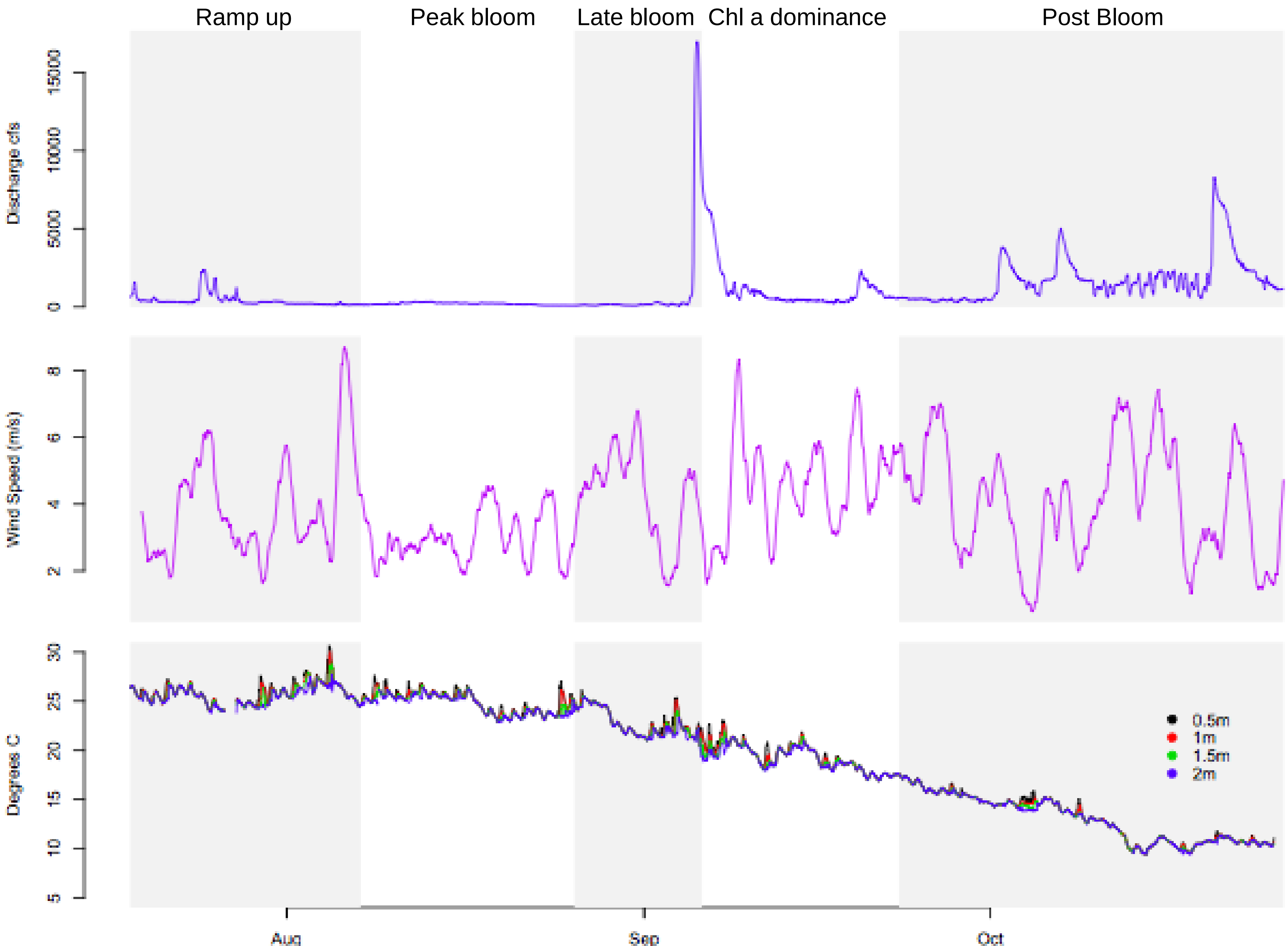
- Hourly:
  - Sonde measurements (DO, pH, phycocyanin, Chl a, turbidity, temp.) (5 depths)
  - Weather, river variables (temp, wind, discharge, PAR)
- Every 8 hours (5am, 1pm, 9pm)
  - Total nitrogen, total phosphorus, total metals (3 depths)
- Weekly
  - SRP, TDP, NO_3^-, NH_4^+, dissolved metals, colloidal metals, phytoplankton, zooplankton, TSS, PAR

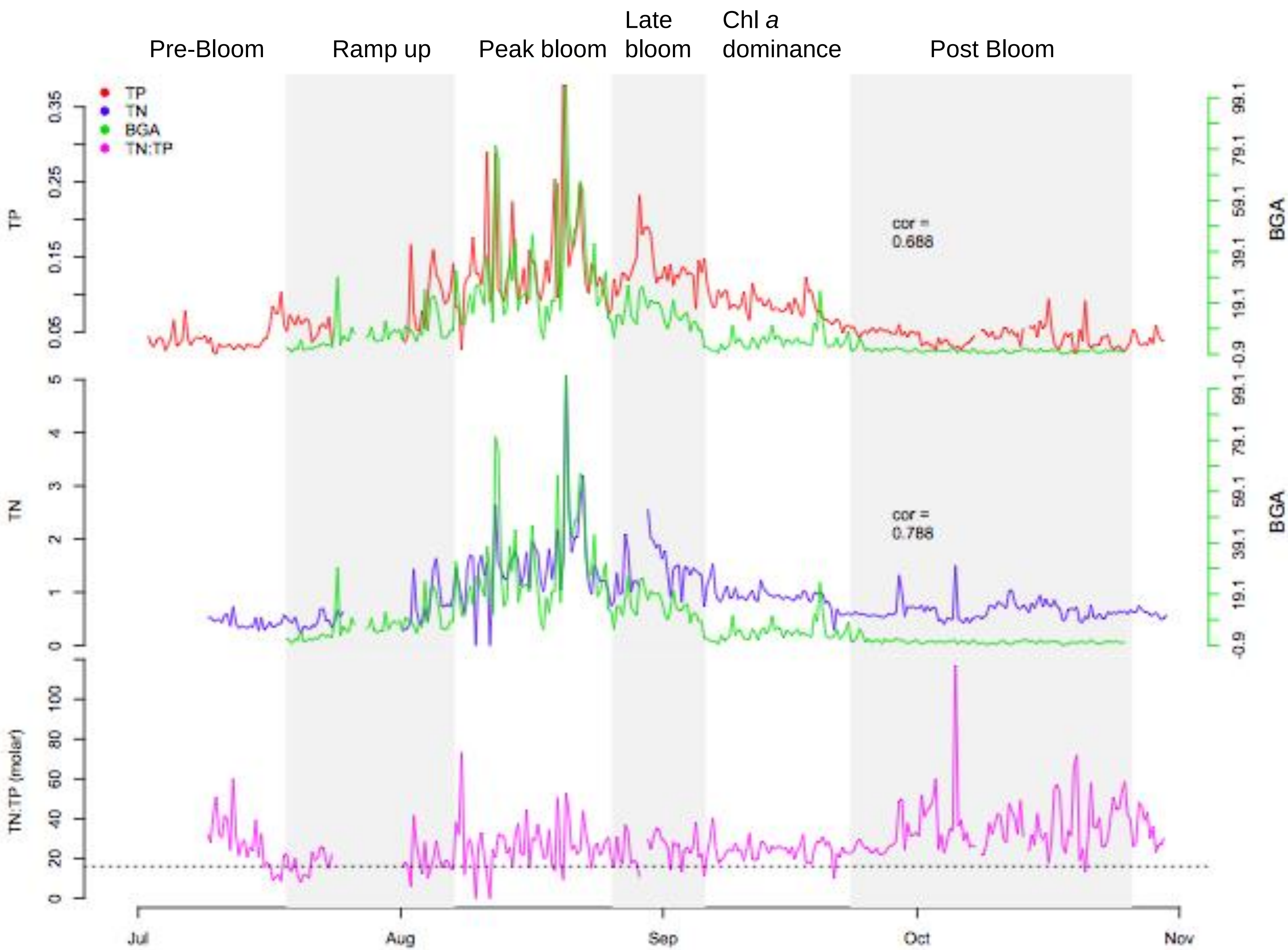
Data: Phytoplankton Dynamics



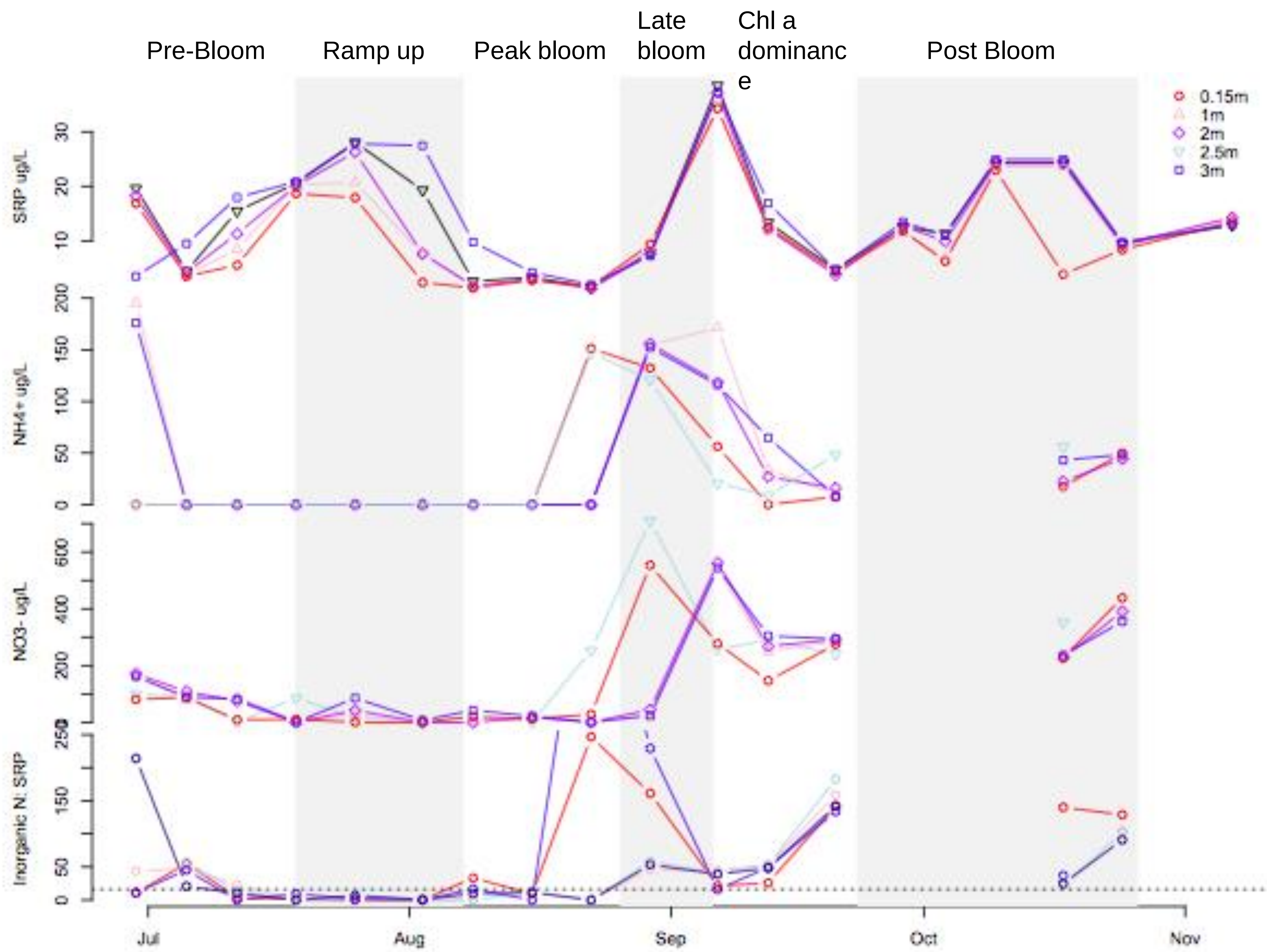
Data: Environmental Conditions



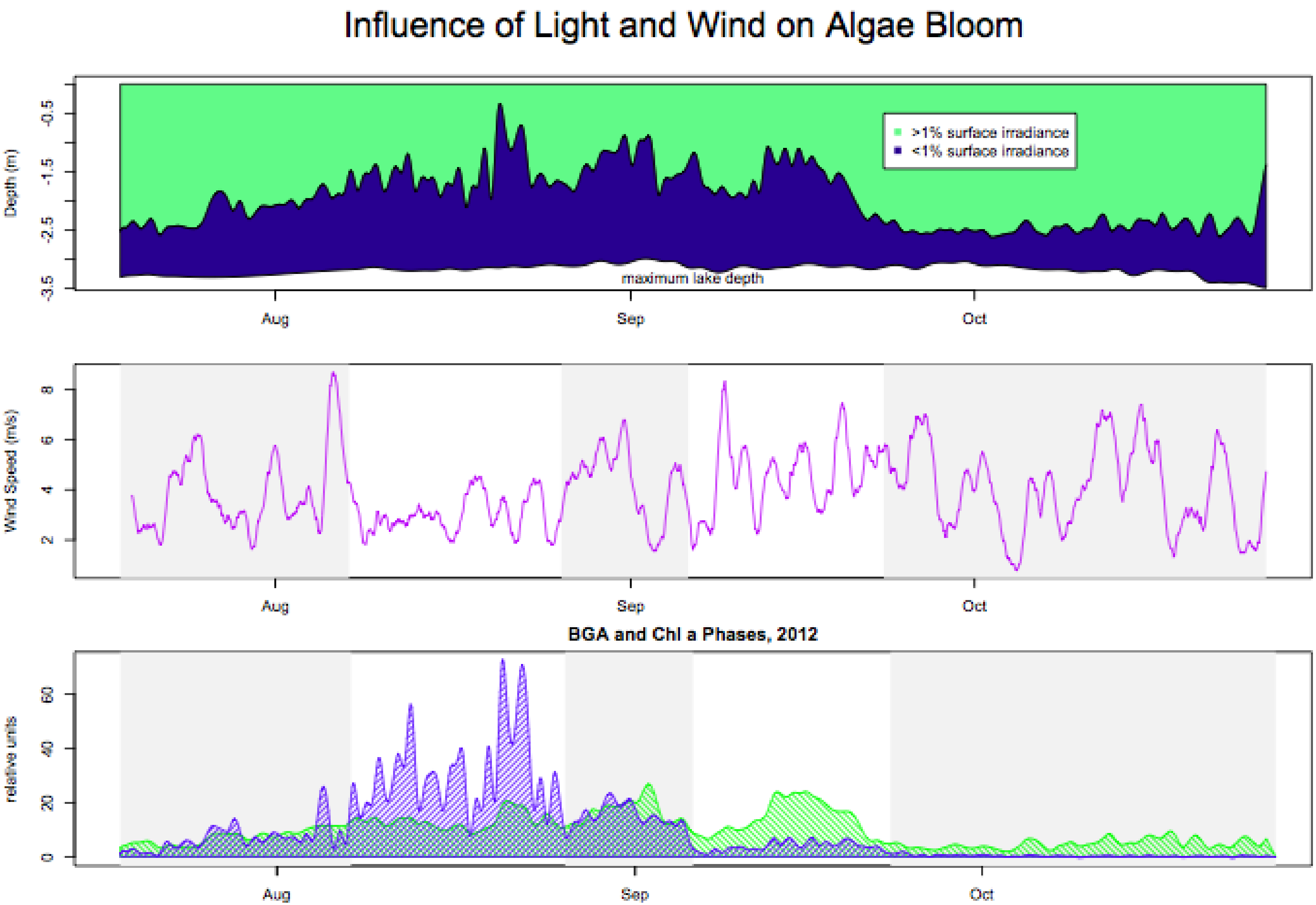
Total Nitrogen and Total Phosphorus



Available Nutrients



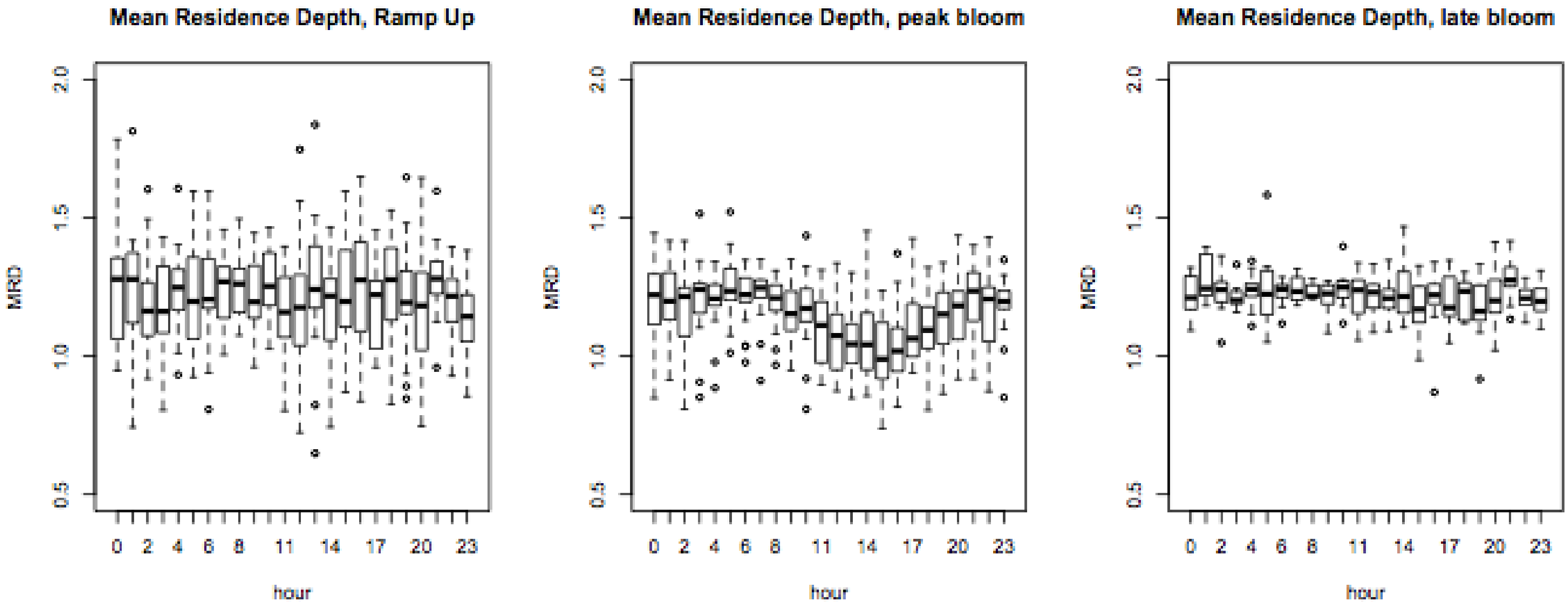
Light Limitation

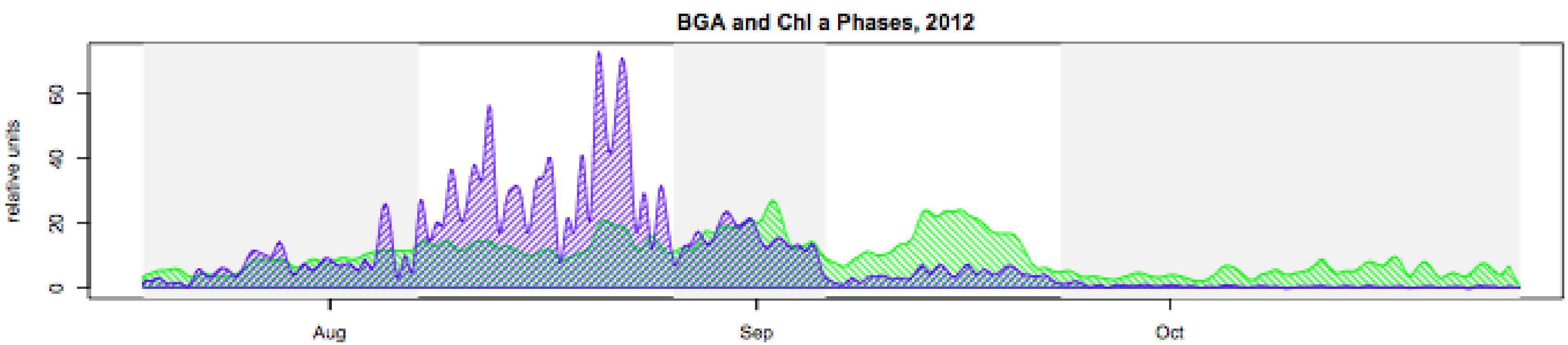


1% irradiance curve reconstructed from turbidity, chl a, and weekly PAR measuremen

Light Limitation

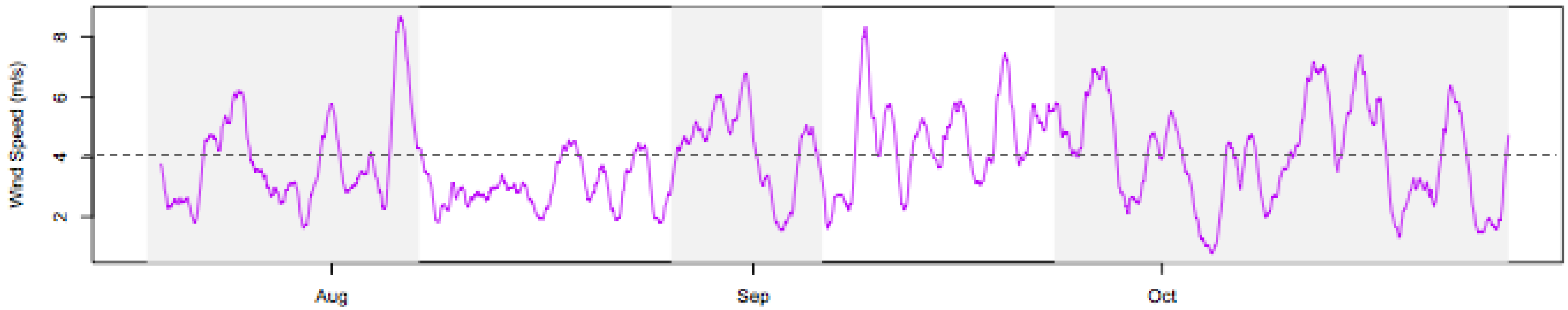
Light, Wind, and Buoyancy Regulation





1% irradiance curve reconstructed from turbidity, chl a, and weekly PAR measuremen

Light Limitation



Effect of wind on plankton distribution

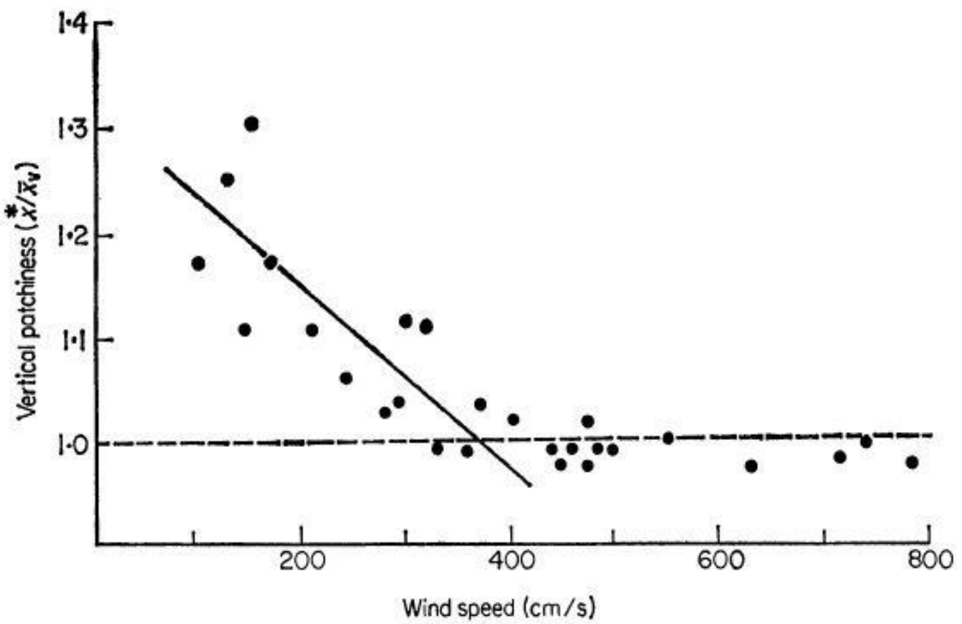


FIG. 8. The relationship between vertical patchiness in the blue-green algae and wind speed. $\overset{*}{x}/x_v$ values calculated for chlorophyll *a* profiles at a single station. Regression line fitted to patchiness estimates at wind speeds below 400 cm/s.

George and Edwards 1976

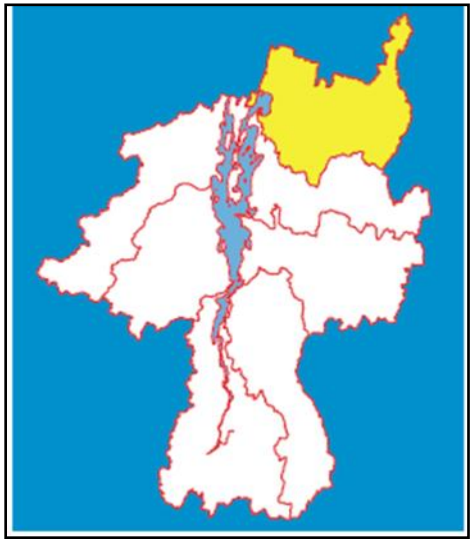
Conclusions

- 2012 cyanobacteria bloom driven by internal processes
  - Very low runoff from rivers
- Missisquoi bay was P limited before and after bloom, but N-limited during bloom
- Increase in total P during bloom driven by sediment loading; increase in total N by N fixation
- Light may also be an important limiting resource

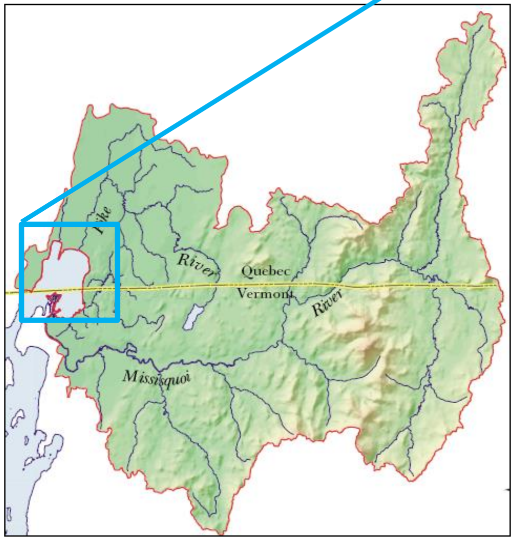
Exogenous and Endogenous Inputs of Bioavailable Phosphorus to Lake Champlain

Courtney D Giles
Postdoctoral Associate, UVM
VT-EPSCoR Research on Adaptation to Climate Change
1 May 2013

Exogenous and Endogenous Inputs of Bioavailable Phosphorus to Missisquoi Bay



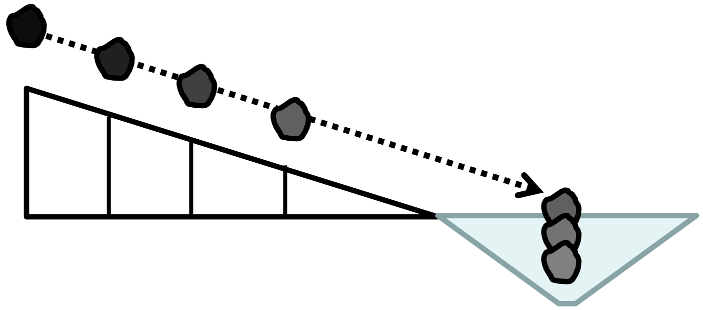
Lake Champlain Basin



Missisquoi Basin

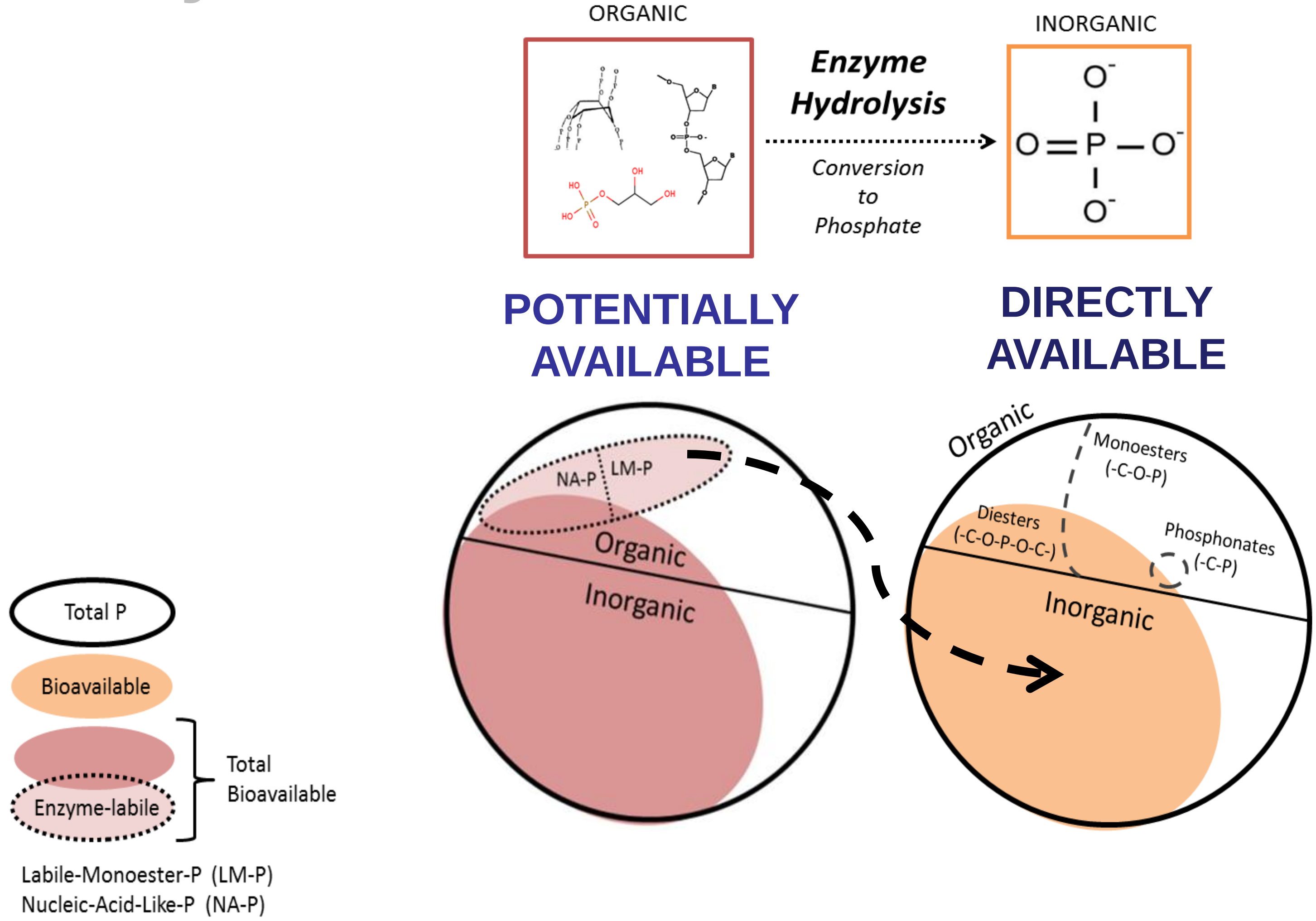
Exogenous and Endogenous Inputs of Bioavailable Phosphorus to Missisquoi Bay

Terrestrial and
Riverine sources



Internal nutrient
cycling and
loading from
sediments

Exogenous and Endogenous Inputs of **Bioavailable Phosphorus** to Missisquoi Bay



Enzyme Hydrolysis Method

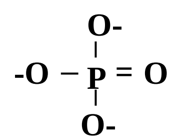
Directly bioavailable phosphate

Potentially bioavailable, ‘**enzyme-labile**’ phosphorus

4. Phosphate is measured colorimetrically

2. Enzymes are added to target specific classes of P

\+ PHOSPHATASES →



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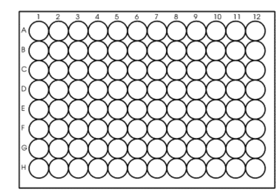
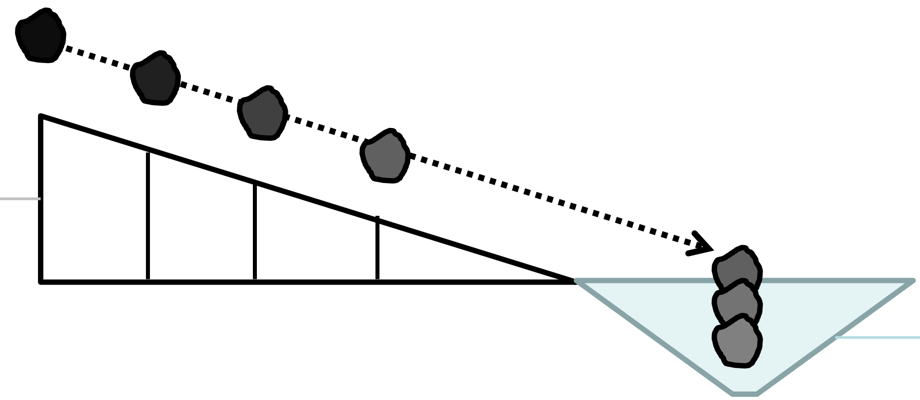


1. P is extracted from suspended or settled sediments

3. Phosphate release is proportional to P in targeted class

Current Studies in the Missisquoi Basin

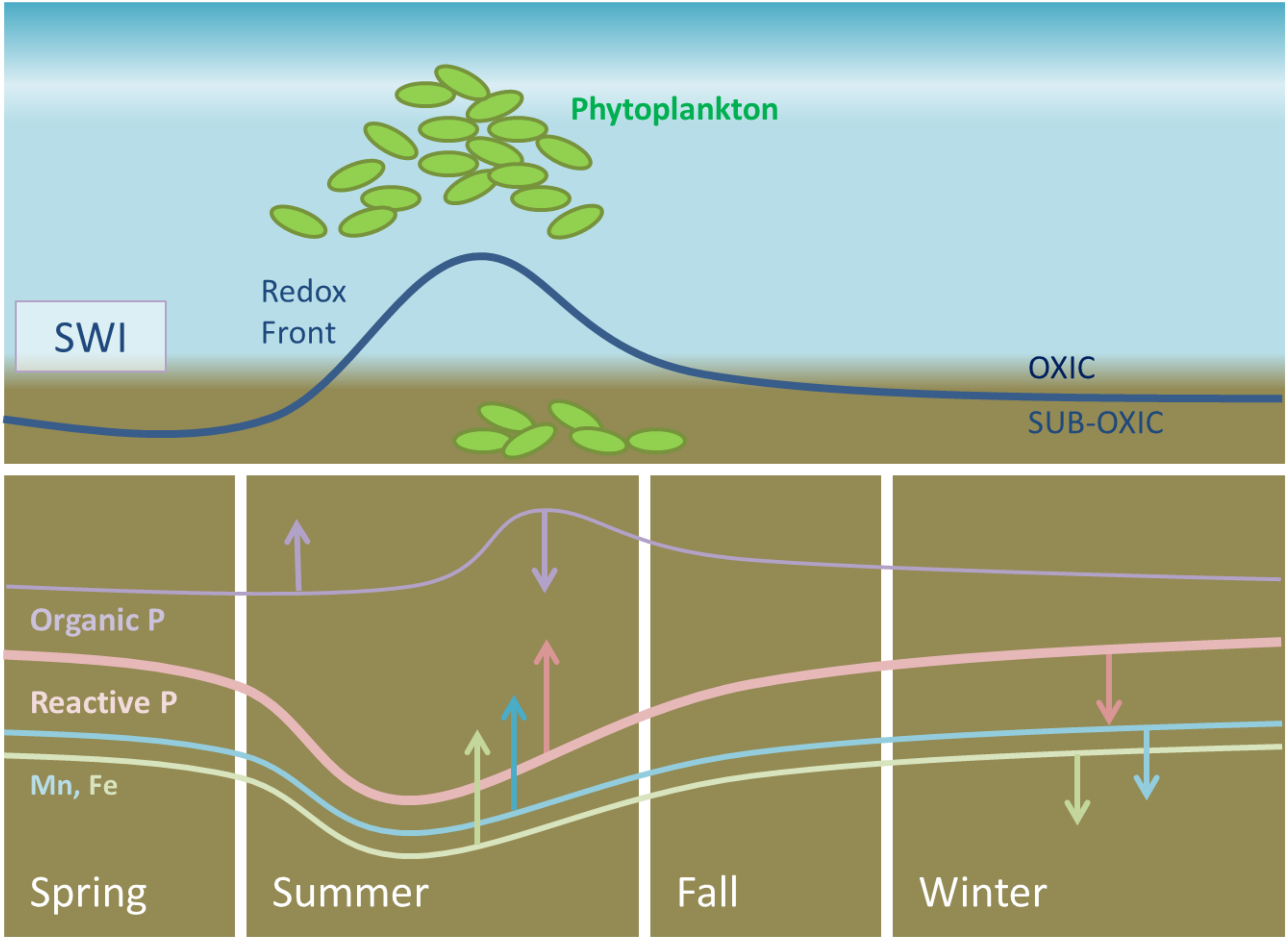


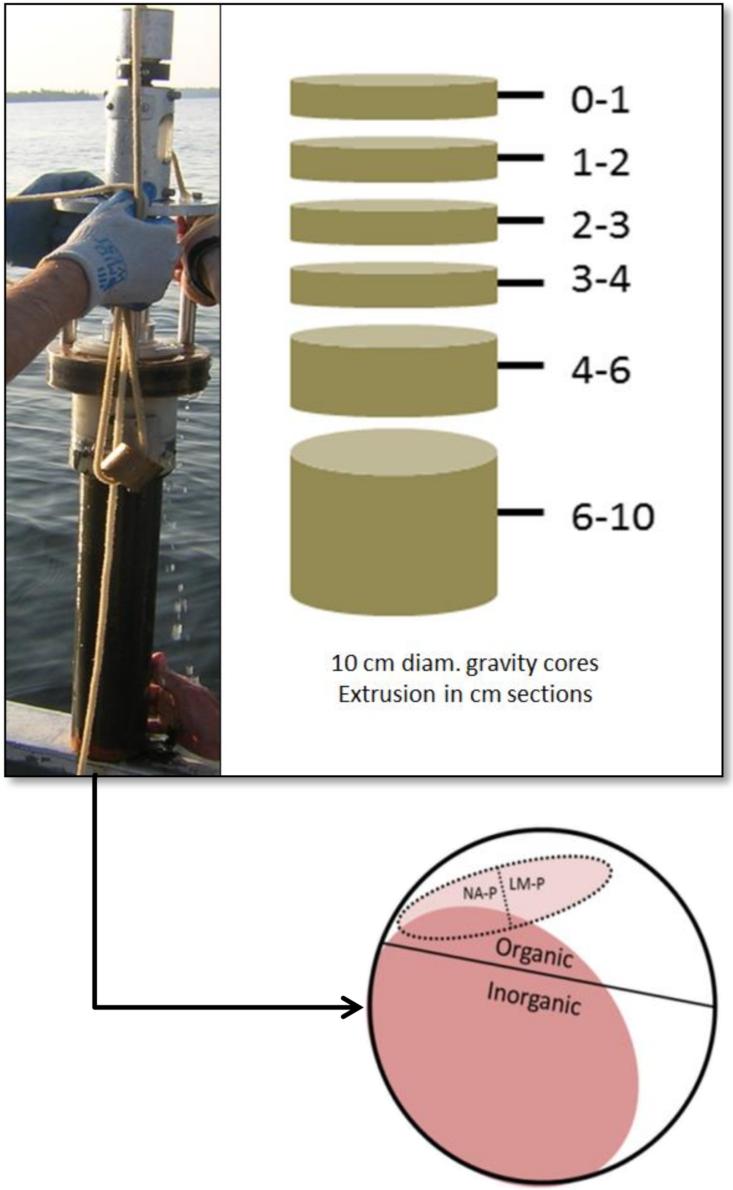
(1) Assessing Phosphorus Mobility and Bioavailability in Missisquoi Bay Sediments

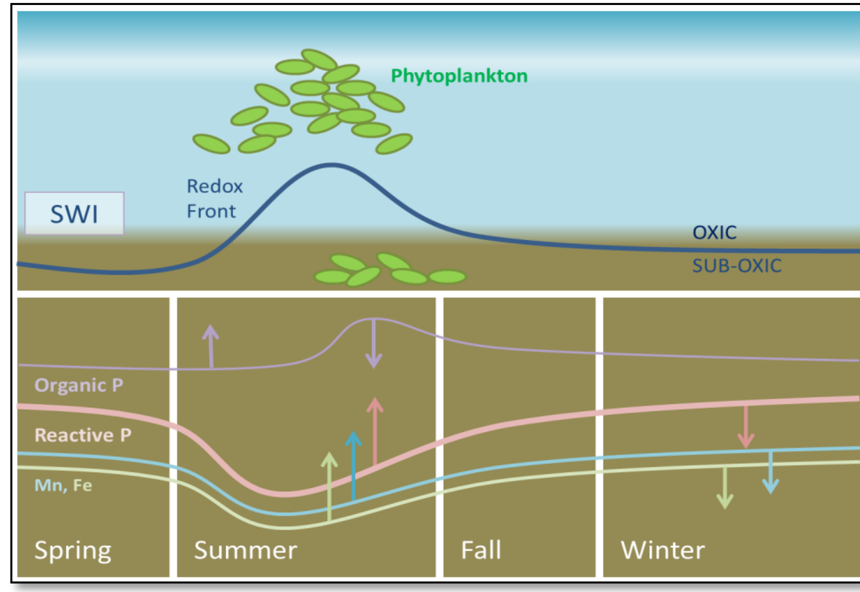
(2) Characterization of Particle-Bound Phosphorus bioavailability in Missisquoi Basin Streams

Phosphorus Mobility and Bioavailability
in Missisquoi Bay Sediments

How does P mobility and bioavailability vary seasonally and over the course of an algal bloom?


Phytoplankton
SWI
Redox Front
OXIC
SUB-OXIC
Organic P
Reactive P
Mn, Fe
Spring
Summer
Fall
Winter





Objectives

- Apply enzyme hydrolysis method to archived lake sediments
- Monitor the bioavailability of sediment phosphorus in Missisquoi Bay on a monthly and seasonal basis.

Smith et al. (2011). *Limnol. Oceanogr*. 56(6): 2251; Smith, MS Thesis (2009)

Sediment Phosphorus Dynamics in Relation to Bloom Stage

TIME

BLOOM STAGE

11 Oct. 2007
(No Bloom)

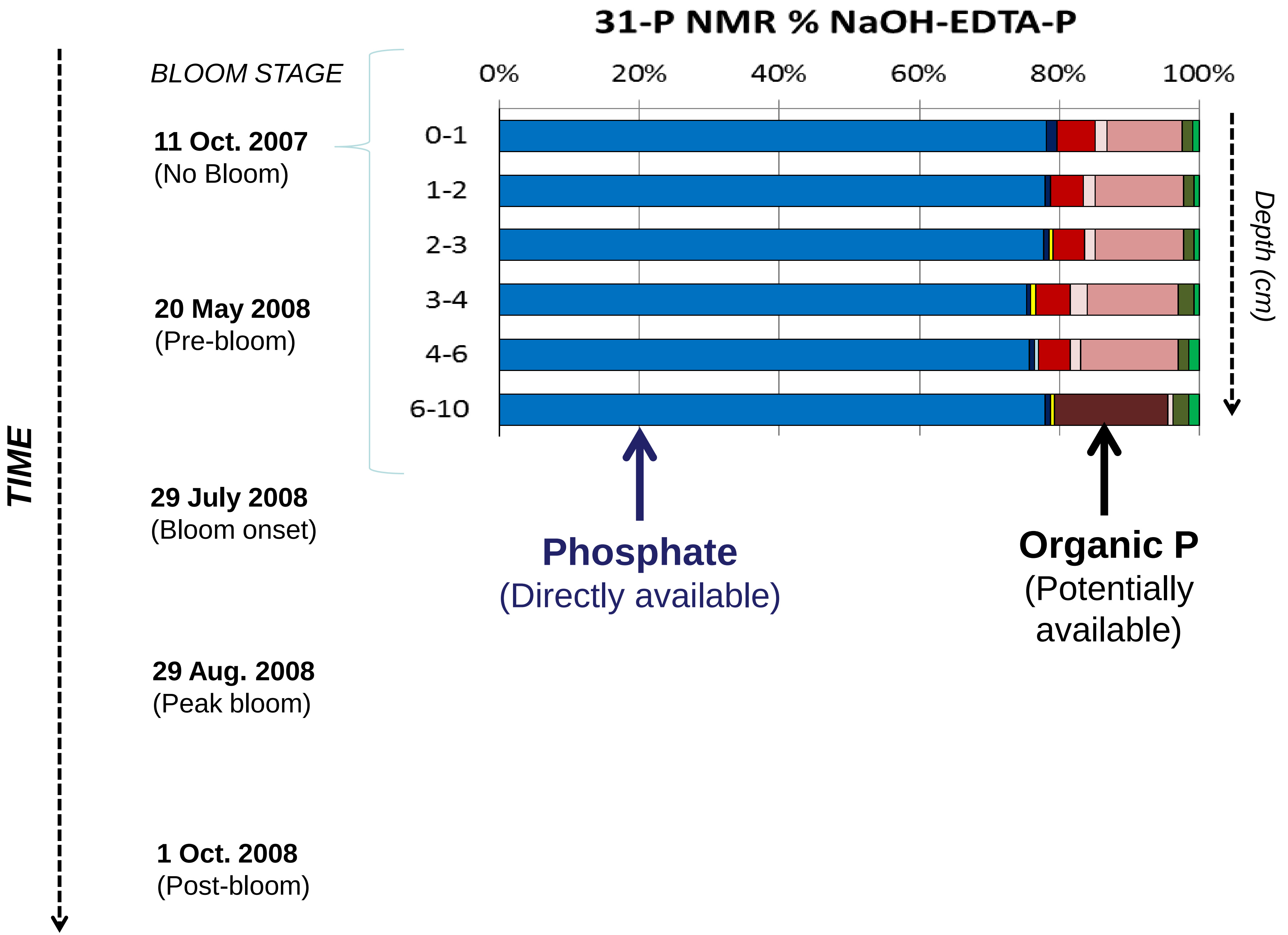
20 May 2008
(Pre-bloom)

29 July 2008
(Bloom onset)

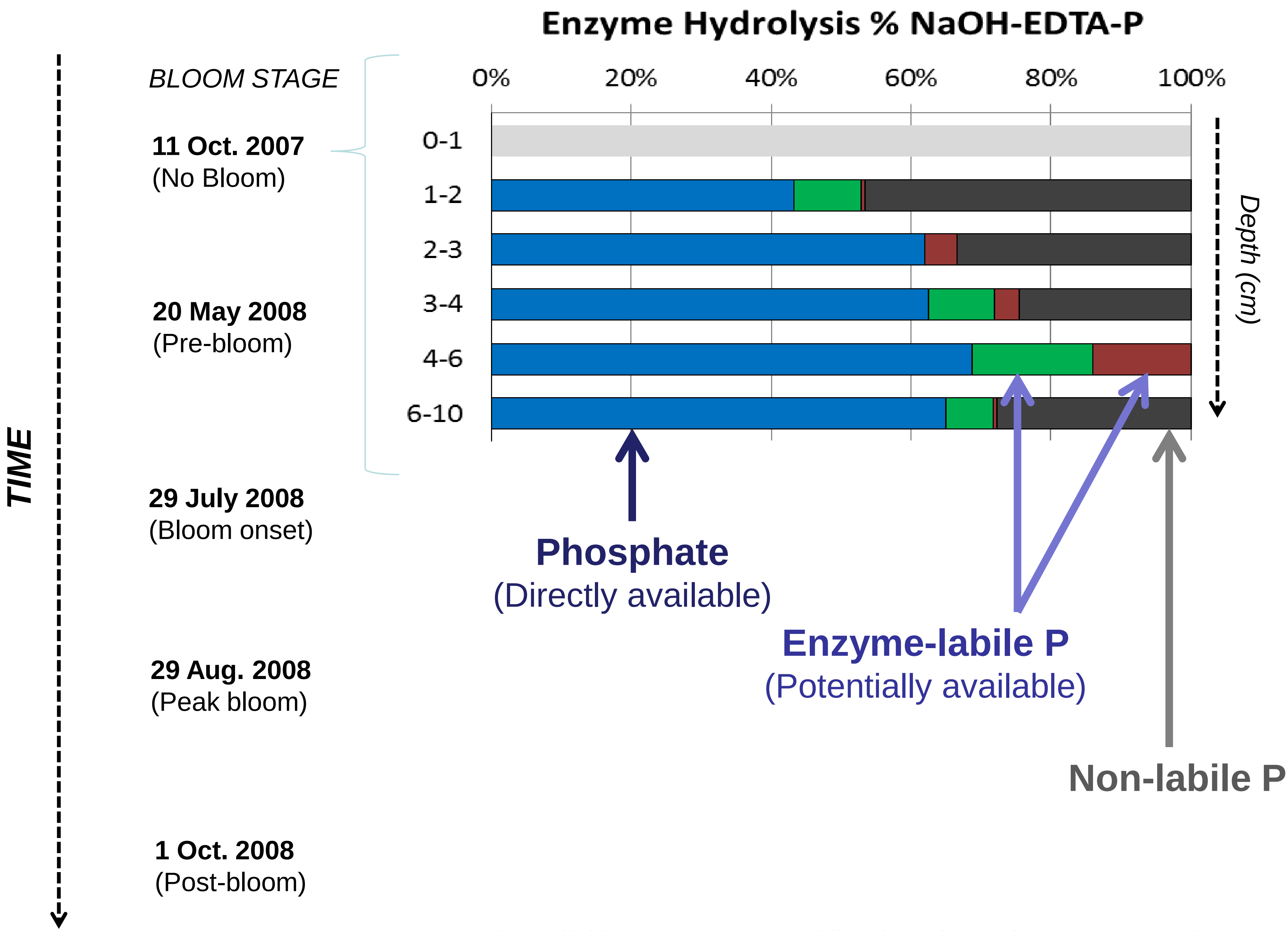
29 Aug. 2008
(Peak bloom)

1 Oct. 2008
(Post-bloom)

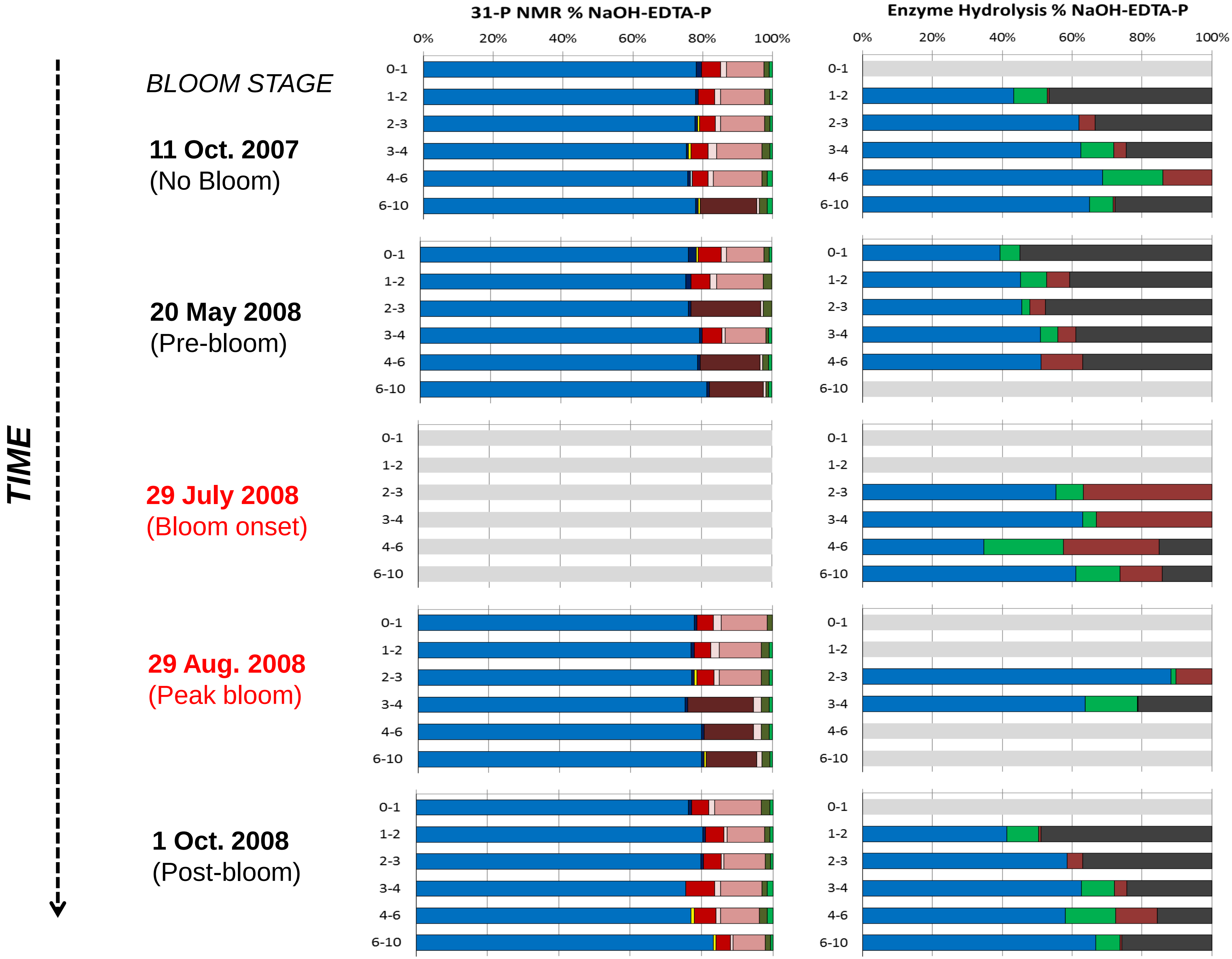
Smith, MS Thesis (2009): *Phosphorus Species by Solution 31-P NMR Spectroscopy*



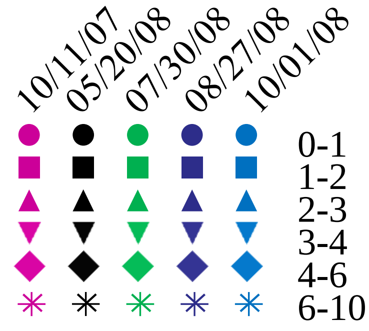
Smith, MS Thesis (2009): *Phosphorus Species by Solution 31-P NMR Spectroscopy*

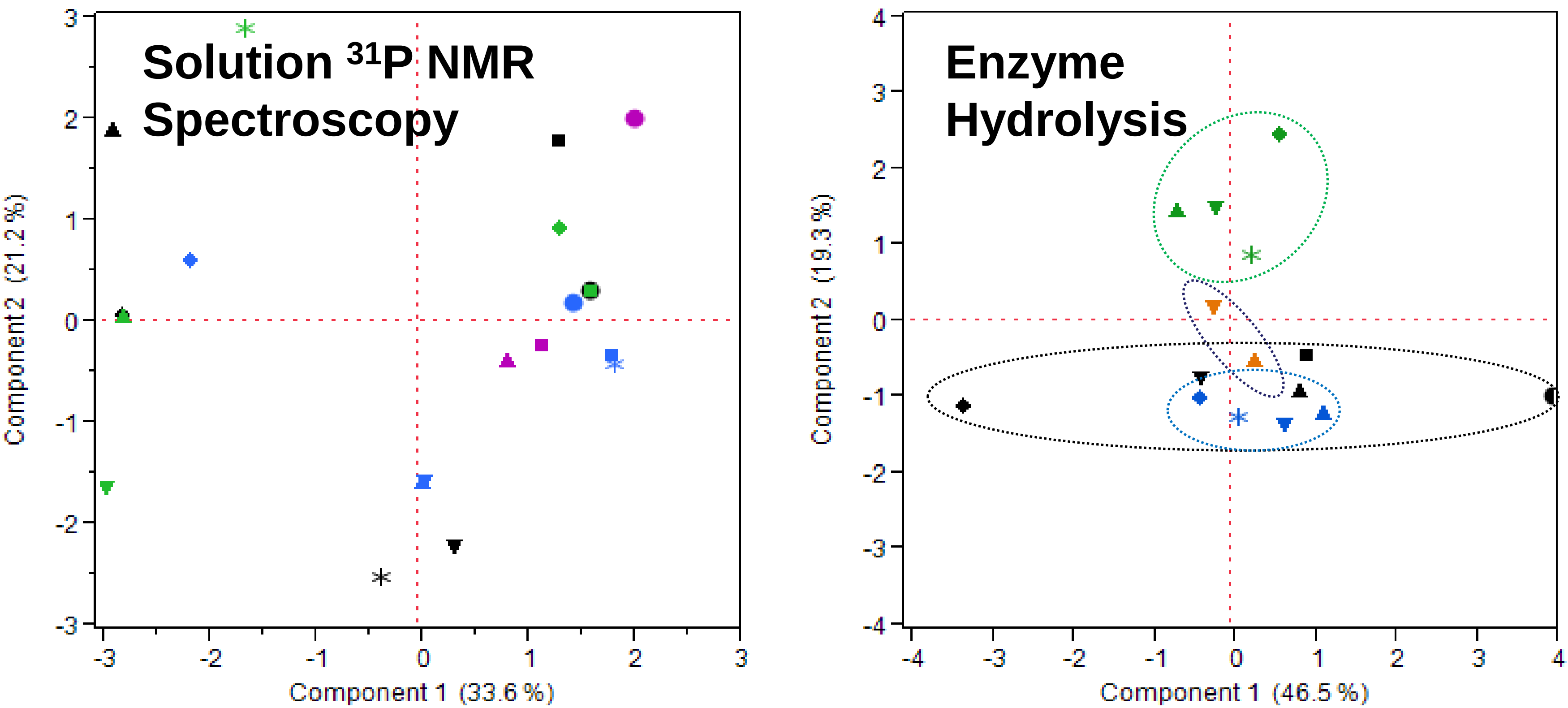


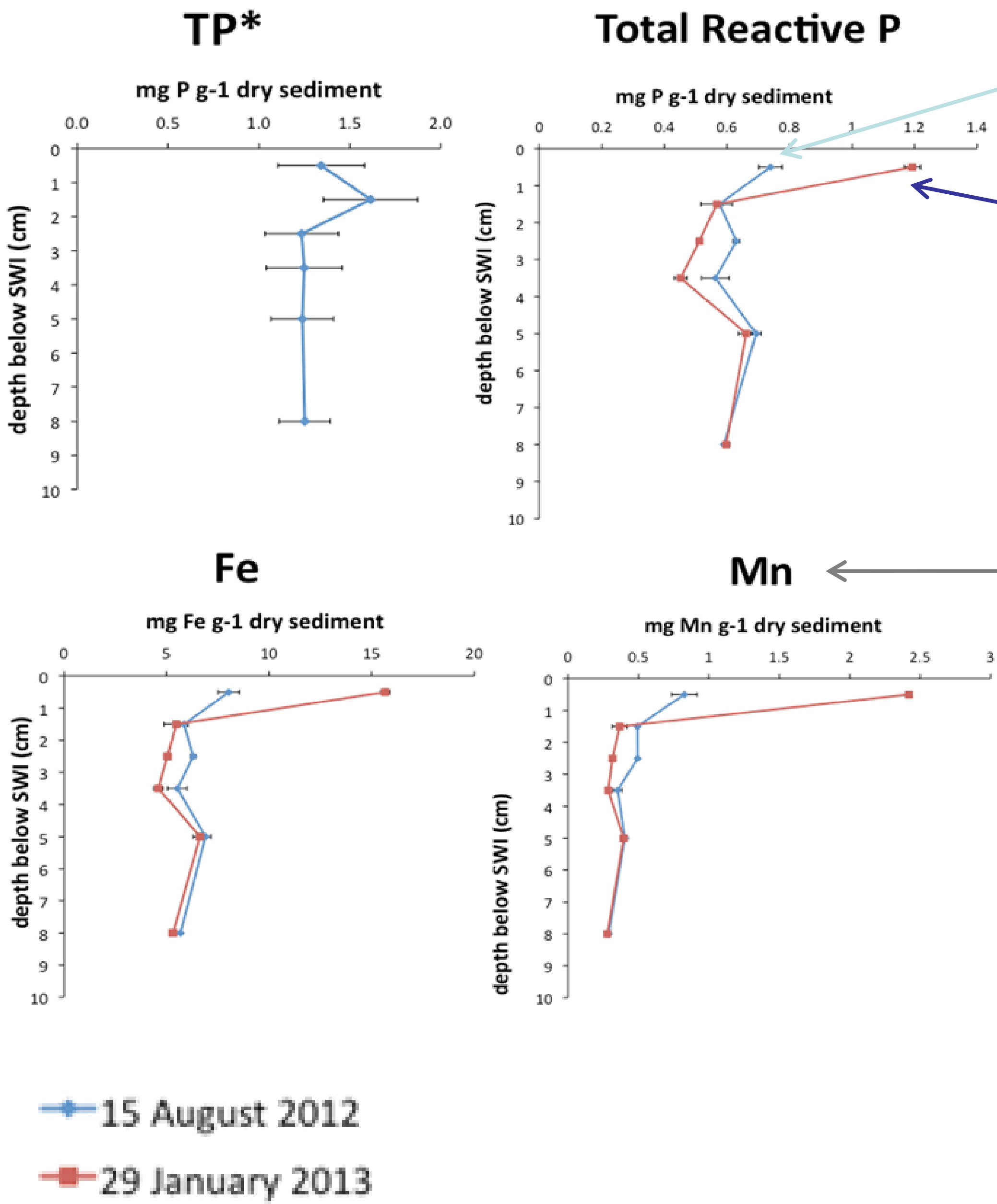
Bioavailable and Enzyme-Labile Phosphorus by Enzyme Hydrolysis Method


31-P NMR % NaOH-EDTA-P
Enzyme Hydrolysis % NaOH-EDTA-P
0%
20%
40%
60%
80%
100%
BLOOM STAGE
TIME
11 Oct. 2007
(No Bloom)
20 May 2008
(Pre-bloom)
29 July 2008
(Bloom onset)
29 Aug. 2008
(Peak bloom)
1 Oct. 2008
(Post-bloom)
0-1
1-2
2-3
3-4
4-6
6-10

Unique bioavailable P profiles in Missisquoi Bay sediments related to bloom stage







Mobilization in summer

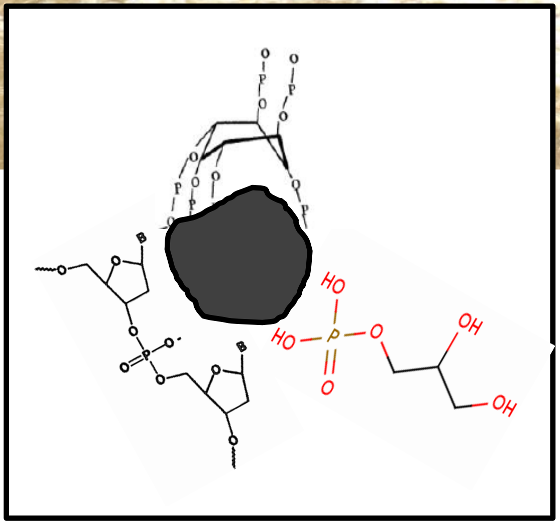
Accumulatio n in winter

Correlation with metals

Cor (P, Fe) = 0.97
Cor (P, Mn) = 0.89

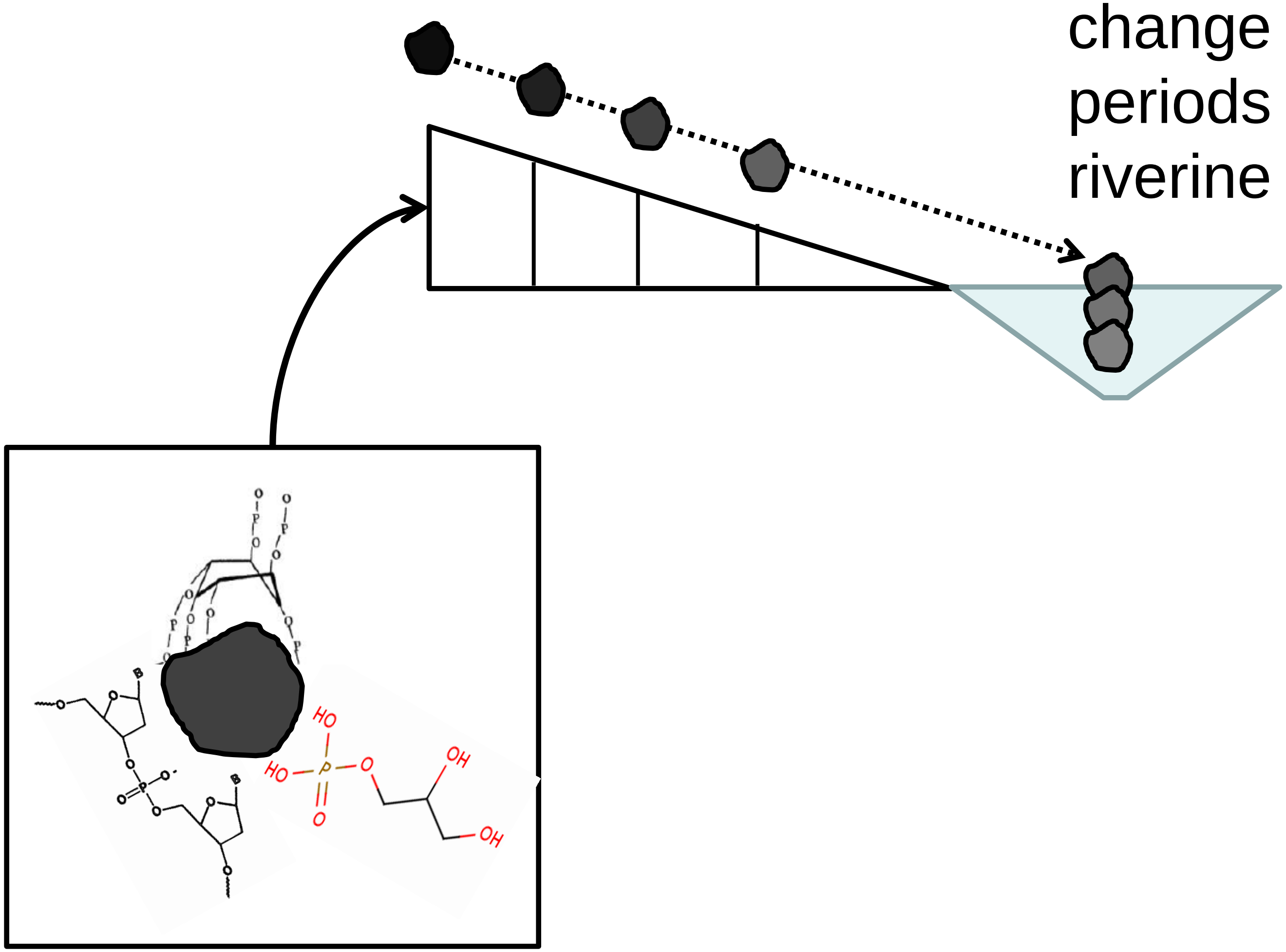
Seasonal changes in P accumulation and release from sediments

Particle-Bound Phosphorus Bioavailability in Missisquoi Basin Streams

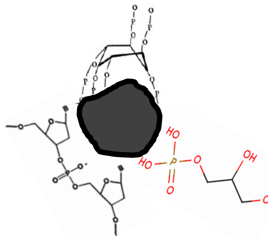


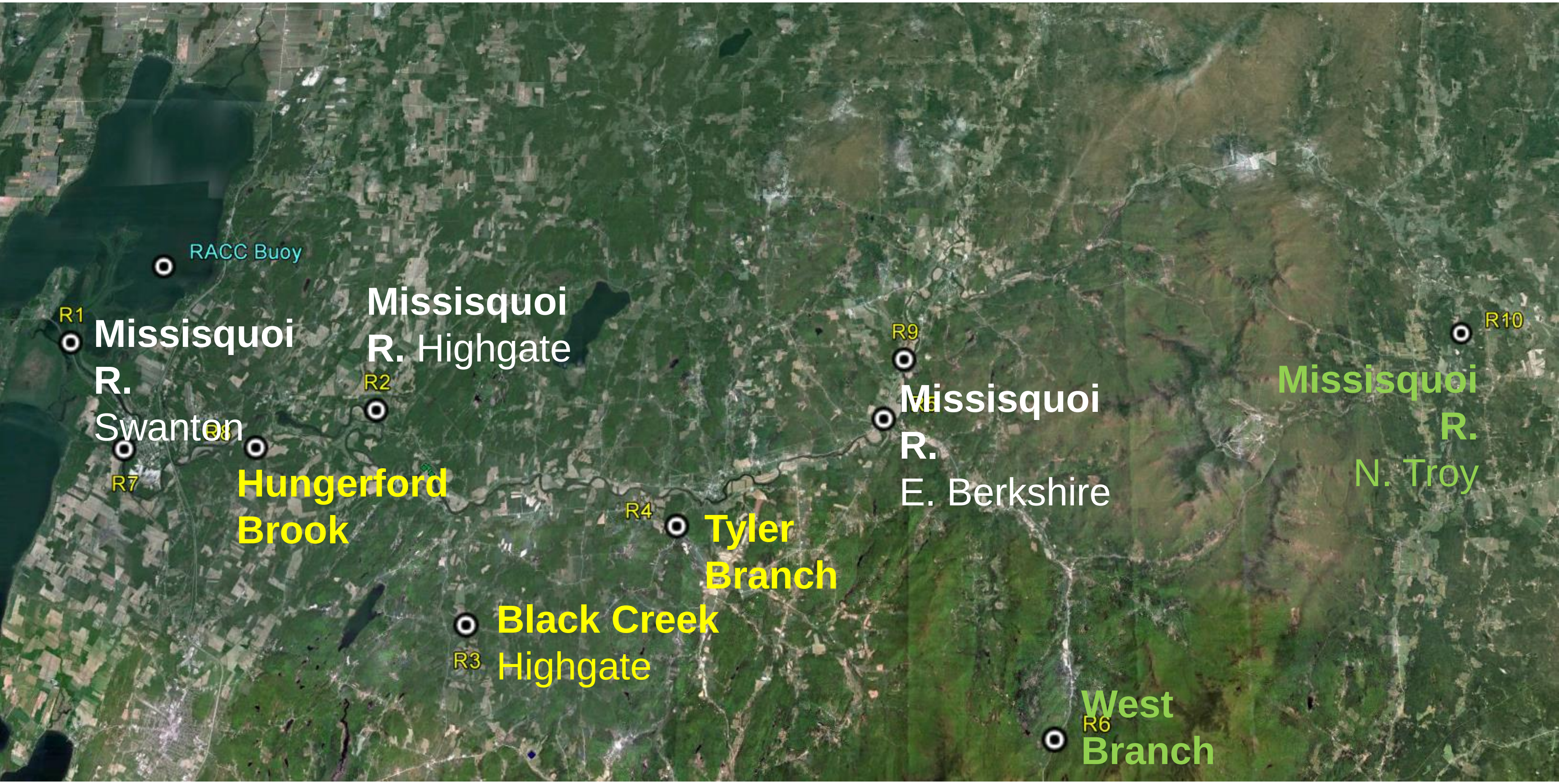
What is the spatial variability of particulate P bioavailability within the Missisquoi

How does this change during periods of high riverine discharge?

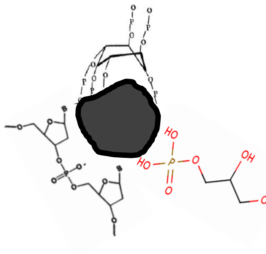


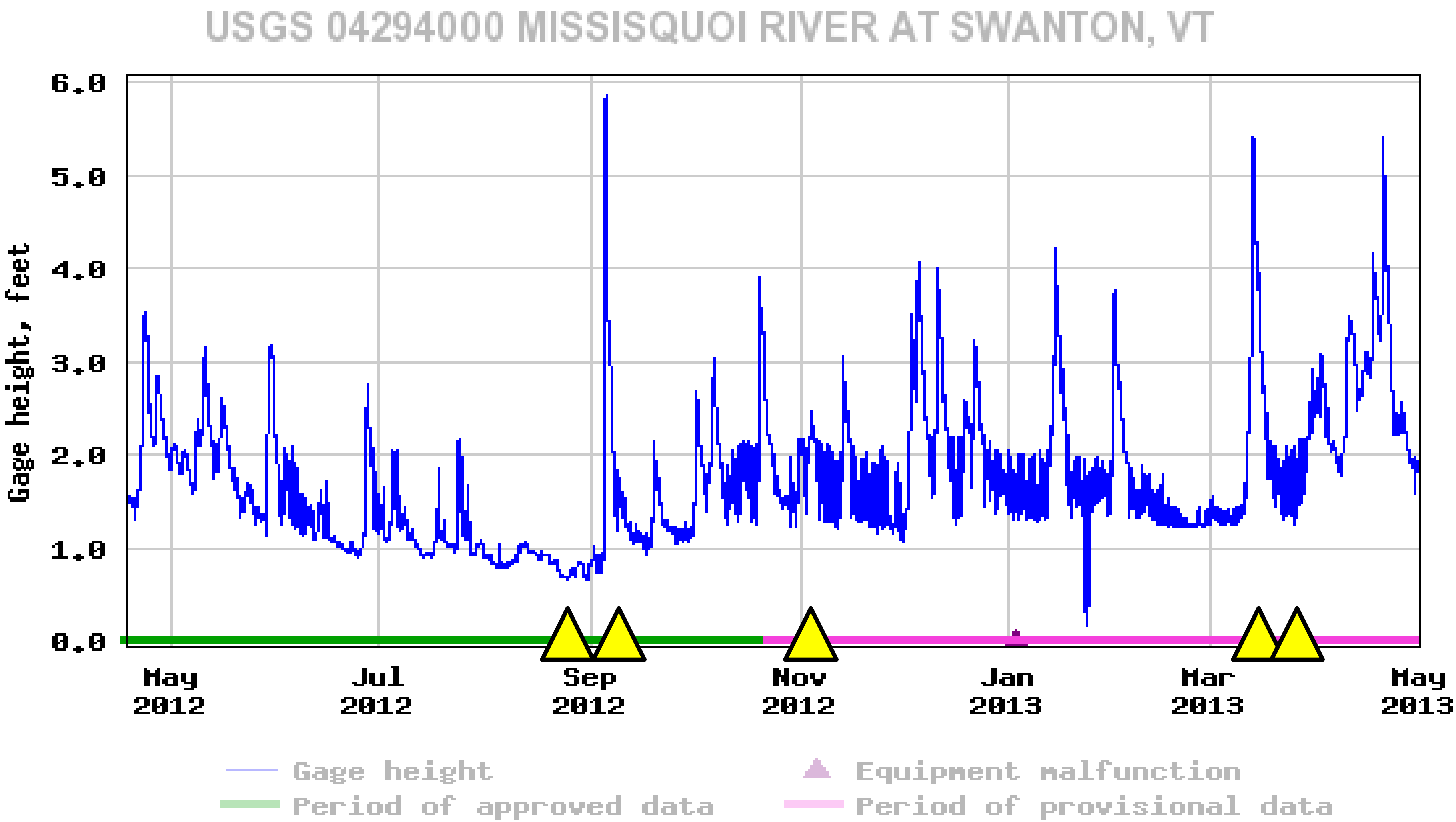
Hydrologic Transect and End Member Locations in Missisquoi Basin



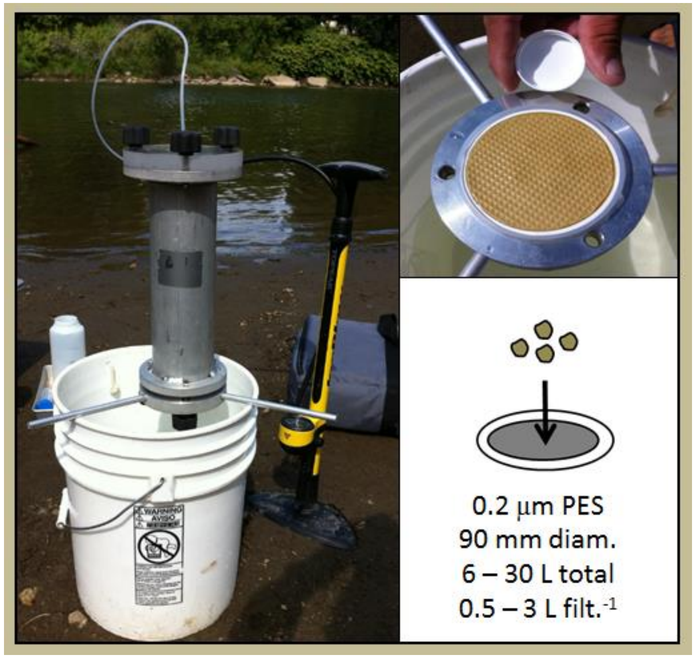


Baseline and Storm Flow Sampling 2012-2013

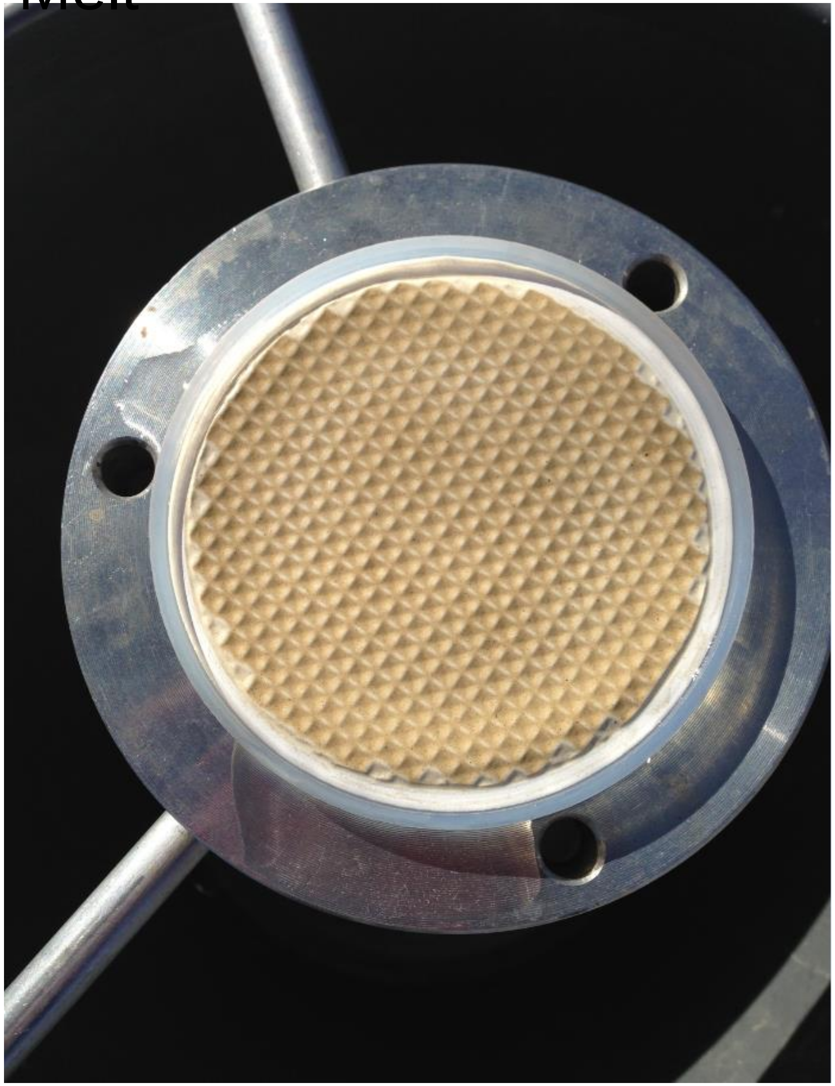




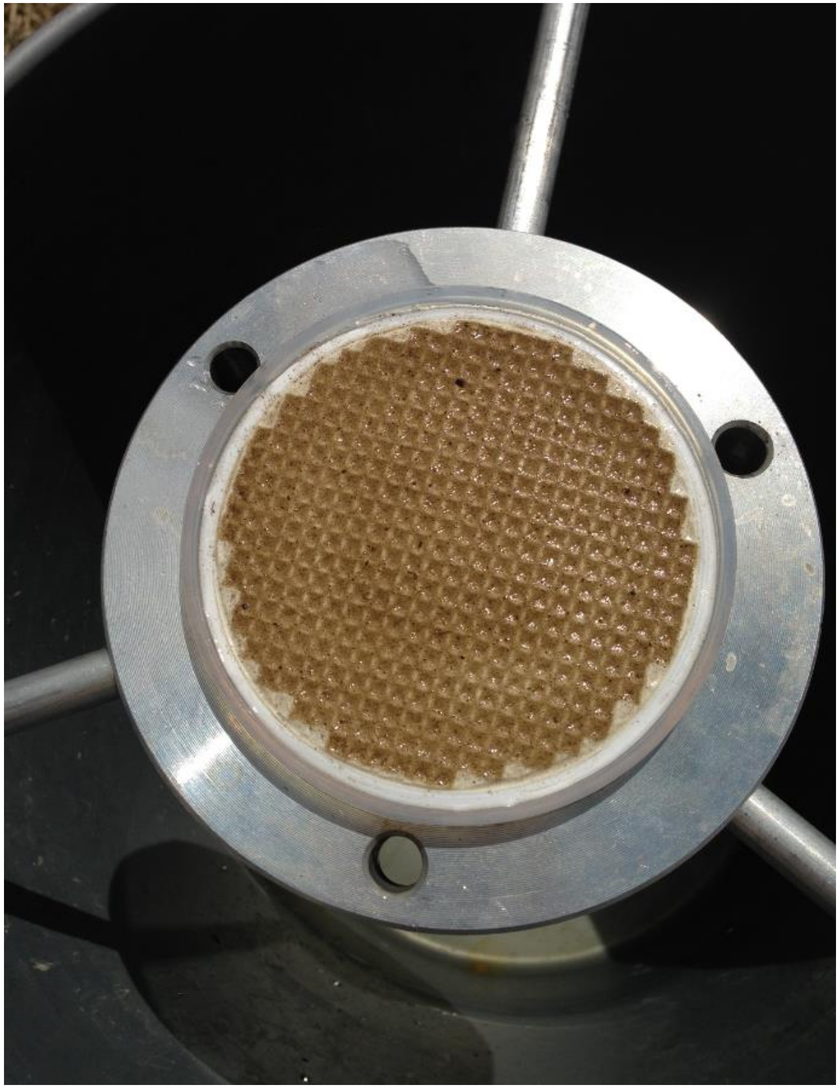
Particulate Phosphorus Collection



Missisquoi River Particulates 17 April 2013, Peak Snow Melt



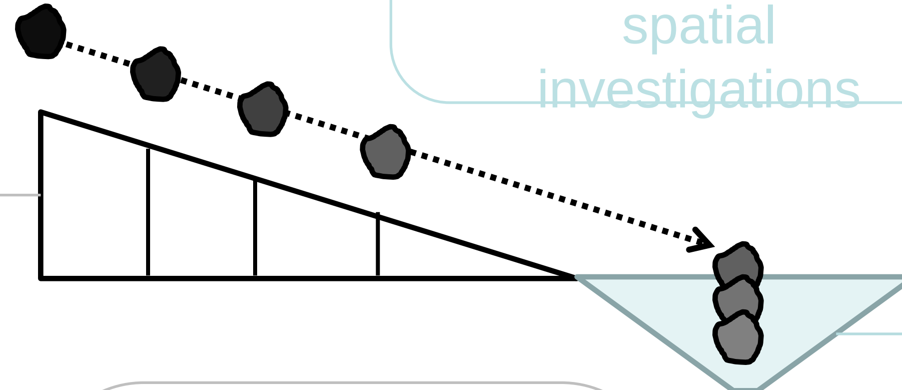
Swanton, VT



East Berkshire, VT

2013 Efforts

Monthly monitoring of sediment P dynamics and spatial investigations



Bioavailability estimates for stream particulates

Monthly base-flow and post-storm sampling

Load estimates for particulate P classes

Thank You!

Andrew Schroth

Jane Hill

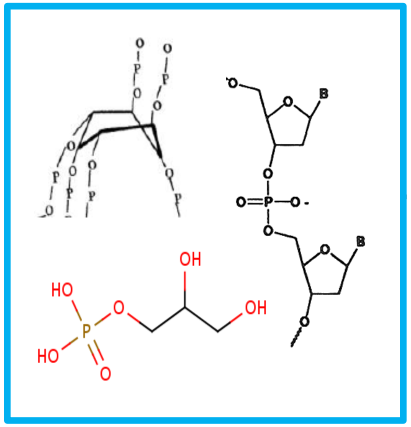
NATIONAL SCIENCE FOUNDATION

Vermont EPSCoR

RACC Research on Adaptation to Climate Change

Exogenous and Endogenous Inputs of Bioavailable Phosphorus to Missisquoi Bay

ORGANIC
Phosphorus

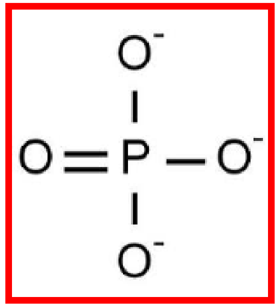


Potentially Bioavailable

Enzyme Hydrolysis

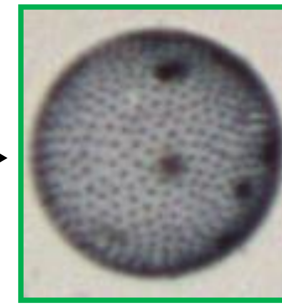
Conversion to Phosphate

INORGANIC
Phosphate



Directly
Bioavailable

Consumption

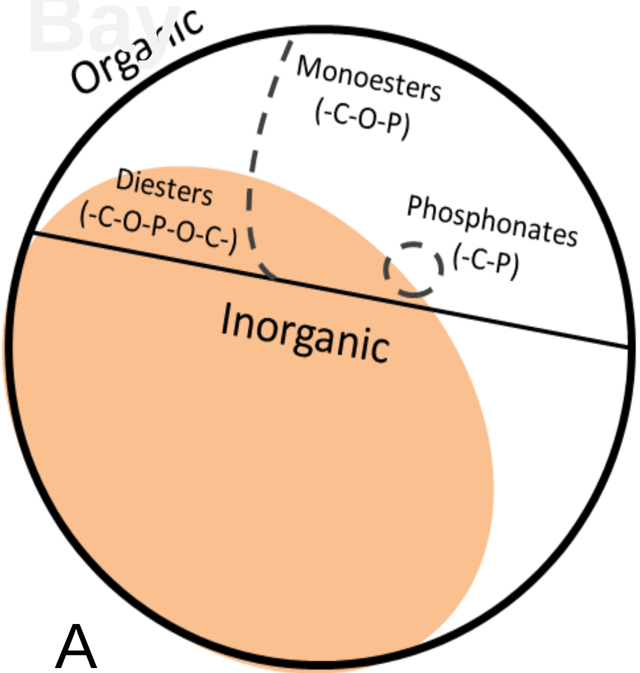


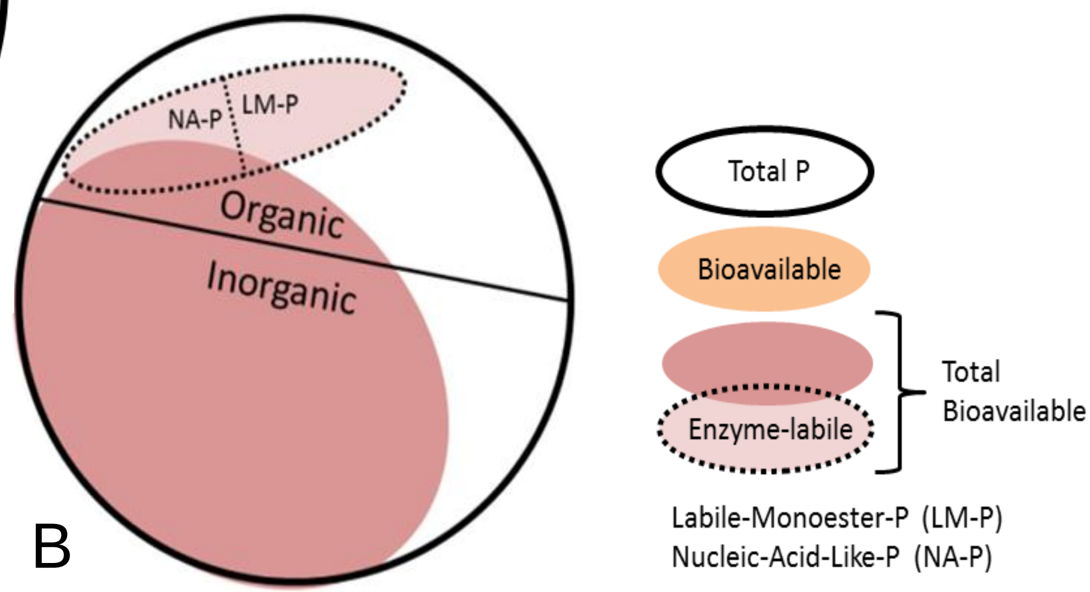
Primary producers
e.g. blue-green algae

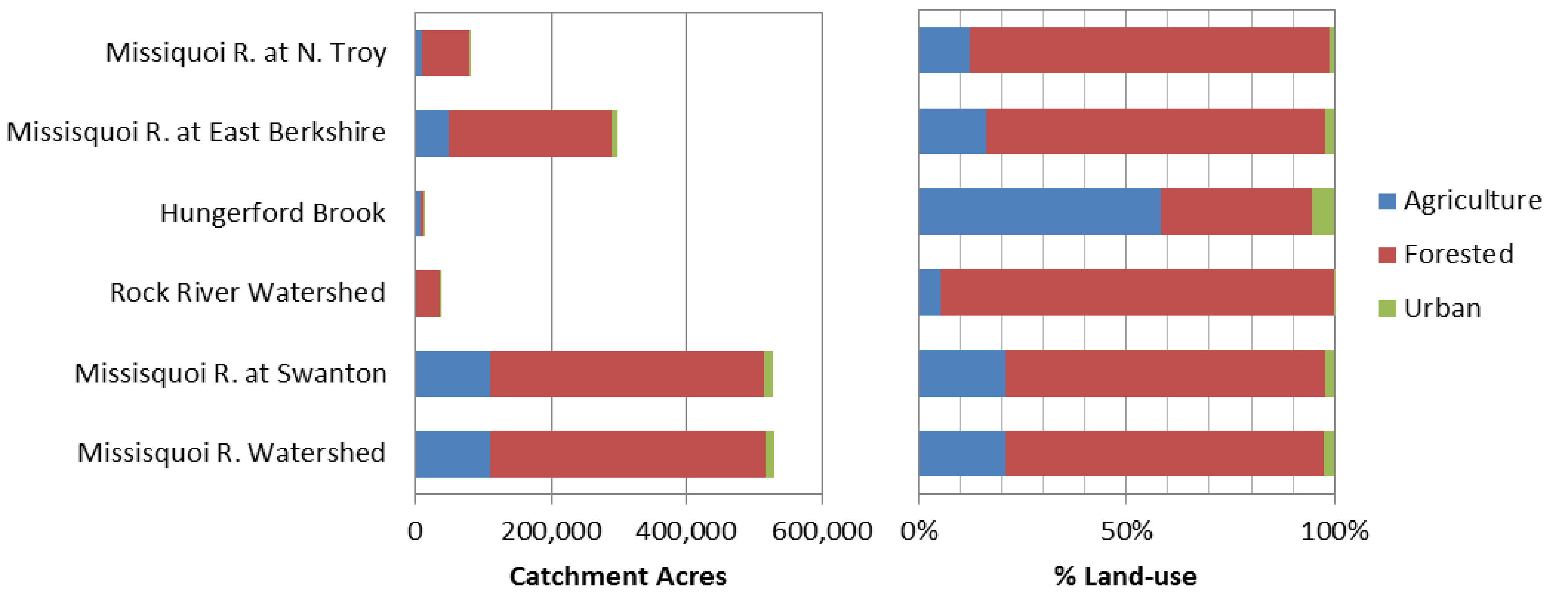
Microcystis courtesy J. Stockwell

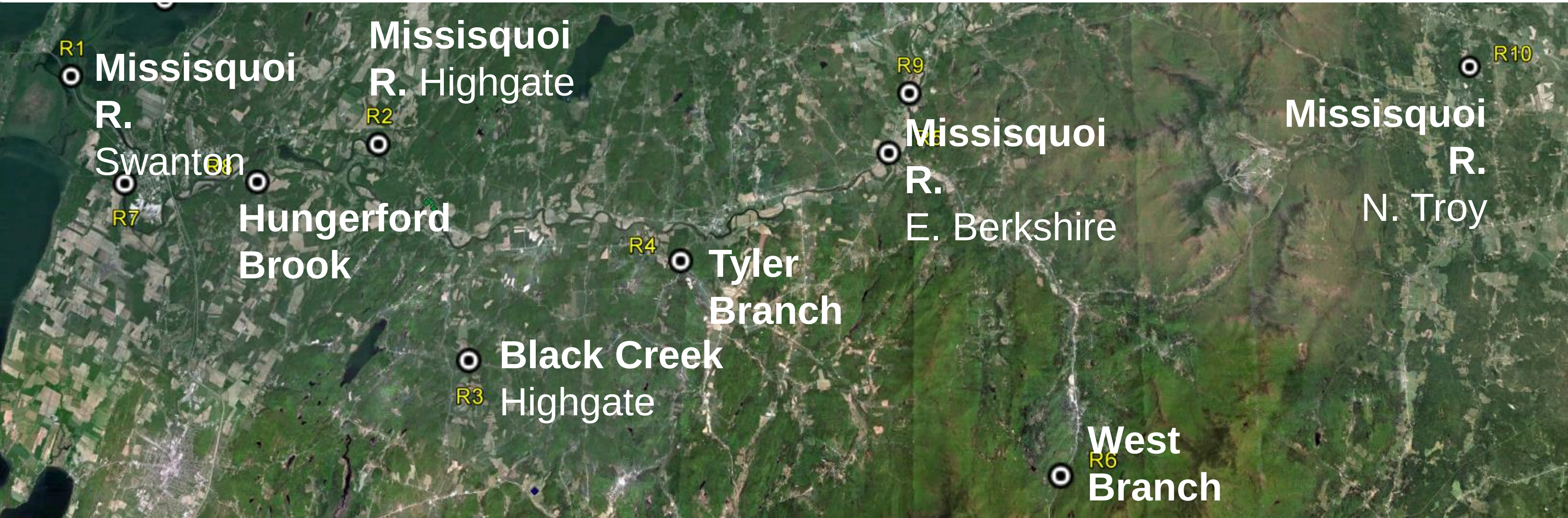
Exogenous and Endogenous Inputs of Bioavailable Phosphorus to Missisquoi Bay

Phosphorus Class Definitions and Relative Bioavailability






Missiquoi R. at N. Troy
Missisquoi R. at East Berkshire
Hungerford Brook
Rock River Watershed
Missisquoi R. at Swanton
Missisquoi R. Watershed
0
200,000
400,000
600,000
Catchment Acres
0%
50%
100%
% Land-use
Agriculture
Forested
Urban


R1
Missisquoi R. Swanton
R8
R7
Missisquoi R. Highgate
R2
Hungerford Brook
R4
Tyler Branch
Black Creek Highgate
R3
R9
Missisquoi R. E. Berkshire
R10
Missisquoi R. N. Troy
West Branch
R6