Vermont EPSCoR

Experimental Program to Stimulate Competitive Research

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

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Peter Isles

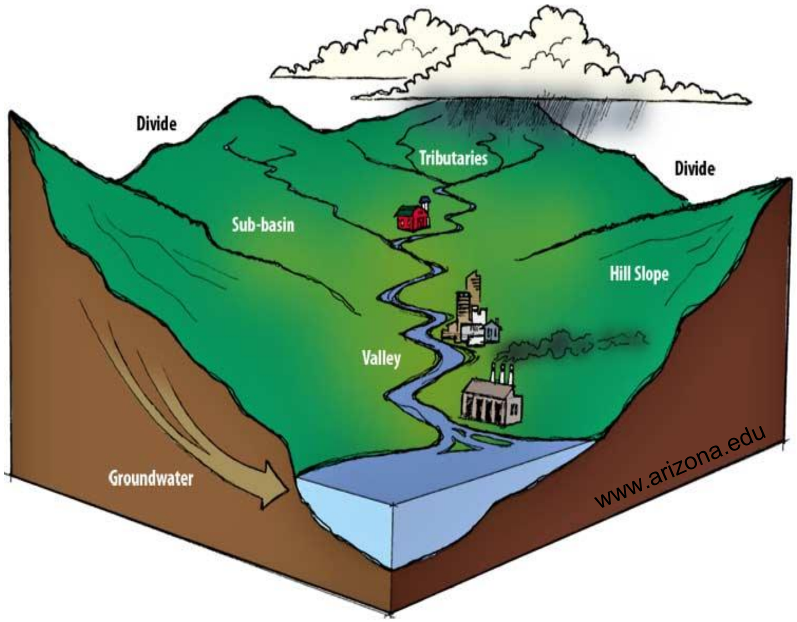
Question 1

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

Internal

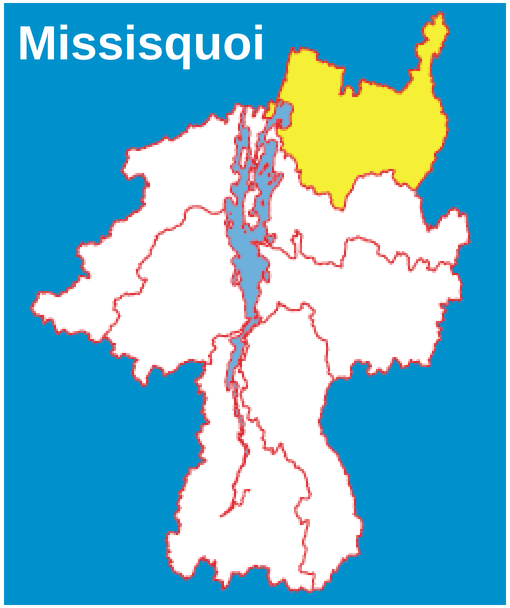
External

Approach to Question 1



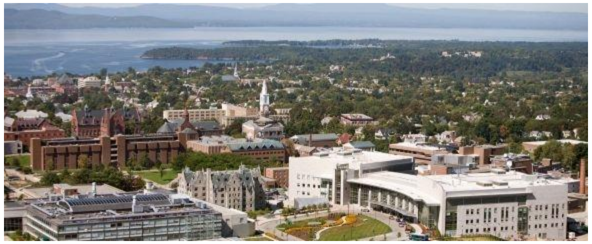
- What are the important sources of nutrients & sediment to the lake?
- How do land use and climate affect the nature and strength of these sources?
- How are nutrients and sediments transformed in transport to the lake and within the lake?
- How do the loadings of these materials affect lake processes?

Focus Watersheds



Agriculture: runoff, groundwater, soils, stream bank erosion

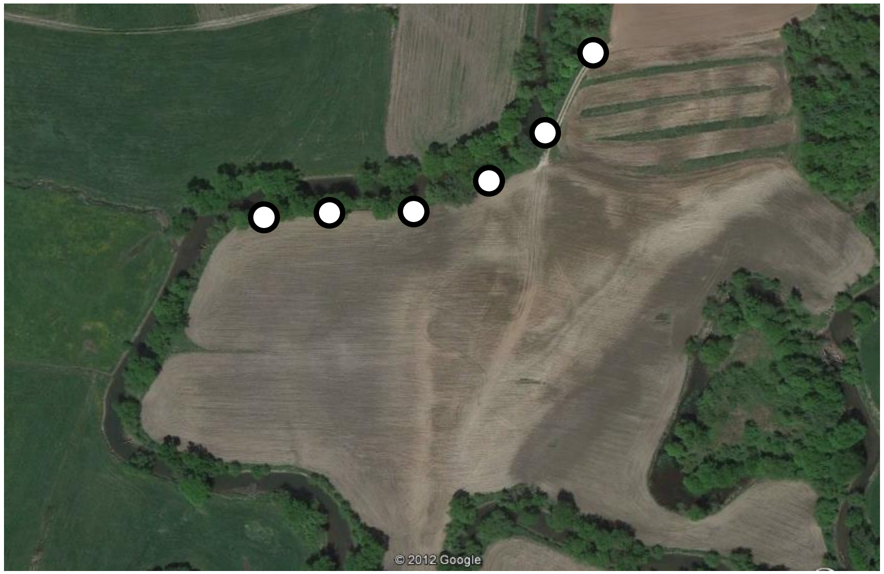
Forested: soils, groundwater, roads, channel migration, erosion



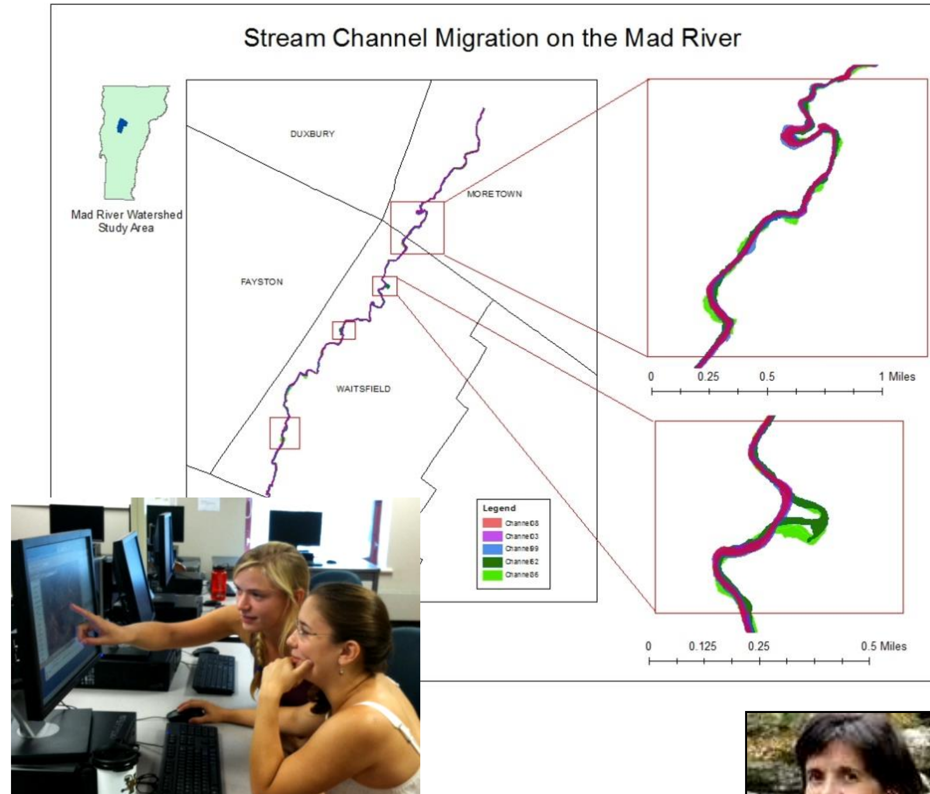
Urban: stormwater runoff, wastewater, stream erosion

What we have accomplished?

Source area characteristics



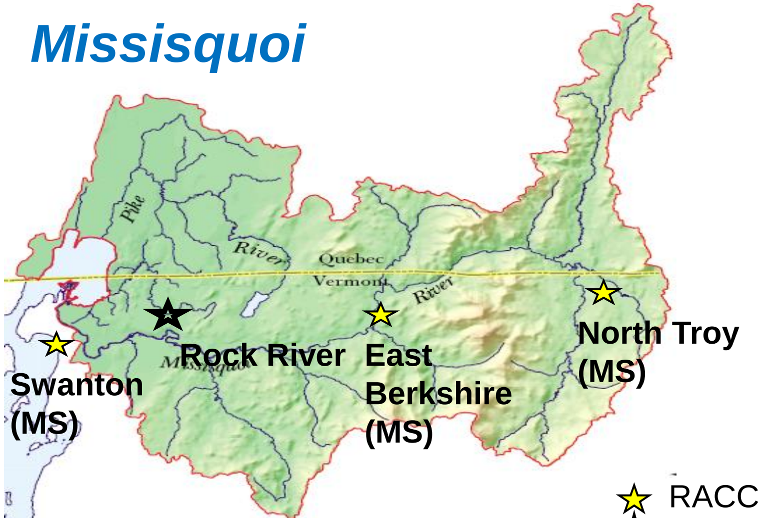
N/P Distribution across riparian zones



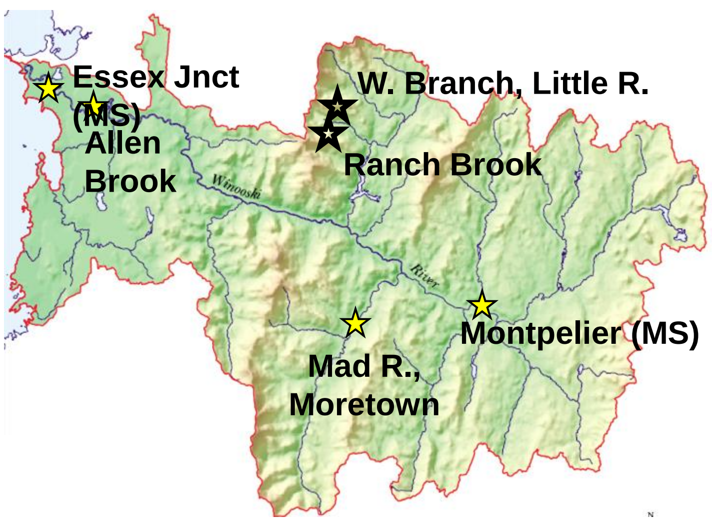
What we have accomplished?

Instrumented key sub-watersheds

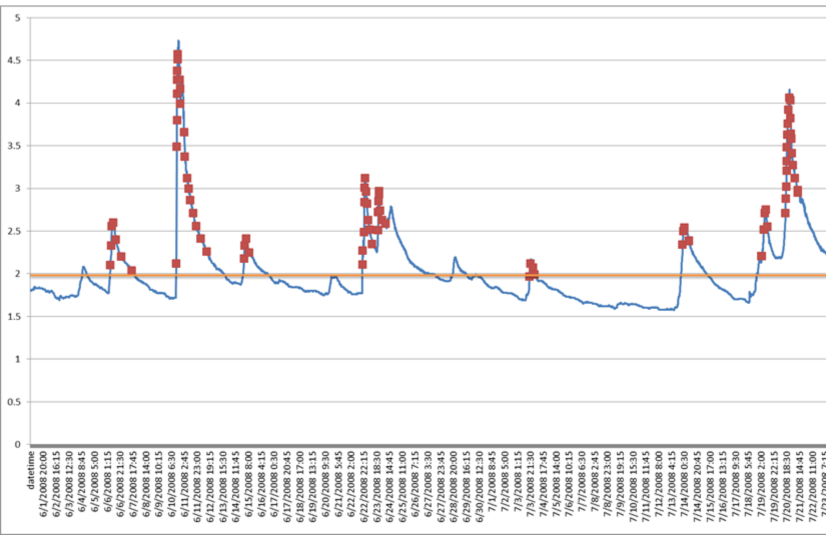
Missisquoi



Winooski



Capture Storm Event Biogeochemical Evolution with Automated Sampling



Modify ISCO Programs for 2013 Effort

What we have accomplished?

Integrated water sampling & analysis network

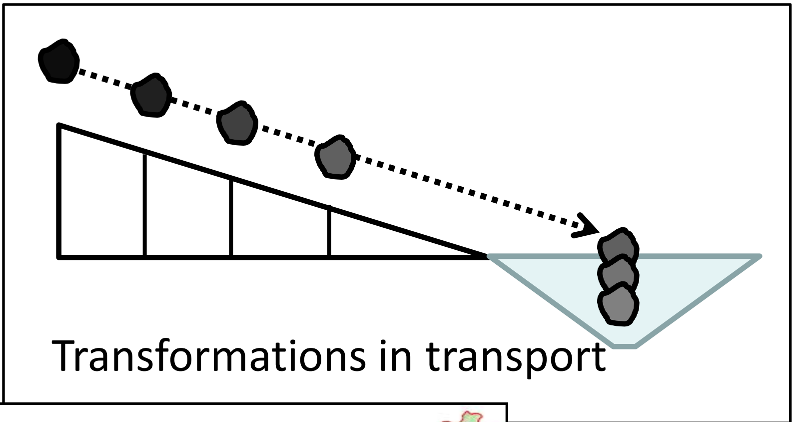
Johnson State College

St. Michael's College

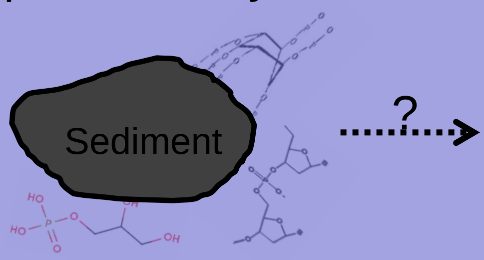
What we have accomplished?

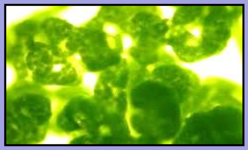
Characterization of P transformations in watershed and lake

- 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?



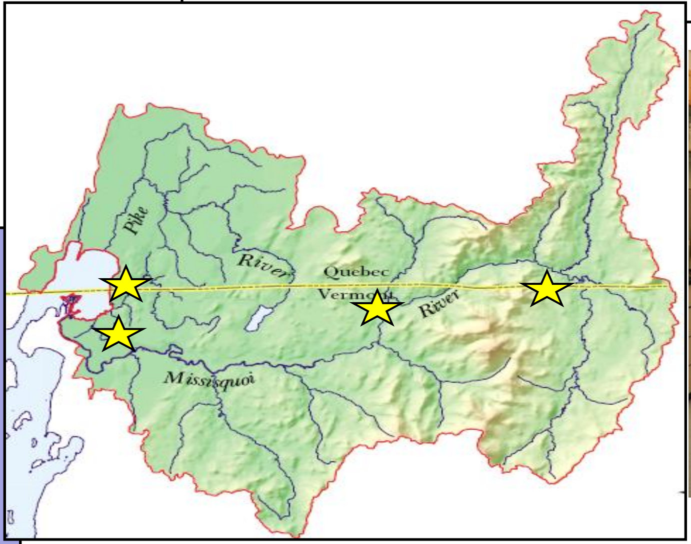
Sediment-Bound-P
Species Analysis

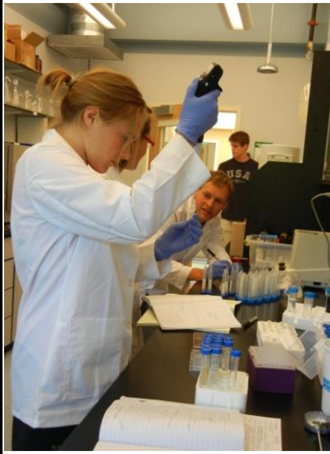




cyanobacteria

ENZYME HYDROLYSIS
Solution ^{31}P NMR Spectroscopy





Future Work: Partitioning P Sources

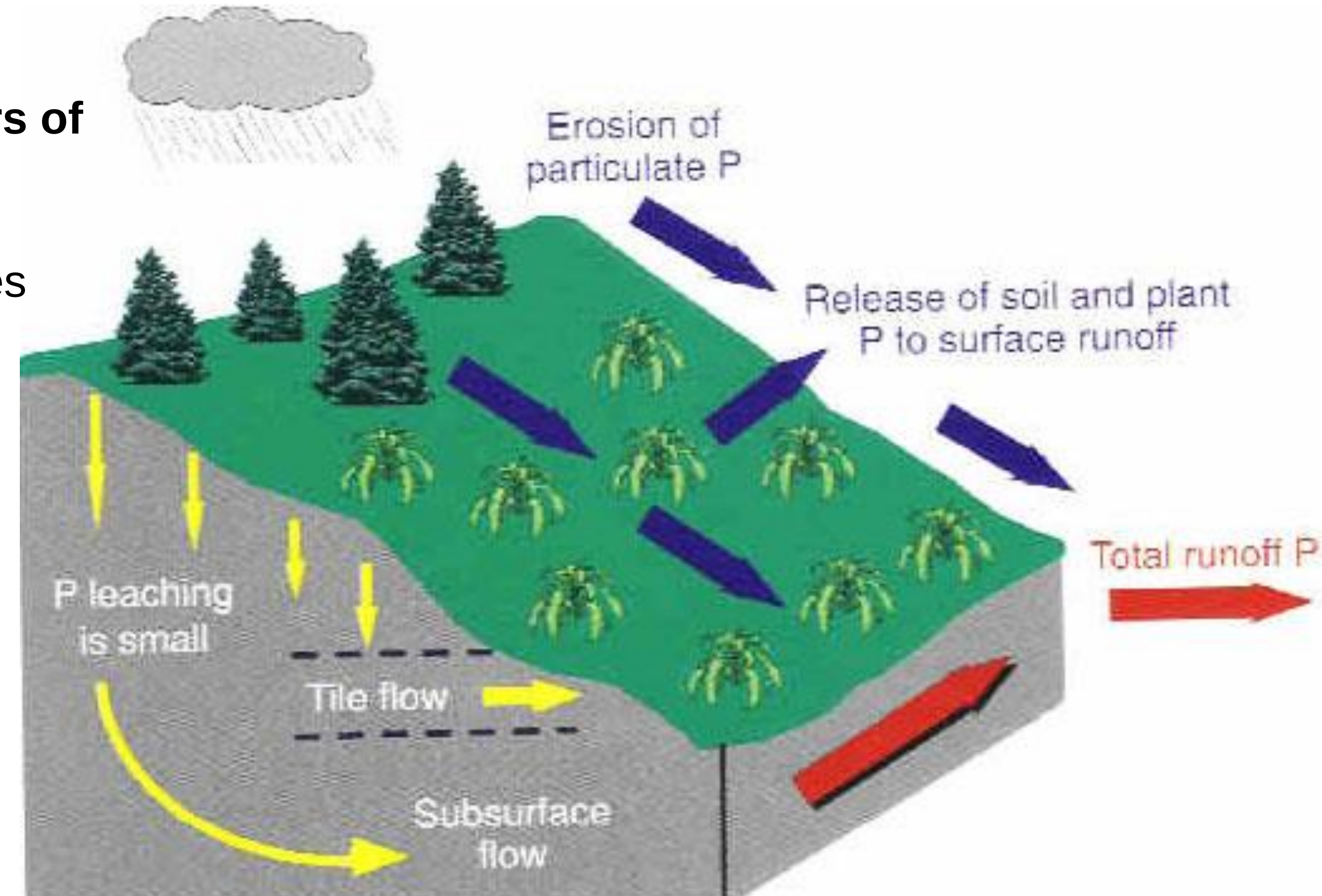
Small Watershed and Time-Series Analyses






Employ Novel Tracers of Process and Source

- Short-Lived Isotopes
- PO_4 Isotopes
- P-Speciation
- Metal Partitioning and Speciation



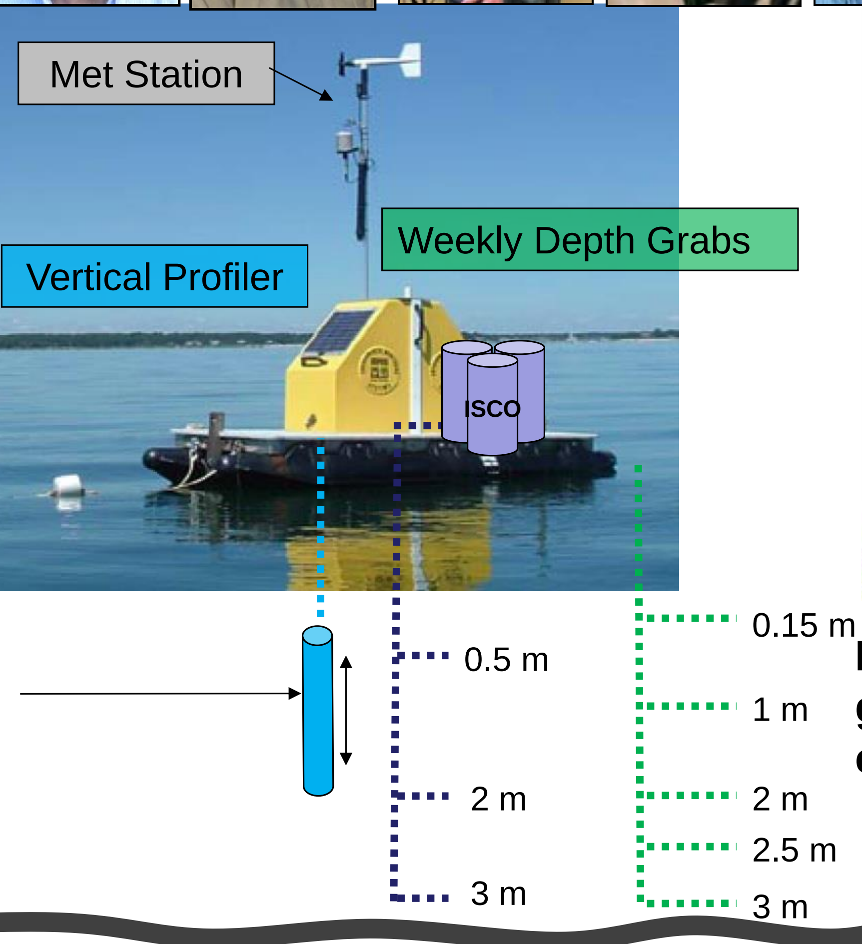
What we have accomplished?

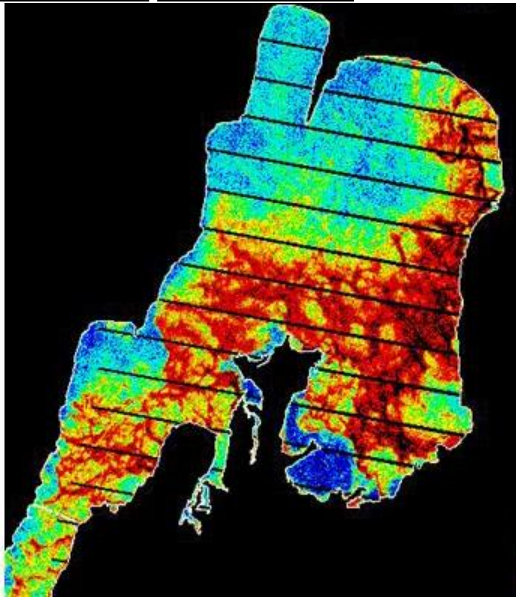
Missisquoi Bay Advanced Environmental Monitoring Systems











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

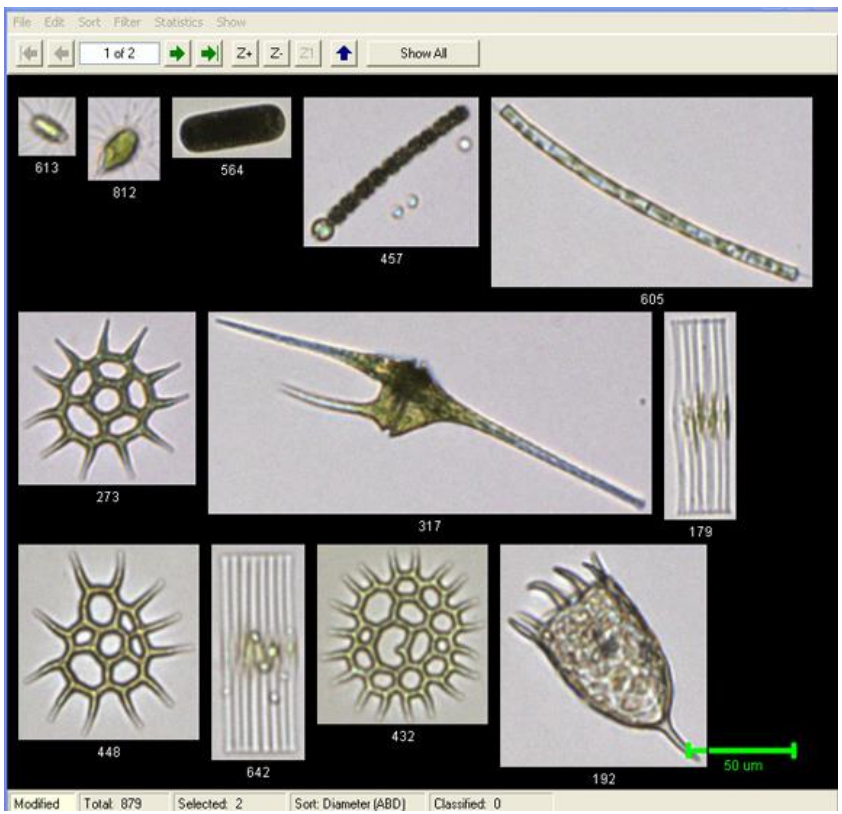
Phytoplankton

Zooplankton

Benthic invertebrates

Aquatic plants

Fish

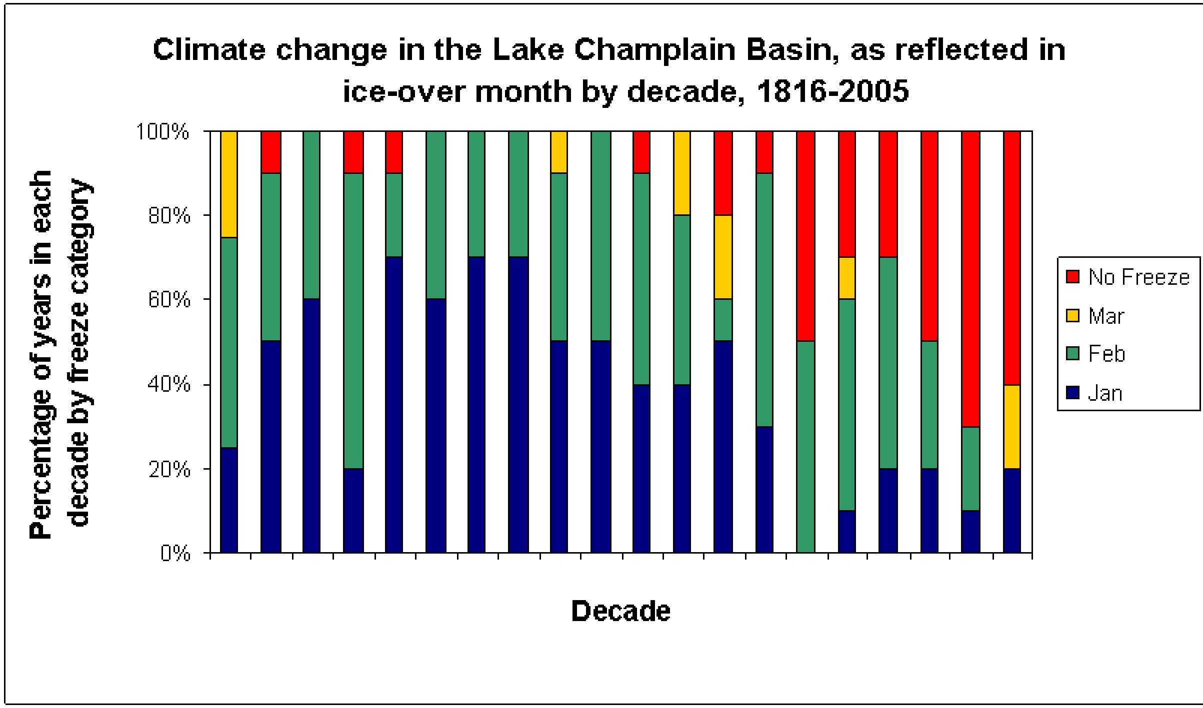


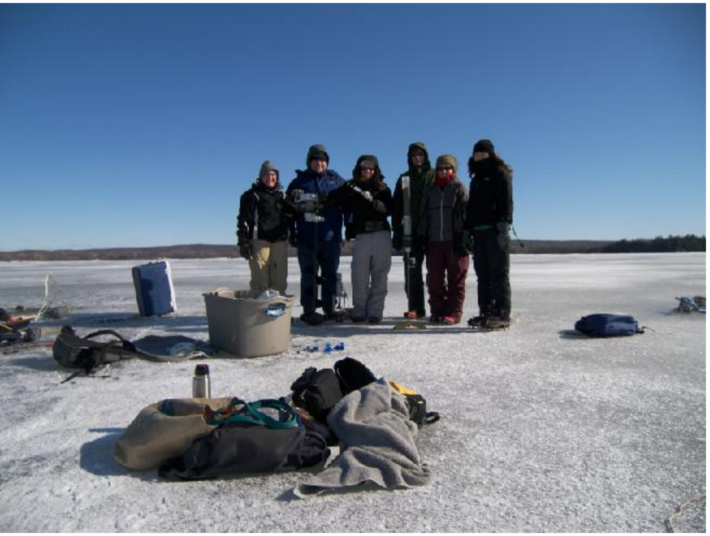
FlowCAM coming to UVM.

What have we accomplished?

Winter Through Ice Sampling

Duration and extent of ice cover is decreasing!



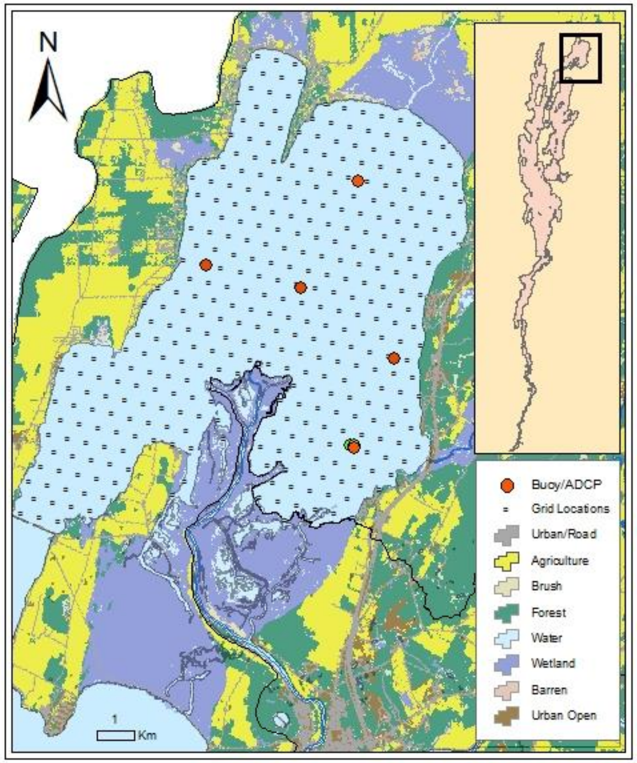


How does ice cover affect lake biology, physics and chemistry?

2013 Winter grab sampling of water profile chemistry/biology and sediment cores

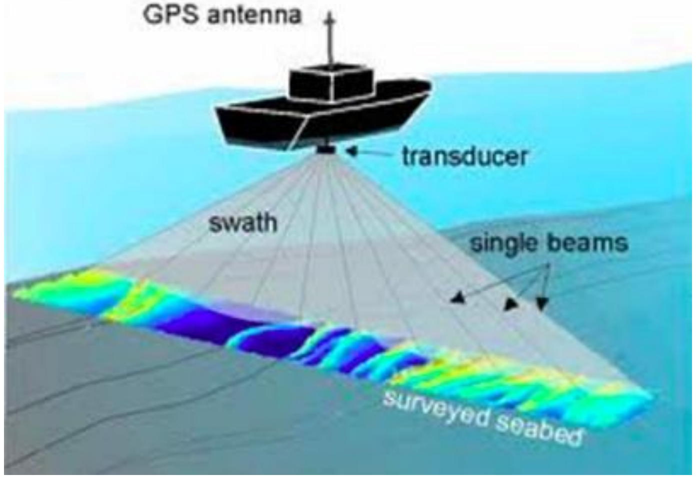
Hydrodynamic array under ice

New Lake Efforts for 2013 Field Season



Bay-Wide Spatial Analyses (Midd, SMC, UVM)

- Increased spatial sampling at different bloom stages
- Bay wide sediment transport analyses, sediment collection and benthic community studies
- Bathymetric mapping of Missisquoi Bay



Real-Time Data Driven Studies (UVM)

- Time series sediment cores
- Diel nutrient/metal cycling studies during peak bloom
- micro-observatory sensor deployment at SWI to study redox chemistry
- New Sensors-High freq DOC, SRP, NO_3^-

Phytoplankton Resource Limitation During the 2012 Bloom

Peter Isles

Q1 PhD Student

RACC

Research on Adaptation to Climate Change

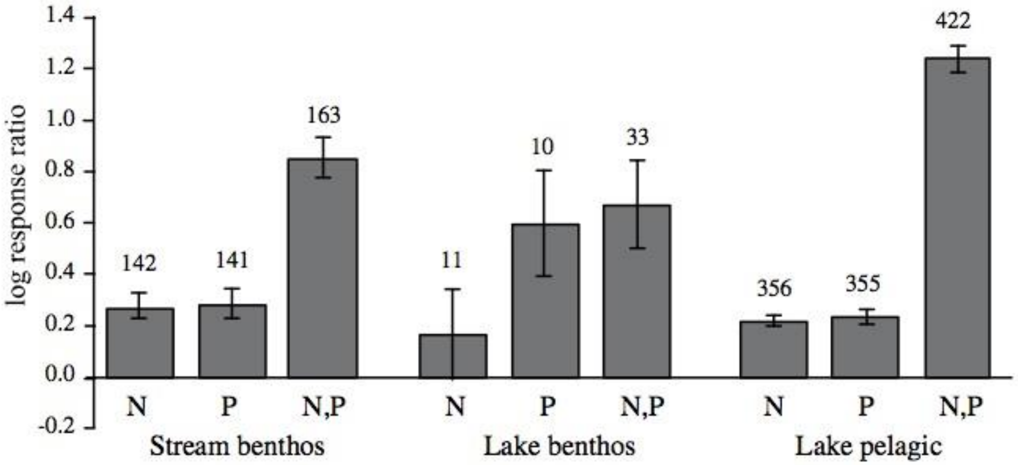
Vermont EPSCoR

Background: Harmful Algae Blooms

- Increasing problem worldwide (Paerl 2009)
- Both coastal waters and freshwaters
- In freshwater, HAB's are usually composed of **cyanobacteria** (blue green algae)
  - May produce liver and neuro-toxins
  - Noxious odors, irritants
  - Negative ecosystem consequences
- Caused by increases in external nutrient inputs and temperature

Background: Nutrient Limitation in Lakes

- Von Leibig's "Law of the minimum" (1840)
- Redfield Ratio, 1934
  - C:N:P ≈ 106:16:1
- 1970's: consensus that P is limiting in Lakes
- Recent results: Co-Limitation



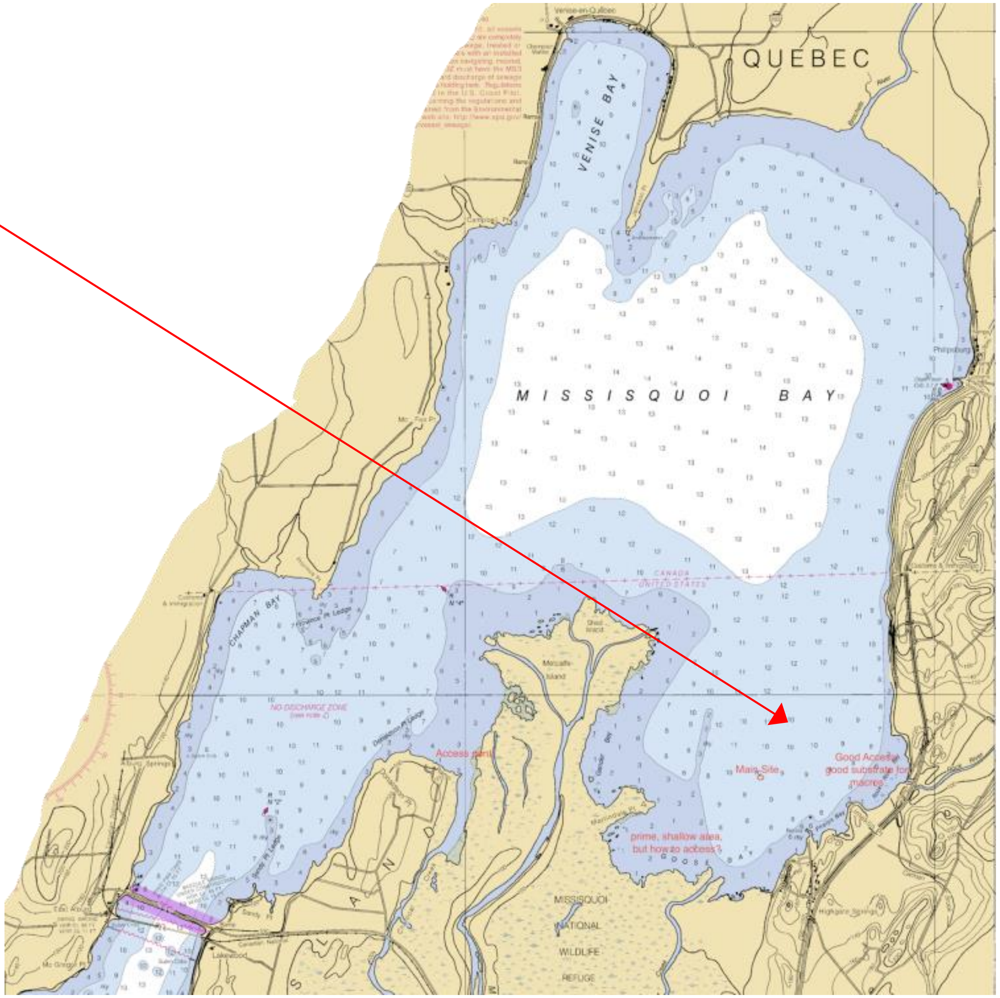
Sterner 2008

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
  - Recycling of nutrients in the water column and at the sediment surface
  - Mechanisms driving release of benthic nutrients

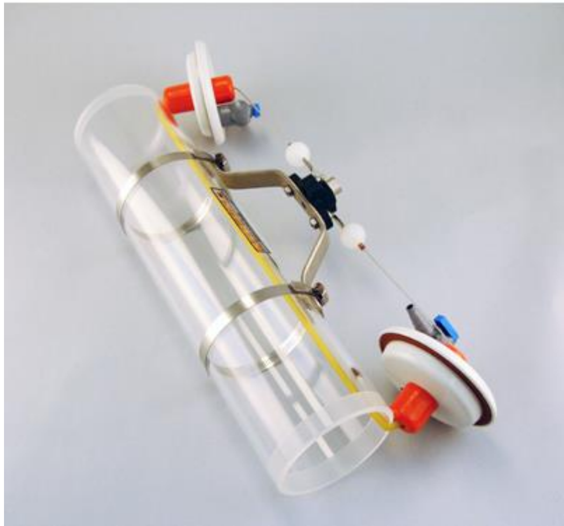
Sampling Strategy: Sample Site

- Water depth ~ 3m
- SE portion of bay insulated from S, E, W winds
- Site of the most intense BGA blooms

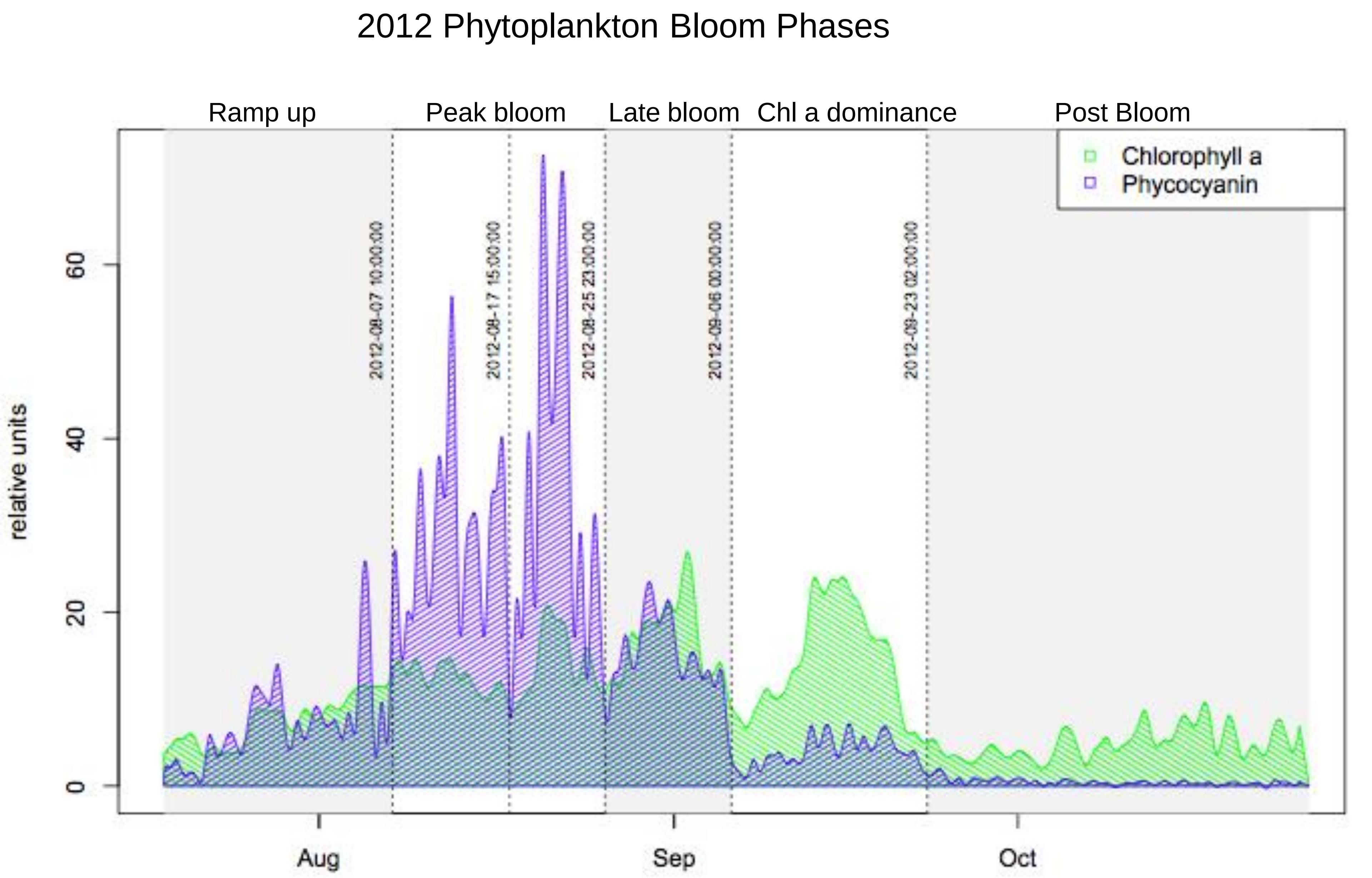


Sampling Strategy:

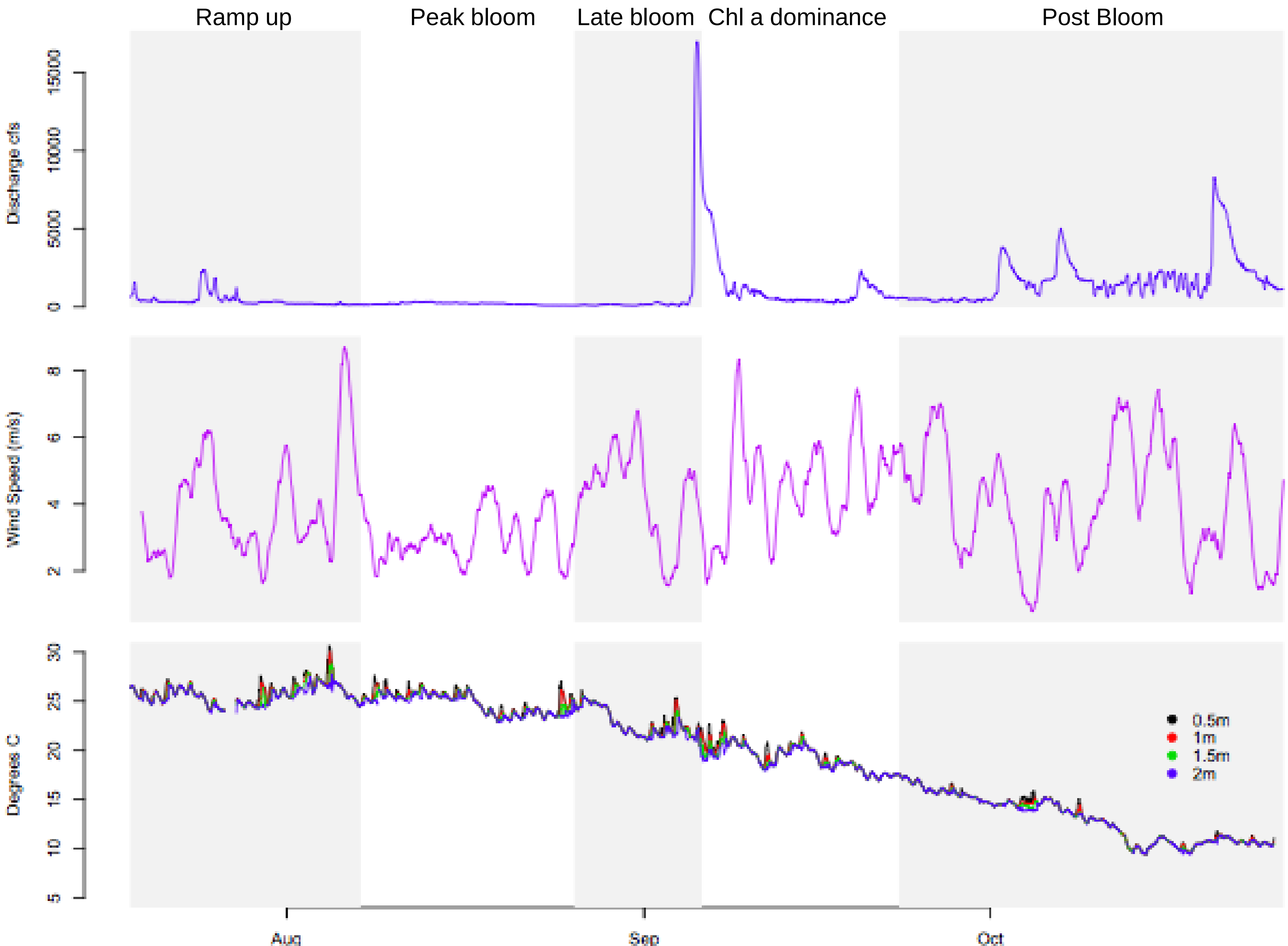
- Hourly:
  - Sonde measurements (DO, pH, turbidity, temp, phycocyanin, chlorophyll *a*) (5 depths)
  - Weather, river variables (temp, wind, discharge, water level)
- Every 8 hours (5am, 1pm, 9pm)
  - Total nitrogen, total phosphorus, total metals (3 depths)
- Weekly
  - SRP, TDP, NO_3^-, NH_4^+, dissolved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



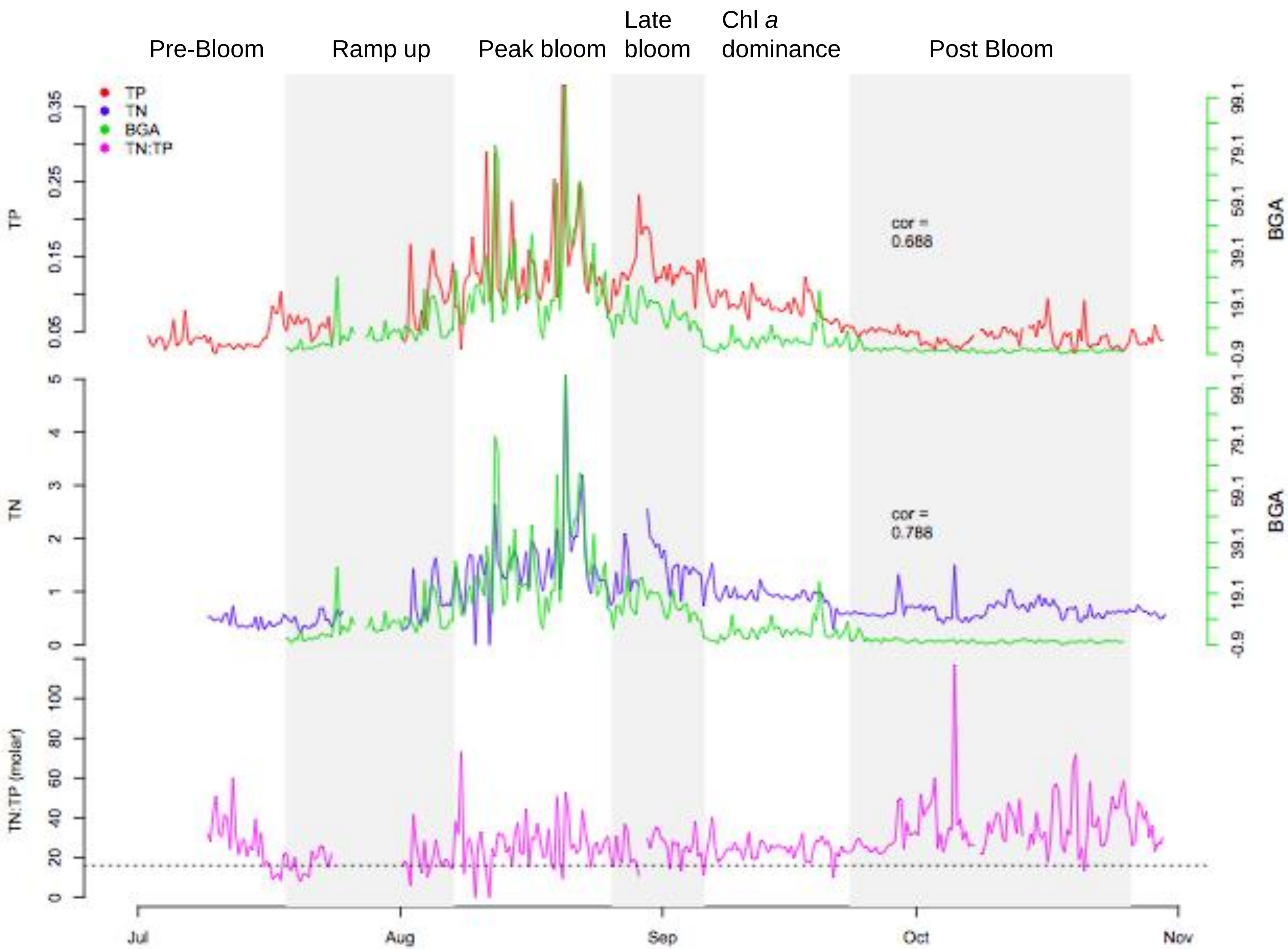
Data: Phytoplankton Dynamics



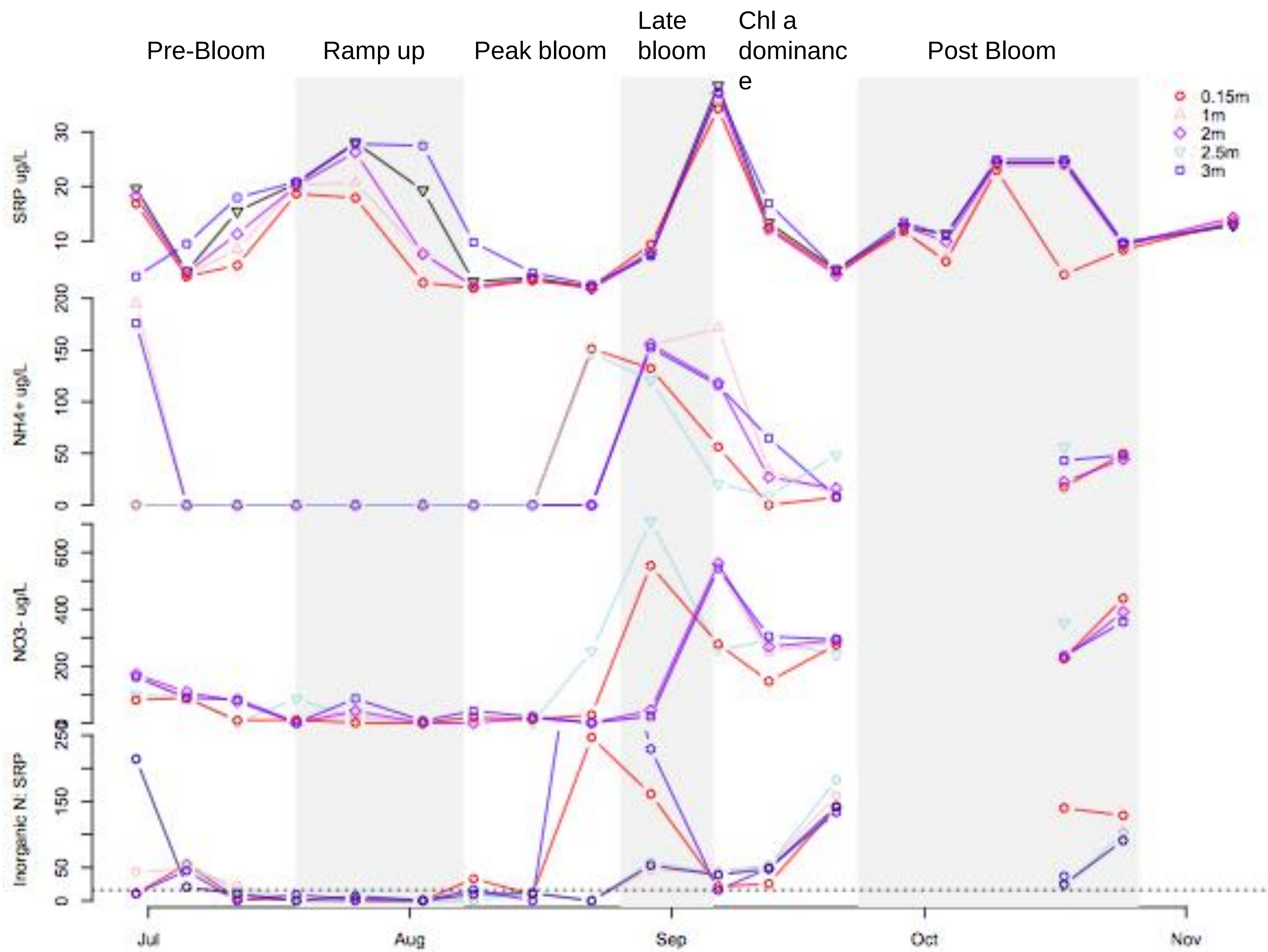
Data: Environmental Conditions



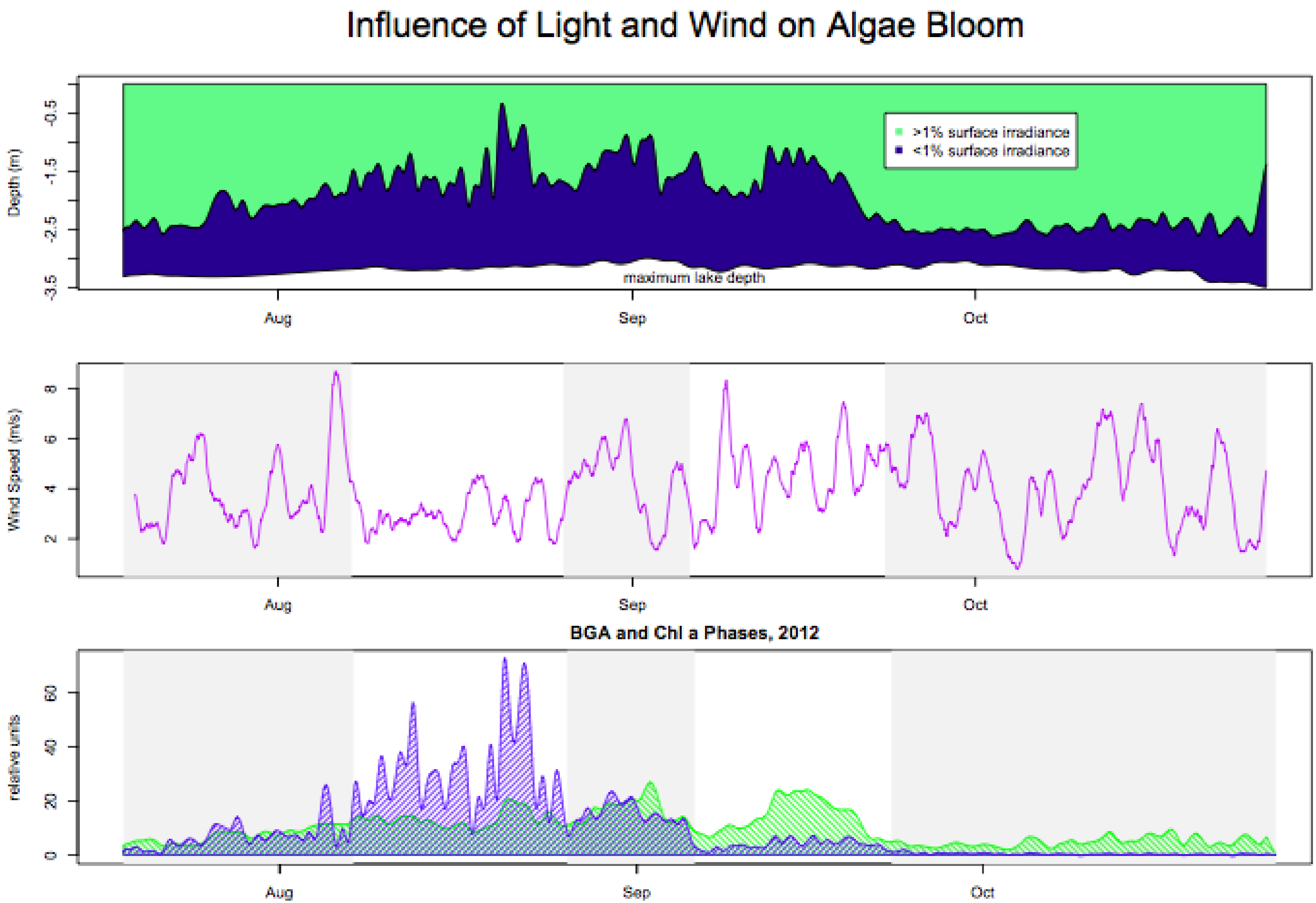
Total Nitrogen and Total Phosphorus



Available Nutrients



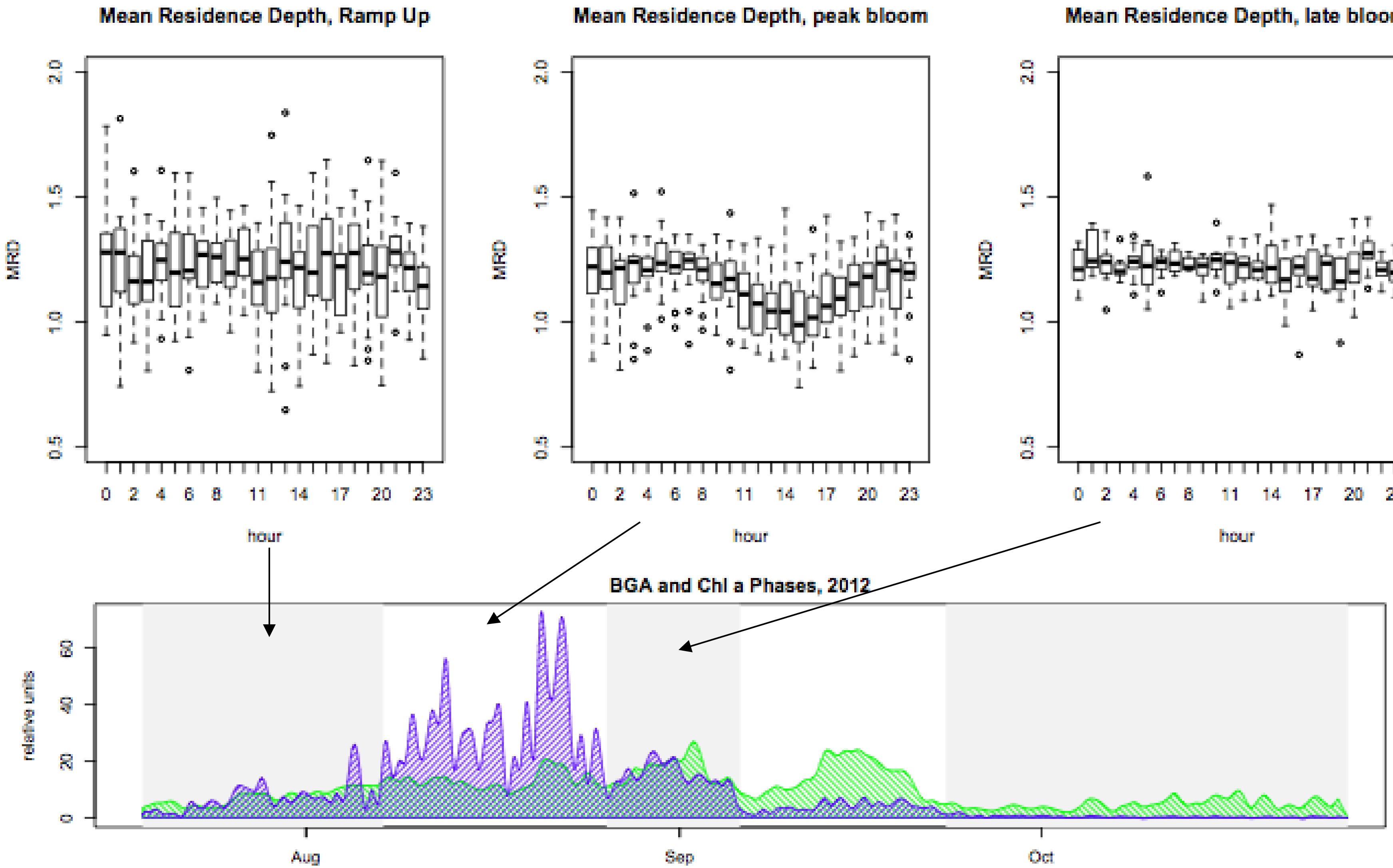
Light Limitation



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

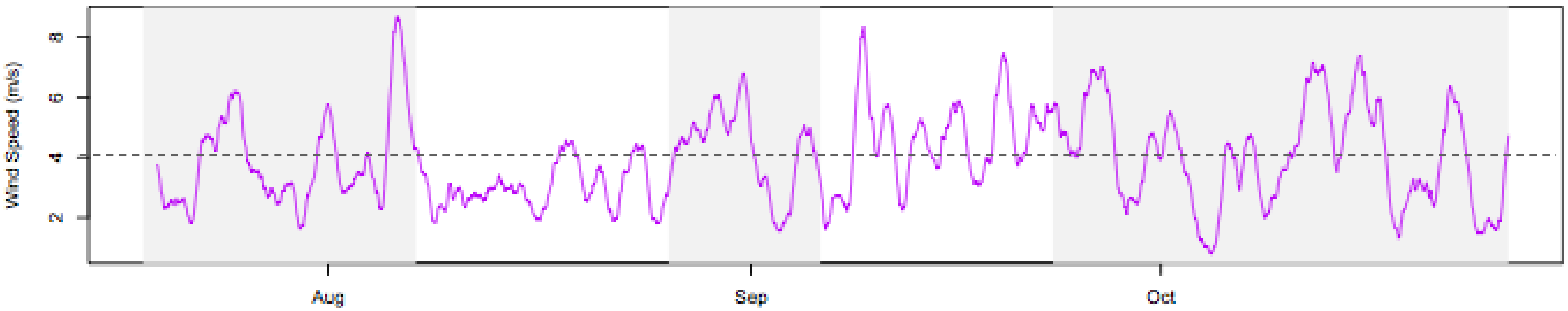
Light Limitation

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

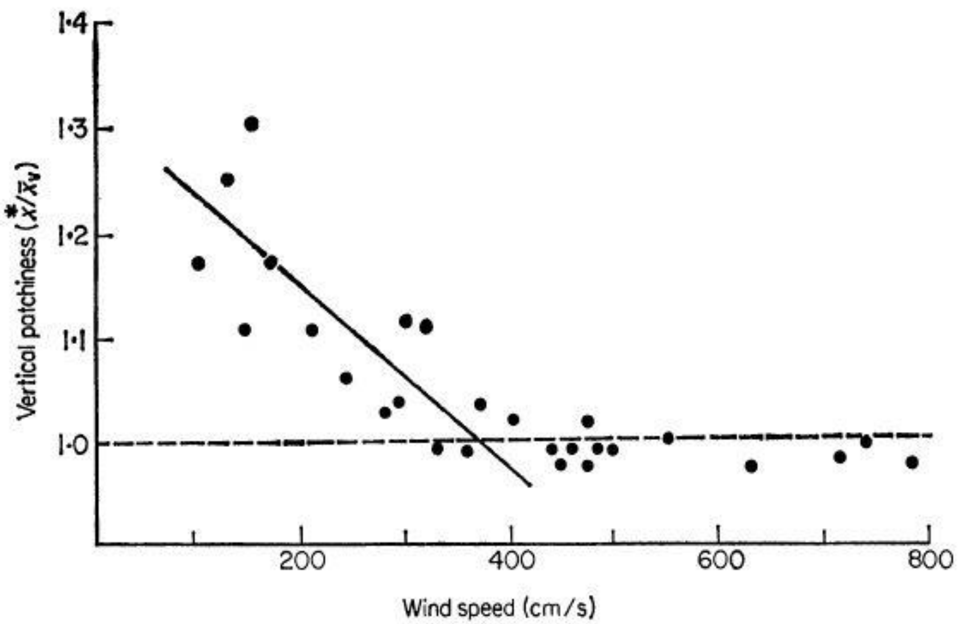


FIG. 8. The relationship between vertical patchiness in the blue-green algae and wind speed. $\overset{*}{x}/x_v$ values calculated for chlorophyll *a* profiles at a single station. Regression line fitted to patchiness estimates at wind speeds below 400 cm/s.

George and Edwards 1976

Conclusions

- 2012 cyanobacteria bloom driven by internal processes (on a seasonal scale)
  - 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
- Cyanobacteria may monopolize light resources when wind speeds are low

Acknowledgements

This work has been a collaboration with the entire Q1 UVM team (Courtney Giles, Andrew Schroth, Greg Druschel, Trevor Gearhart, Jason Stockwell, Elissa Schuett, Yaoyang Xu)

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Thank you to VT EPSCoR and the whole RACC team!