Collaborative Research Initiative on Sustainability and Protection of Springs (**CRISPS**): Quantifying Silver River Hydraulics and Hydrodynamics

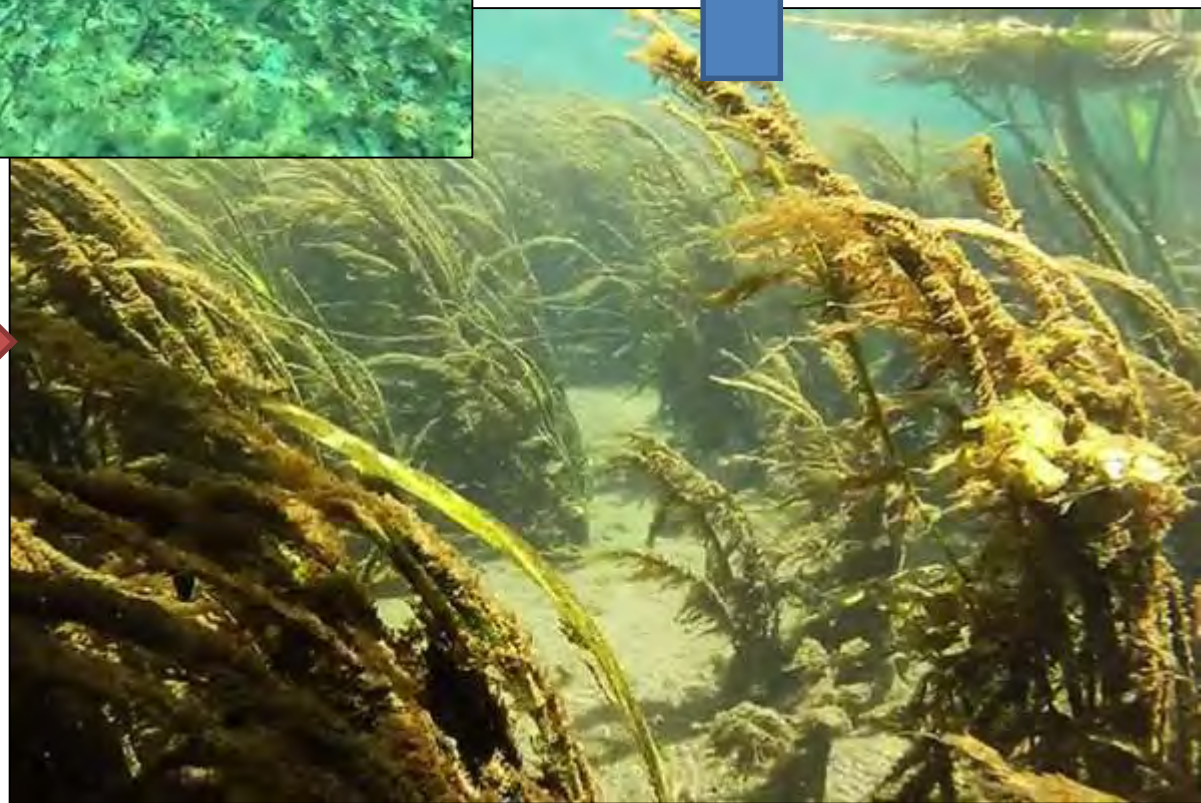
David Kaplan (UF Lead), Pete Sucsy (SJRWMD Lead), Ed Carter, Alexis Johnson, Nathan Reaver, Joseph Stewart, Yanfeng Zhang

UF | UNIVERSITY of FLORIDA
The Foundation for The Gator Nation

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

?

?

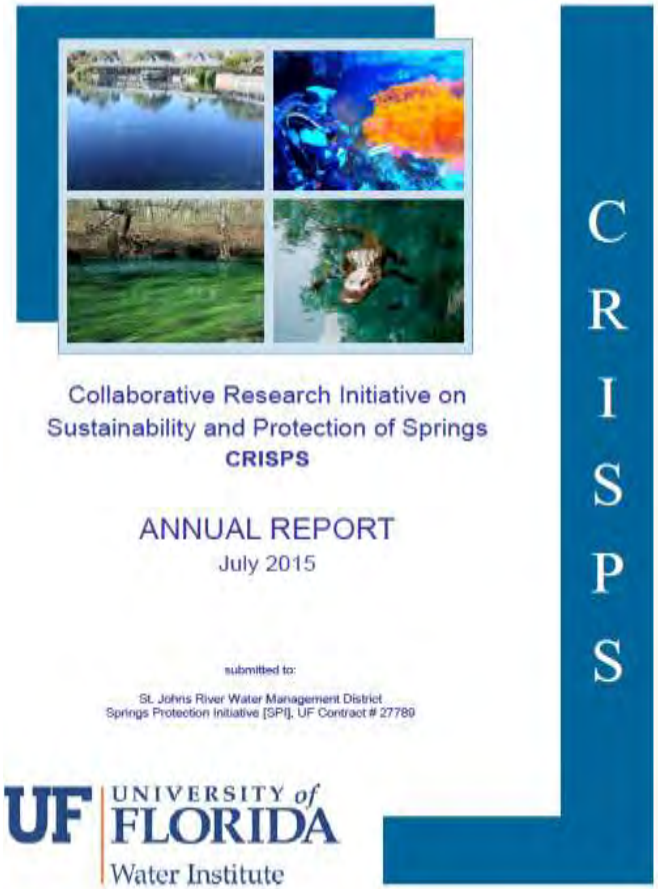


Photos: Ed Carter, SJRWMD

CRISPS?

Collaborative partnership between UF and SJRWMD, with three goals:

1. Improve scientific foundation for management of **nitrate loading** to springs
2. Evaluate whether **reduction of nitrate** alone will be sufficient to restore ecological balance
3. Assess the relative influence and manageability of **non-nitrate drivers**



CRISPS: Focus + Research Elements

SJRWMD Springs Protection Initiative - CRISPS

Project Administration, Management, and Coordination

SJRWMD	**UF/WI**
E. Lowe, Lead Scientist	R. Reddy, Lead Scientist
M. Cullum, Lead Hydrologist	W. Graham, Lead Hydrologist
M. Brabham, Project Manager	L. Staal, Project Manager

Springshed

SJRWMD, Lead
M. Cullum

UF/WI, Lead
J. Jawitz

Integration

Synthesis & Summary

Modelling Integration

Springs Ecosystem

SJRWMD, Lead
E. Lowe

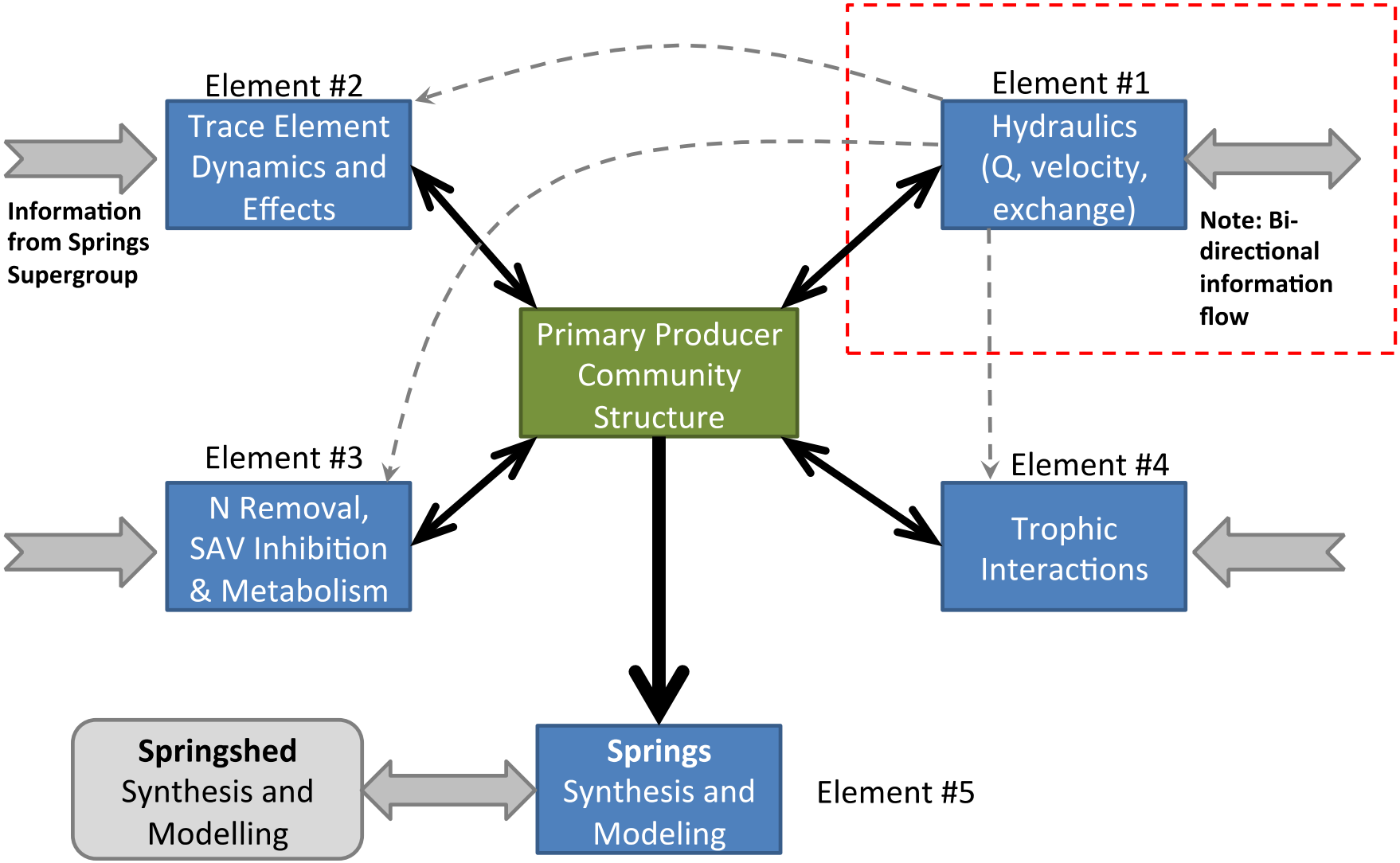
UF/WI, Lead
M. Cohen

SUPERGRROUPS

- **Nitrogen and Phosphorous Loading –Silver Springs sprinshed** — D. Smith and M. Kramer
- **Transport and Loss of Nitrogen' Upper Florida-Silver springs** — P. Burger (others) and J. Jawitz
- **Groundwater Hydrology Subgroup MODFLOW-CFP** — Patrick Burger and W. Graham
- **Nitrogen biogeochemistry-Silver Springs Springshed** — D. Debberfuhland P. Inglett
- **Hydrodynamics/Hydraulics** — P. Sucsy and D. Kaplan
- **Nitrogen Dynamics and Metabolism** — M. Coveney and M. Cohen
- **Benthic sources and sinks** — M. Coveney and J. Martin
- **Trophic Interactions** — Rob Mattson and T. Frazer

Sub-projects initiated 2014

Springs Ecosystem: Research Elements

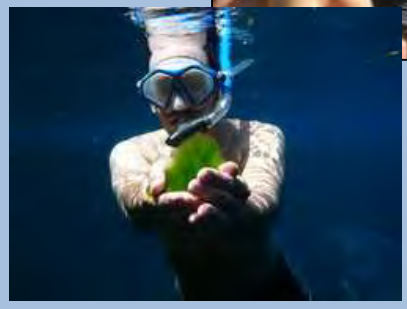


H & H Objective (simplified)

SJRWMD Team

"…determine whether velocity is an important non-nitrate factor influencing the community structure and function of primary producers in the system."*

UF Team



What Do We Need to Know/Do?

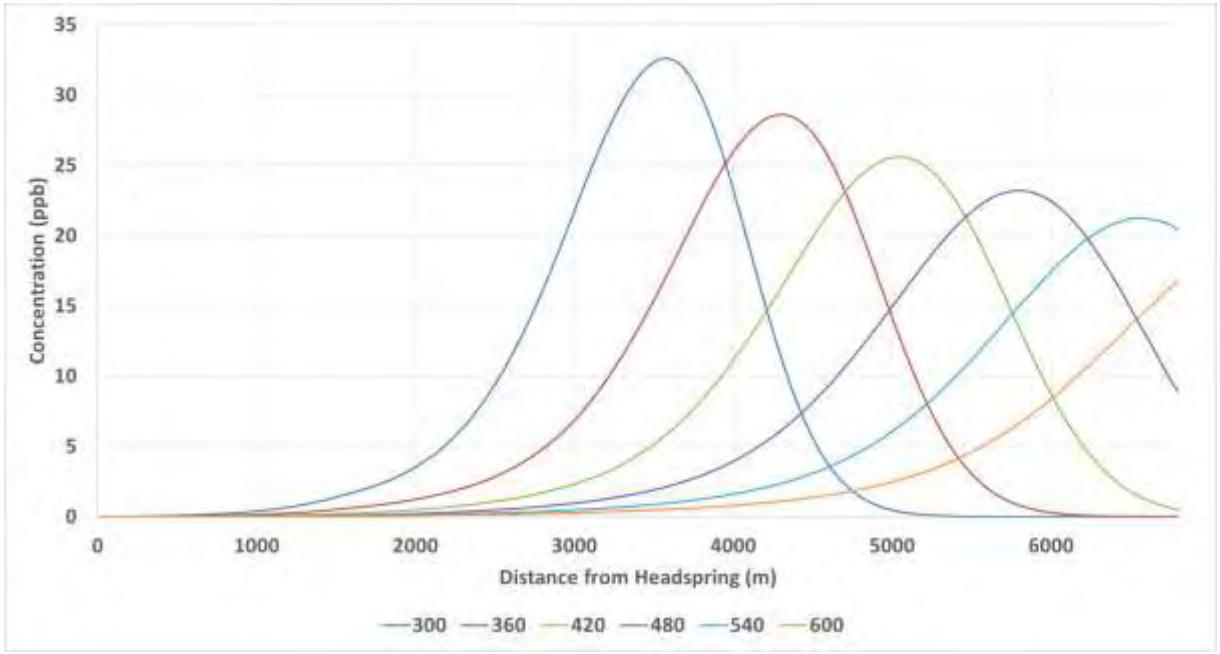
1. Point- and reach-scale velocities and residence time distributions
   - Direct measurements
   - **Dye trace experiments**
2. Critical velocities/shear stresses
   - ***In-situ* flow-ways**
   - **Optical methods?!**
3. River-scale veg-flow interactions
   - EFDC modeling
   - Scenario testing
   - **Play Sherlock Holmes**

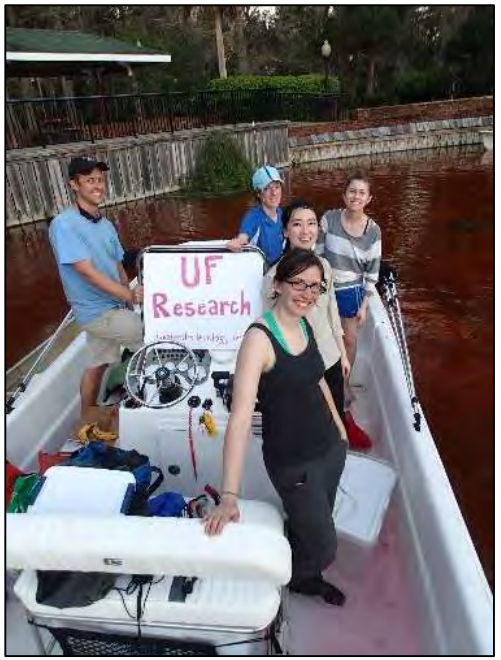
1. Dye Trace – Background

- **Reach-scale** hydrologic characterization
- Calculate residence time and exchange rates with storage zones
  - Nutrient uptake and cycling potential
- Determine if river "behaves" substantially different under different conditions:
  - Channel roughness effects (*vegetation build-up downstream?*)
  - Water surface profile effects (Δ *up/downstream river stage?*)
  - Couple with EFDC model (calibration, scenario testing)

1. Dye Trace – Background

- Release a tracer; monitor its movement through the system
- Salts, dyes, labeled molecules, etc.
- Measure at set location over time: breakthrough curve (BTC)
- **Fitted** BTCs → transport properties: advection, dispersion, transient storage





1. Dye Trace – Methods

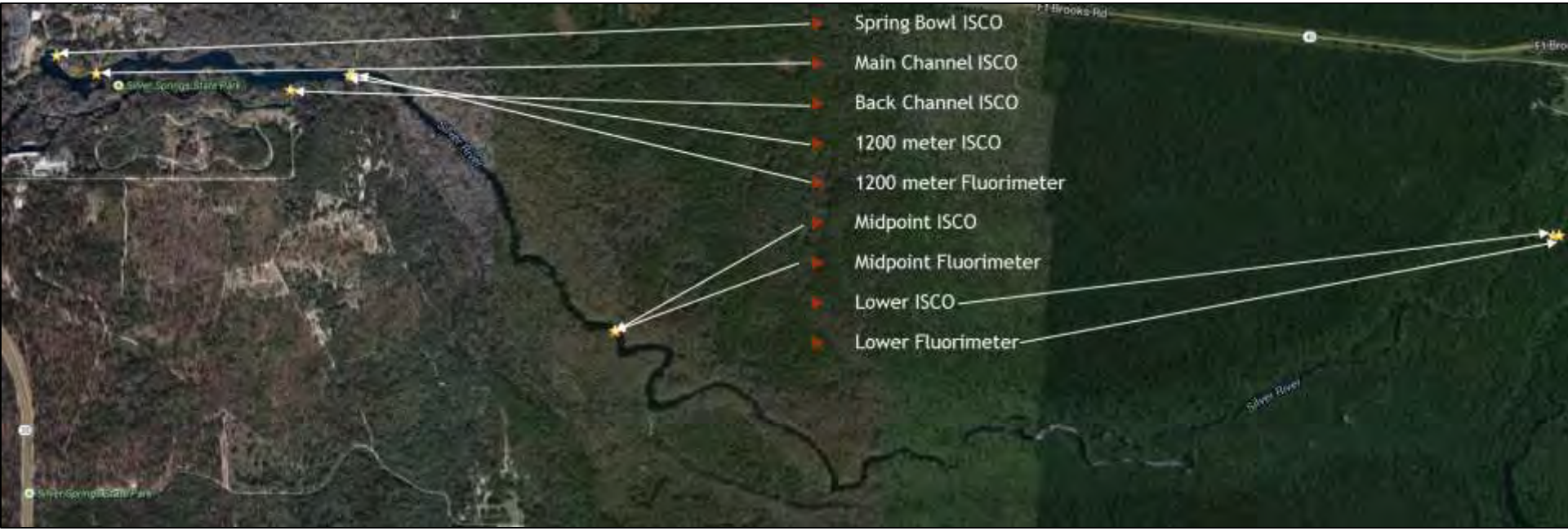
- 1-D Advection-Dispersion Equation vs. **OTIS**

$$\frac{\partial C}{\partial t} = -\frac{Q}{A}\frac{\partial C}{\partial x} + \frac{1}{A}\frac{\partial}{\partial x}\left(AD\frac{\partial C}{\partial x}\right) + \frac{q_{LIN}}{A}(C_L - C) + \alpha(C_S - C)$$

$$\frac{dC_s}{dt} = \alpha\frac{A}{A_S}(C - C_S)$$

A - main channel cross-sectional area [L^2]
A_S - storage zone cross-sectional area [L^2]
C - main channel solute concentration [M/L^3]
C_L - lateral inflow solute concentration [M/L^3]
C_S - storage zone solute concentration [M/L^3]
D - dispersion coefficient [L^2/T]
Q - volumetric flow rate [L^3/T]
q_{LIN} - lateral inflow rate [$L^3/T–L$]
t - time [T]
x - distance [L]
α - storage zone exchange coefficient [/T]

1. Dye Trace – Methods



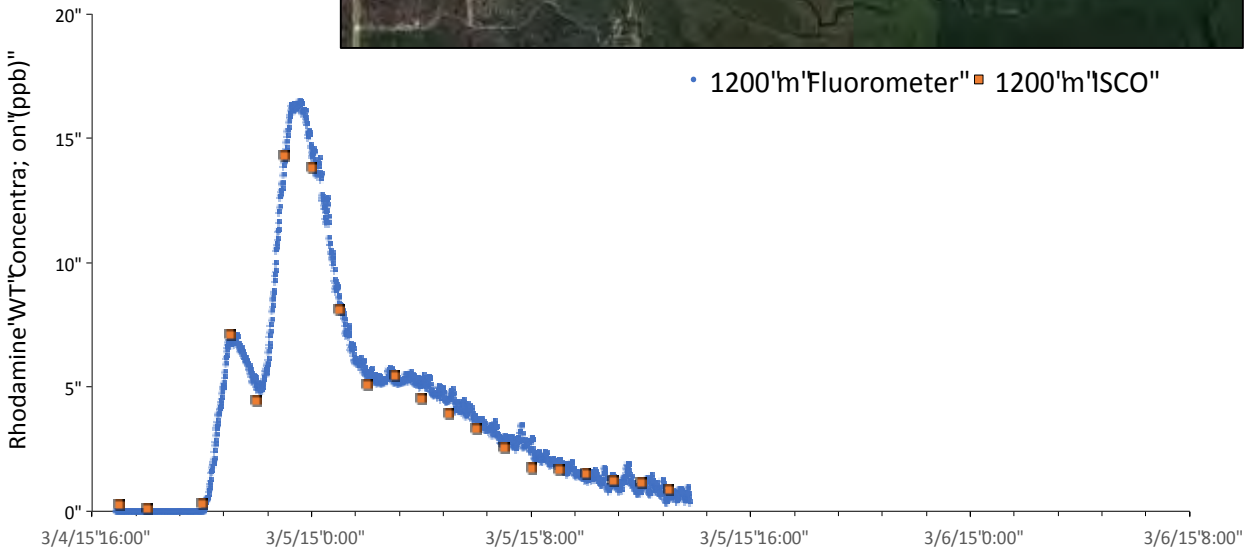
- Injected 18.9 L of 20% Rhodamine WT at Mammoth Vent
- Tracked dye at 9 fixed stations (May 2015); 3 in October 2015
- Collected grab samples to characterize differential mixing
- Compare: October 2009, May 2015, and October 2015

1. Dye Trace – Results

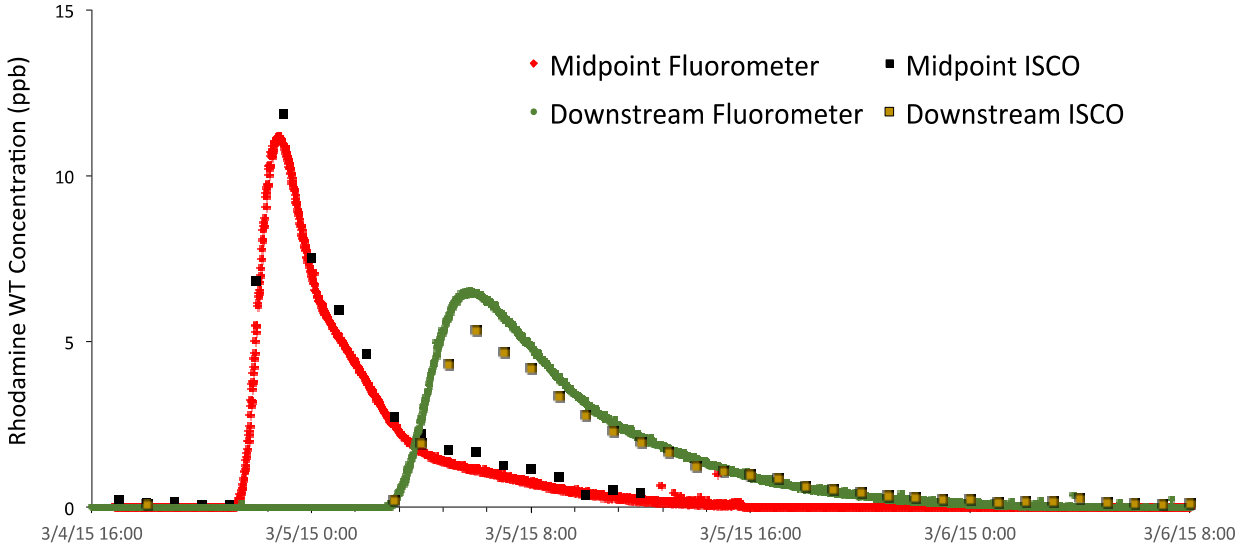
Figure: Ed Carter, SJRWMD

1. Dye Trace – Results

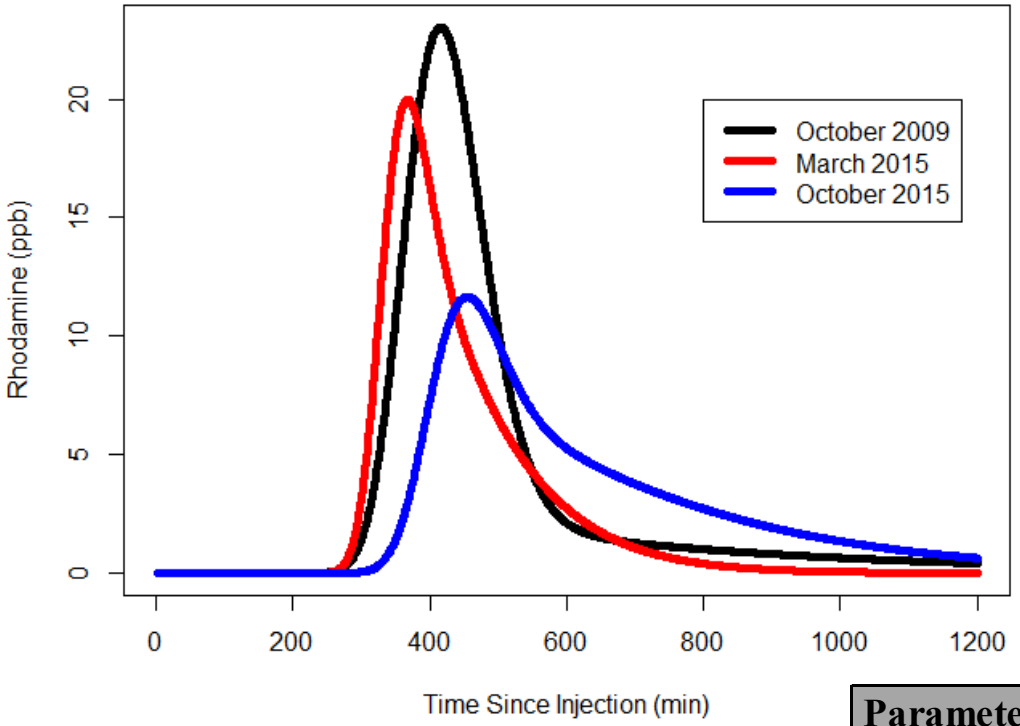
- Three **<u>upstream</u>** peaks (2 back channel flowpaths)
- Full mixing not achieved by 1200 m



- **<u>Downstream</u>** delay and attenuation
- Compare reach-scale mixing over *multiple studies*



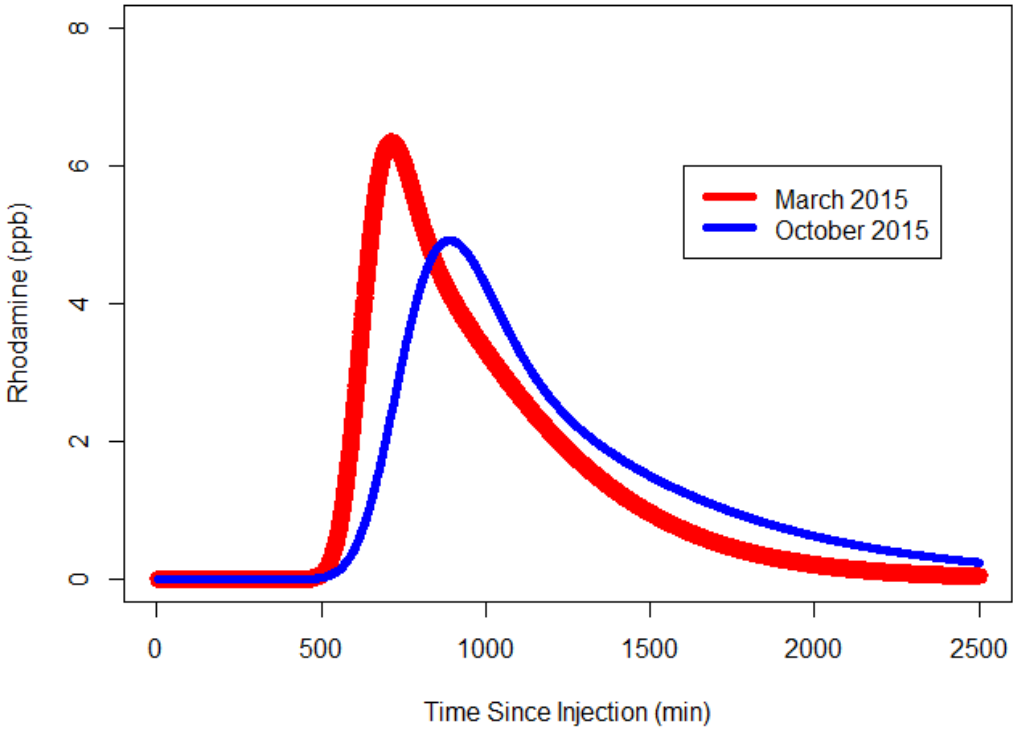
1. Dye Trace – Results: 2009 vs. 2015 (x2)



10/2009: Low Q, low DS stage
03/2015: High Q, low DS stage
10/2015: High Q, high DS stage

Parameter	2009 October	2015 March	2015 October	Units
Q	15.50	19.83	18.69	m^3/s
L	5300.00	5300.00	5300.00	m
A	73.43	80.17	94.62	m^2
A_S	18.10	17.13	39.75	m^2
D	10.69	5.84	7.30	m^2/s
α	1.0694E-05	5.3856E-05	4.2948E-05	1/s
τ	418.45	357.12	447.20	min
u	0.21	0.25	0.20	m/s

1. Dye Trace – Results: 2015 vs. 2015

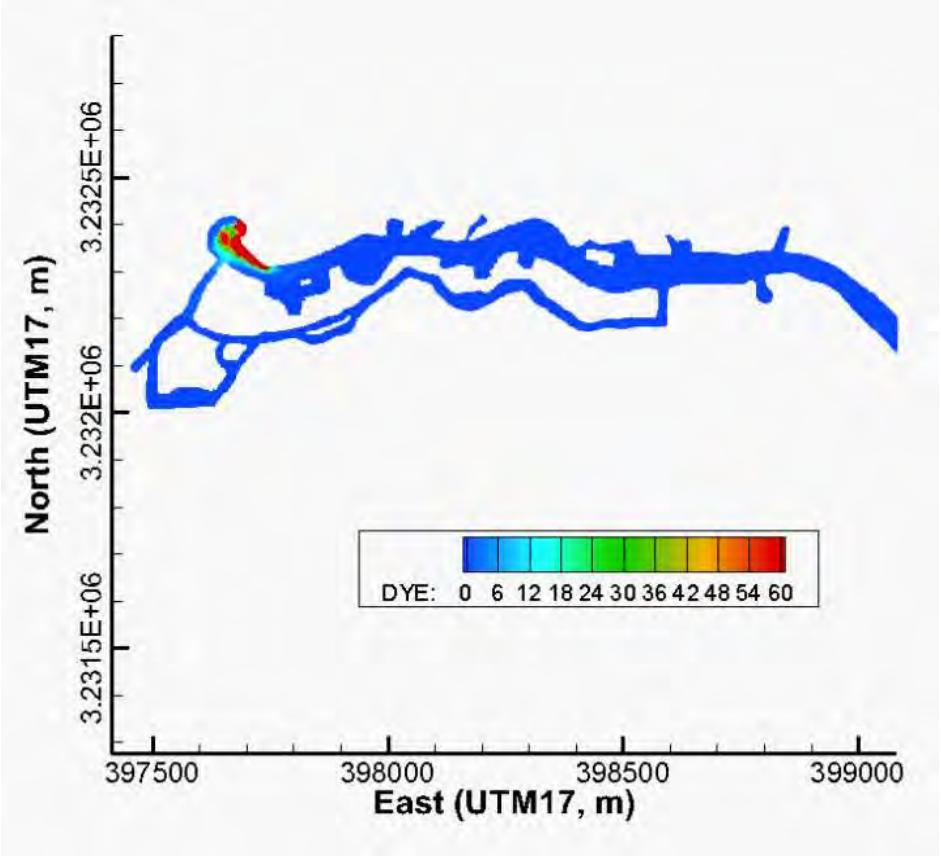


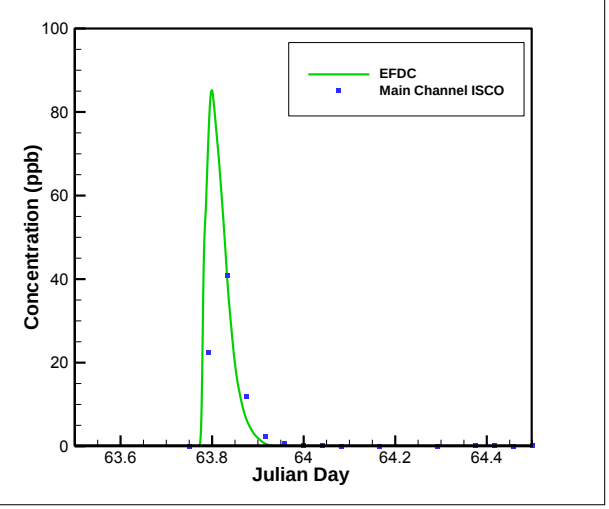
- Whole River: higher advective areas (A) than downstream reach
- Higher velocity (u) in March (low DS h)
- Higher dispersion (D) in October (high DS h, veg, others?)

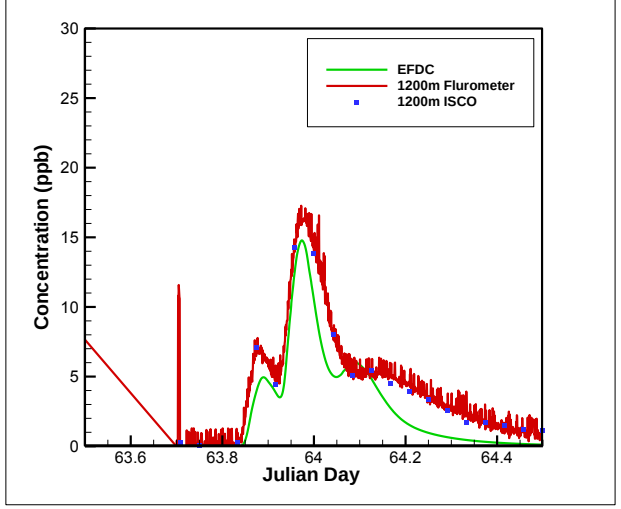
Parameter	2015 March	2015 October	Units
Q	19.83	18.69	m^3/s
L	8150.00	8150.00	m
A	100.71	120.66	m^2
A_S	44.17	47.24	m^2
D	9.00	17.45	m^2/s
α	3.8737E-05	1.9567E-05	1/s
τ	689.85	876.91	min
u	0.20	0.15	m/s

1. Dye Trace – Results: EFDC vs. Measured

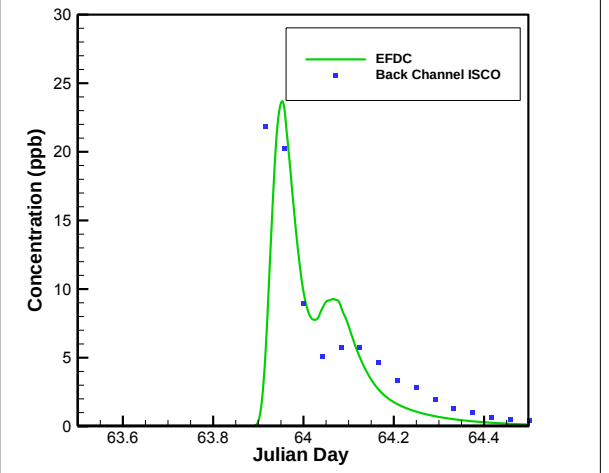
- **EFDC vs. Measured Data**
  - *Initial* simulation of pulsed dye release at Mammoth Vent
  - Compare to data observed from field experiment…

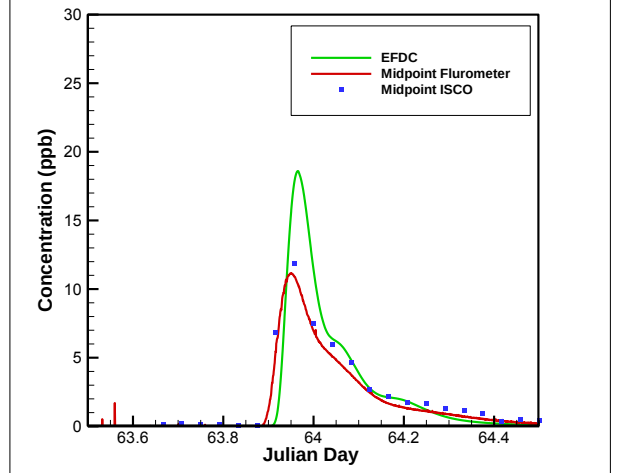


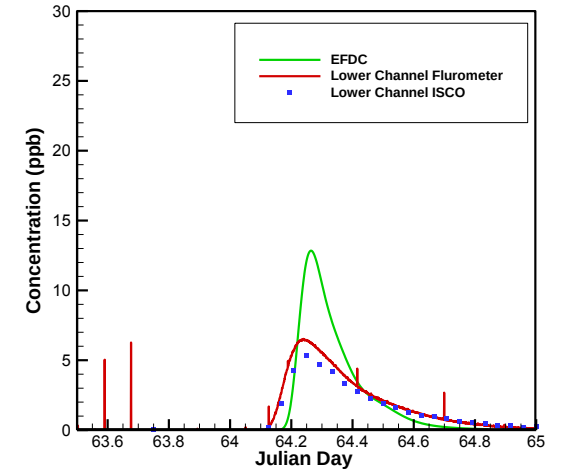

EFDC
Main Channel ISCO
Concentration (ppb)
Julian Day


EFDC
1200m Flurometer
1200m ISCO
Concentration (ppb)
Julian Day

Spring Bowl ISCO
Main Channel ISCO
Back Channel ISCO
1200 meter ISCO
1200 meter Fluorimeter
Midpoint ISCO
Midpoint Fluorimeter
Lower ISCO
Lower Fluorimeter


EFDC
Back Channel ISCO
Concentration (ppb)
Julian Day


EFDC
Midpoint Flurometer
Midpoint ISCO
Concentration (ppb)
Julian Day


EFDC
Lower Channel Flurometer
Lower Channel ISCO
Concentration (ppb)
Julian Day

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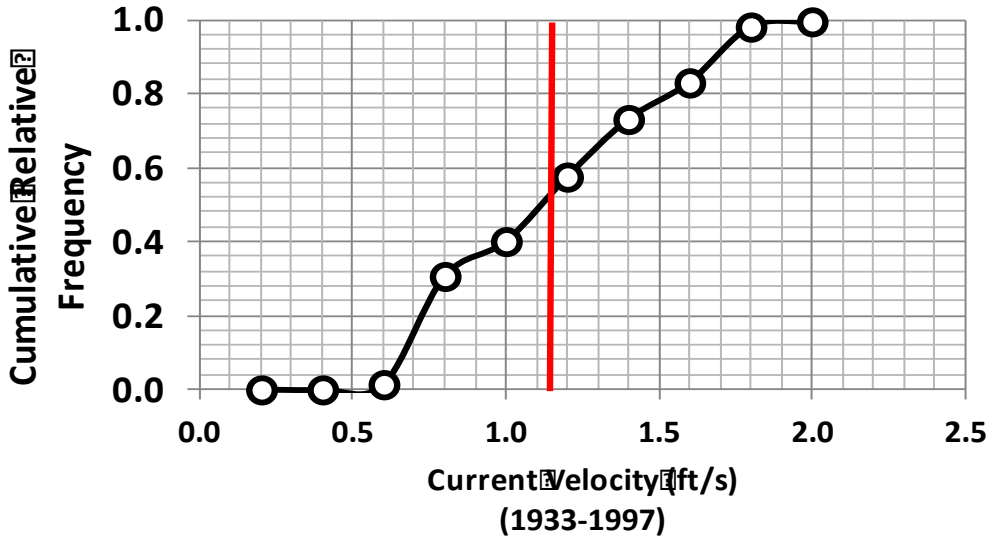
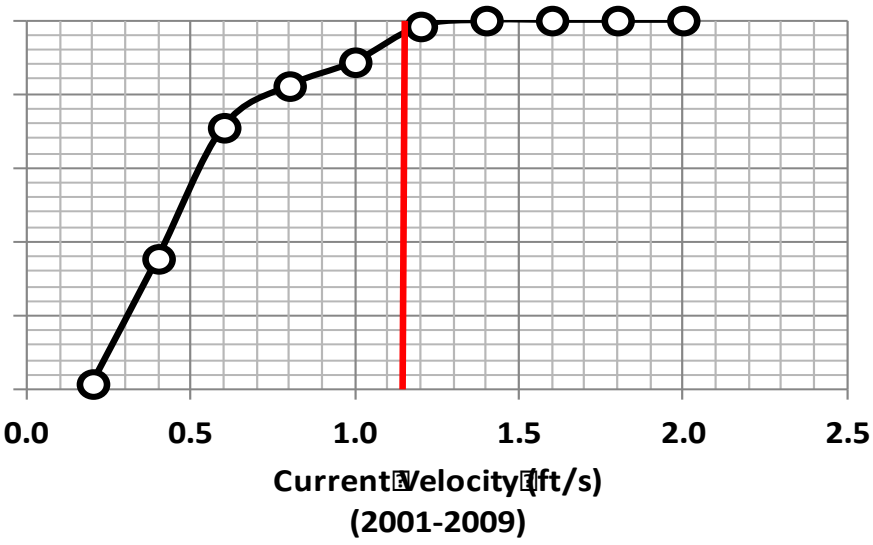
2. Critical Velocity/Shear Stress

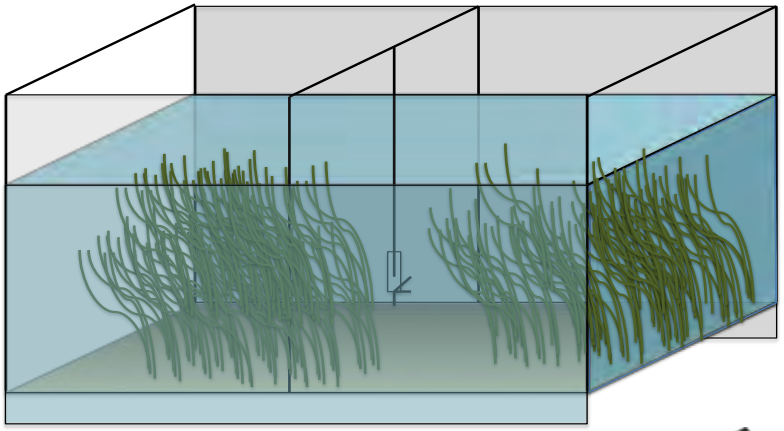


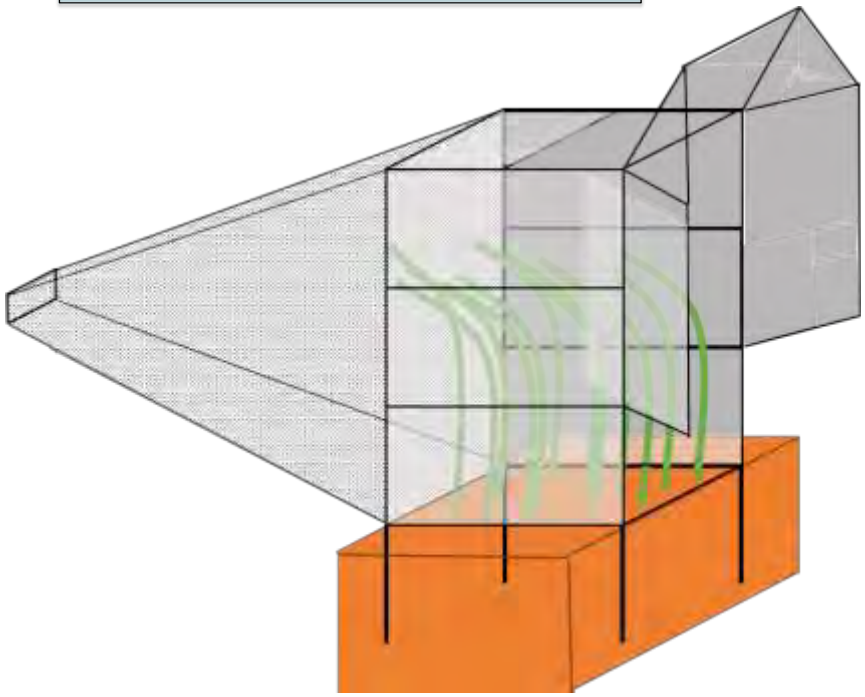


2. Critical Velocity – Methods

A. Flow-ways

- Submerged/emergent structures
- Modify opening to channel or exclude flow
- Measure velocity profiles, cover, downstream transport
- *When does algae slough?*
- *When does vegetation reconfigure?*
- **<u>Status</u>**: it's in the water!





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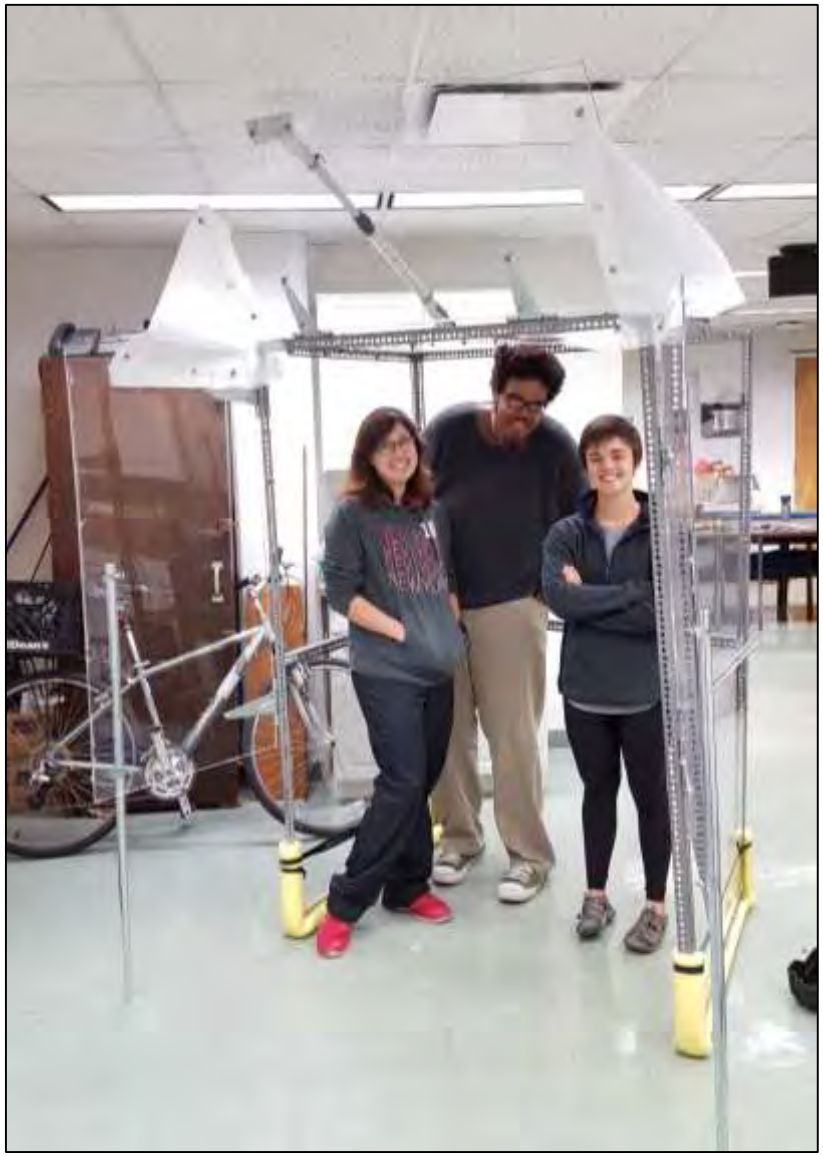

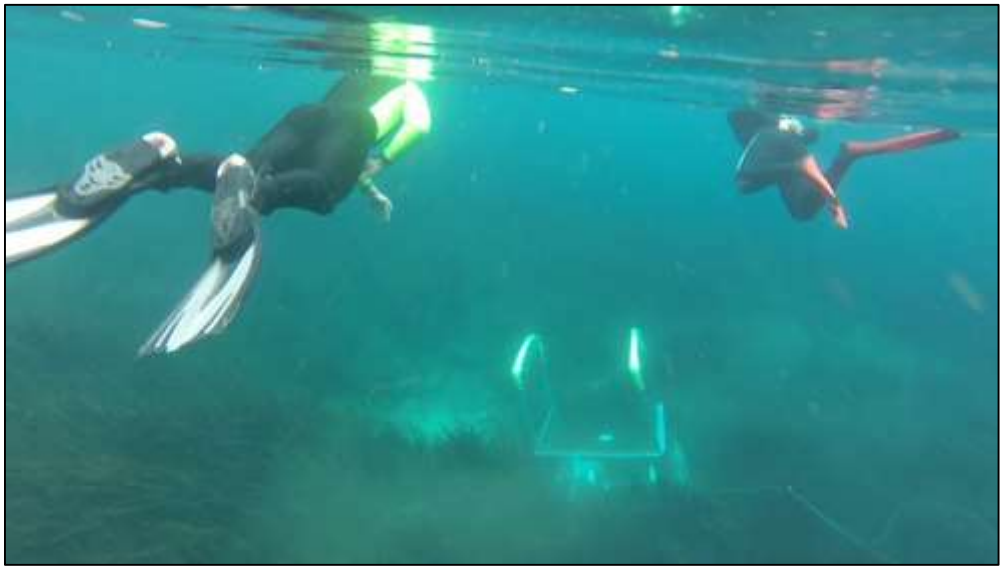

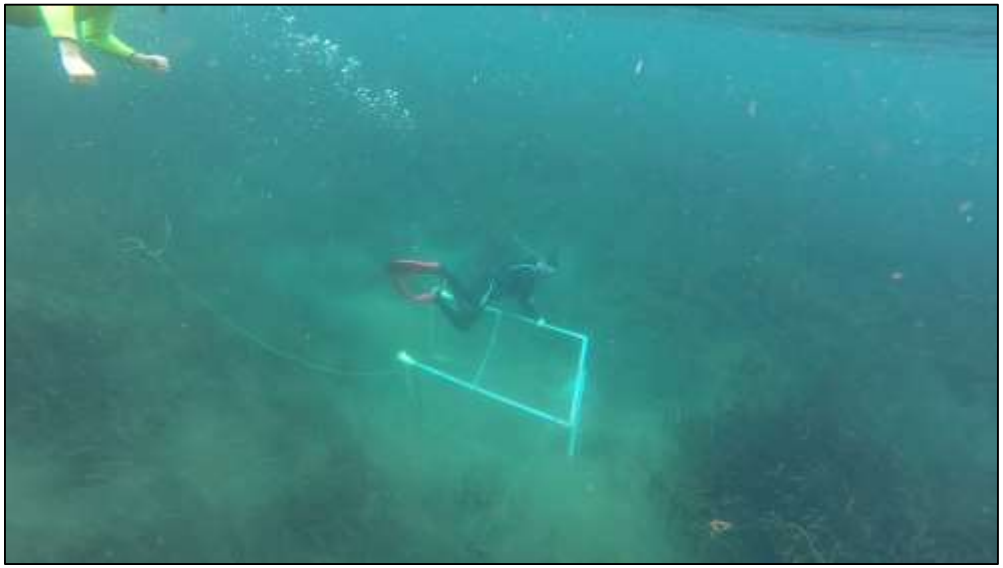

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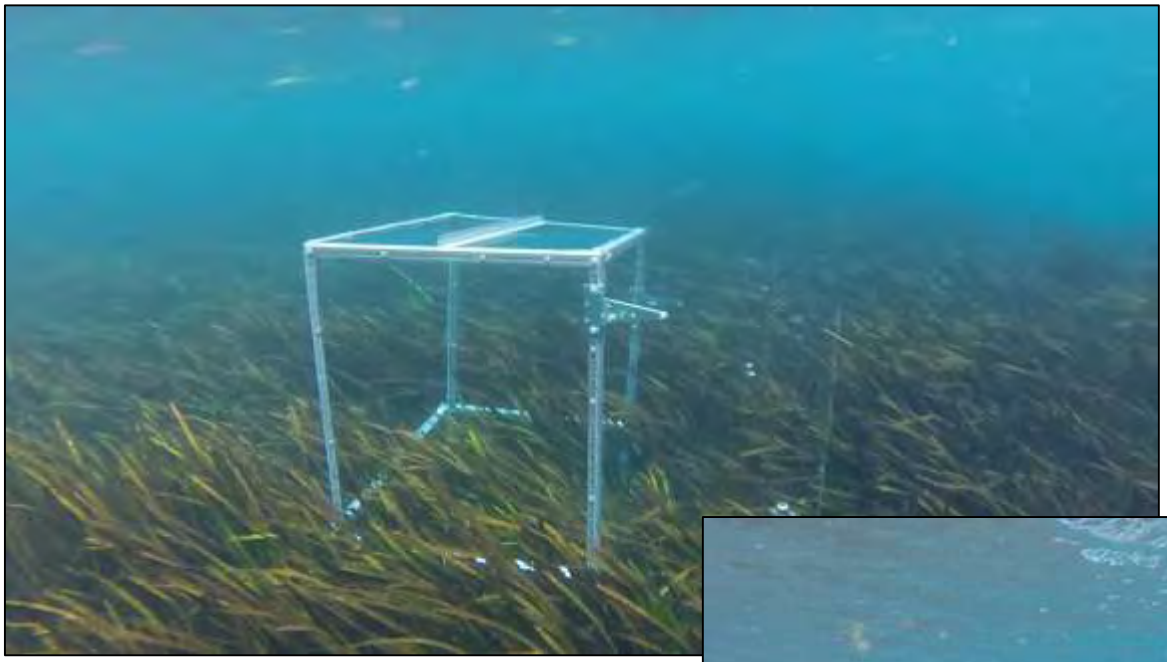

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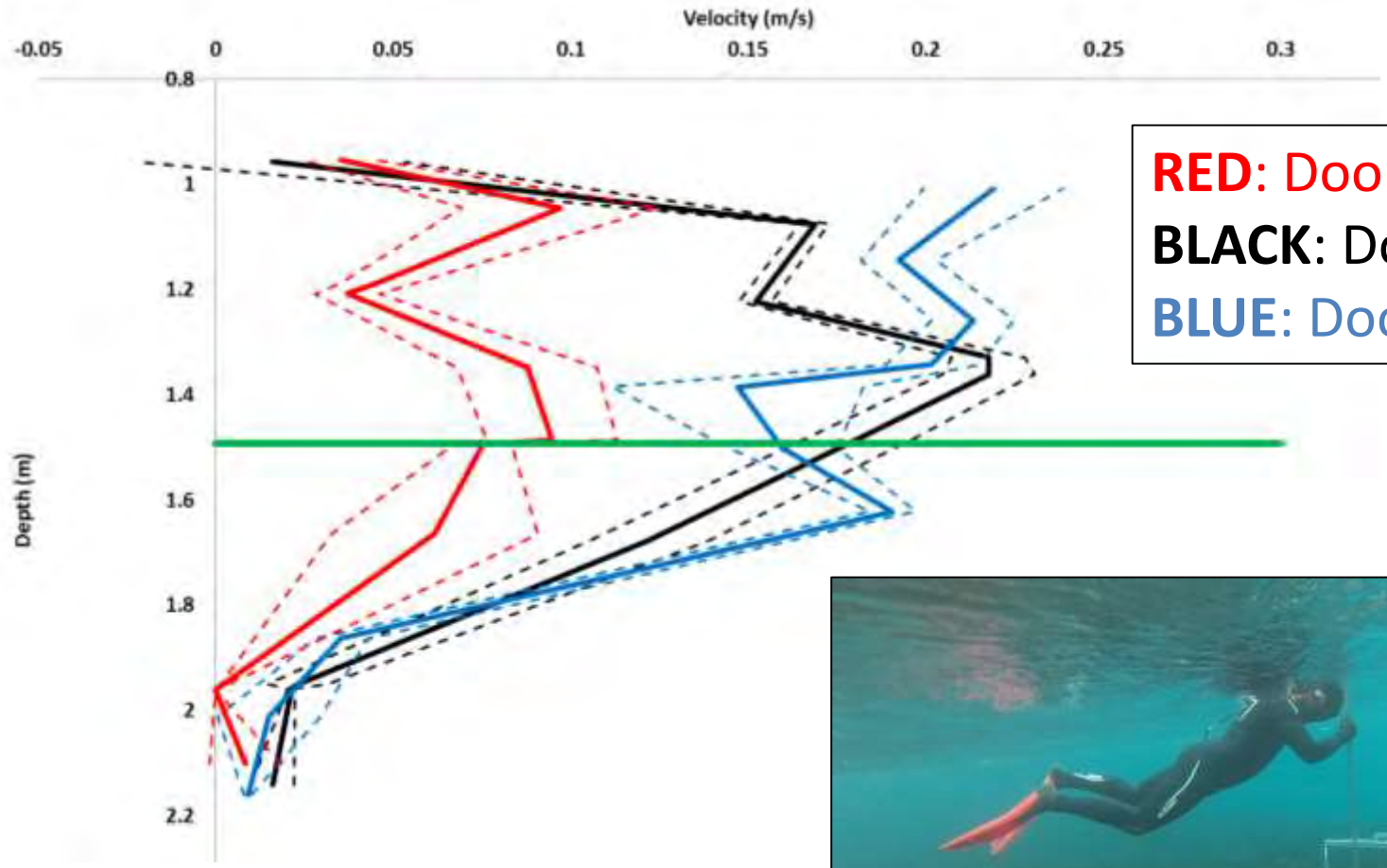


RED: Doors "closed"
BLACK: Doors straight
BLUE: Doors "opened"

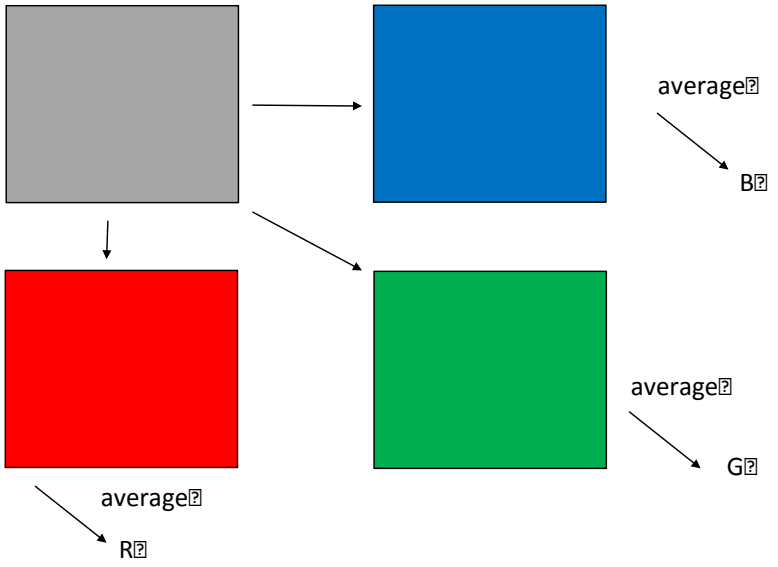
2. Critical Velocity – Methods

B. Optical Methods

- Goal: collect algal cover and velocity data over wide area to explore correlations and critical velocity
- Current methods impractical for high resolution, spatially distributed data and relies on human estimation
- We seek a rapid, quantitative method to cover large areas (image processing)

2. Critical Velocity – Methods

B1. Average Image Color Shift



$$Color = \log(Band\ 1) - \log(Band\ 2) = \log\left(\frac{Band\ 1}{Band\ 2}\right)$$

$$ColorBG = \log(B) - \log(G) = \log\left(\frac{B}{G}\right)$$

$$ColorGR = \log(G) - \log(R) = \log\left(\frac{G}{R}\right)$$

2. Critical Velocity – Methods

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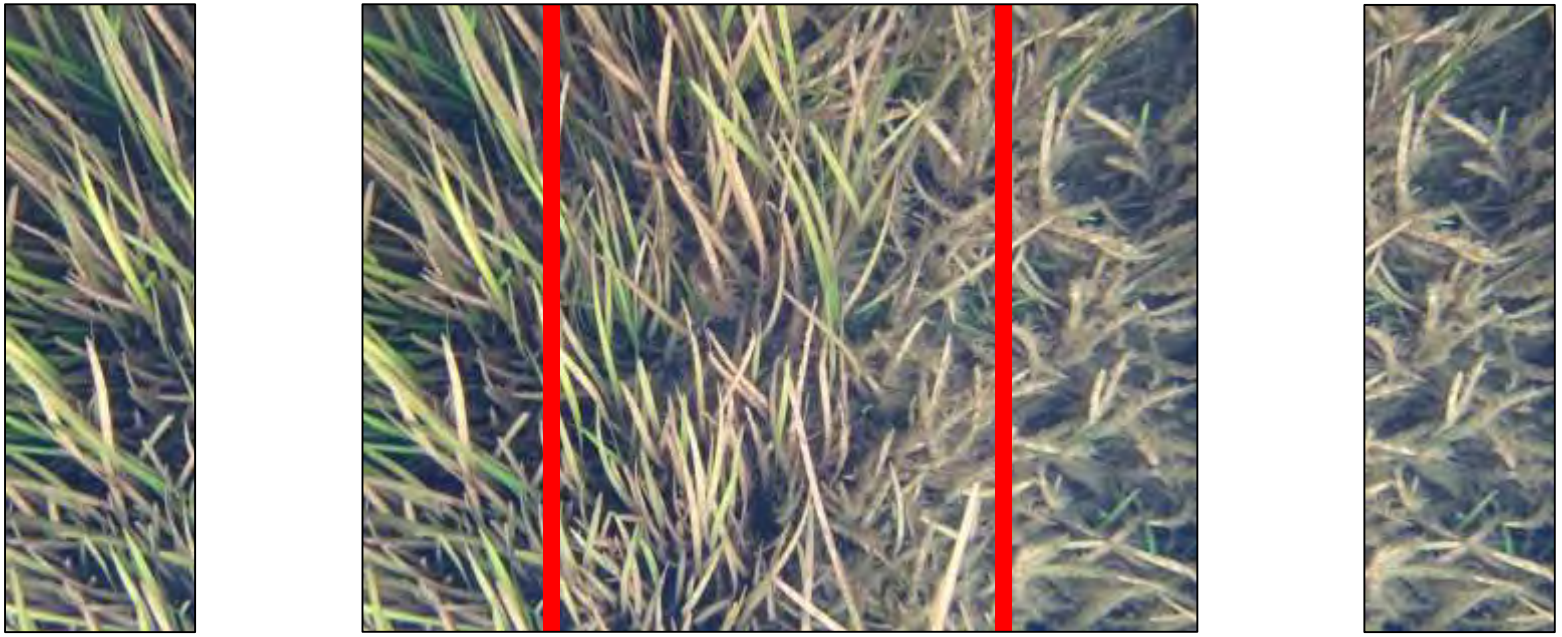
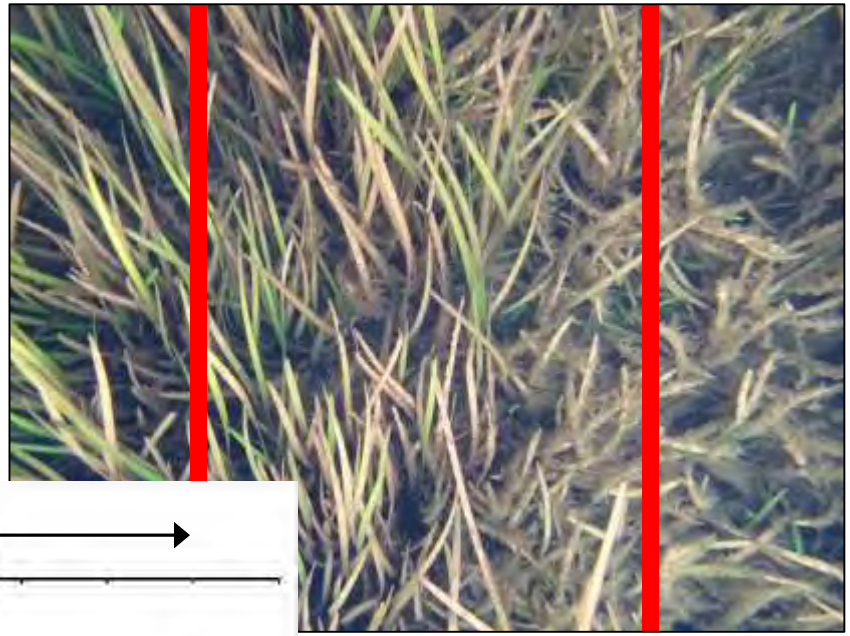


2. Critical Velocity – Methods

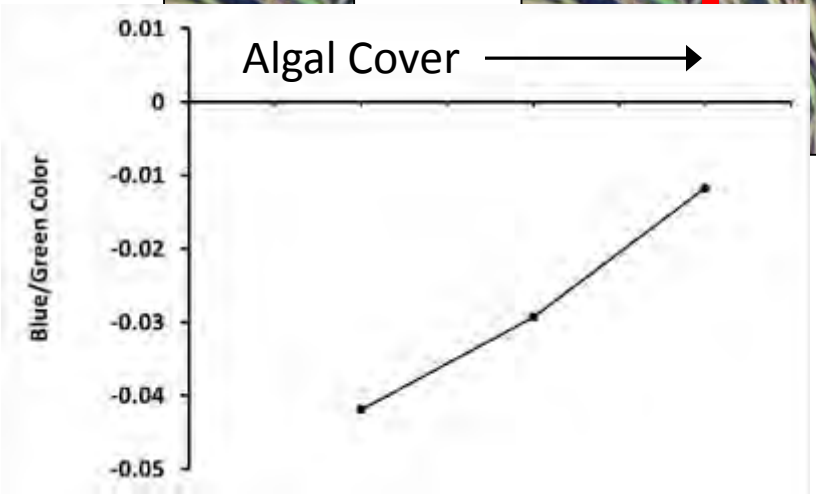
B1. Average Image Color Shift

BG Color = -0.0419

BG Color = -0.0293



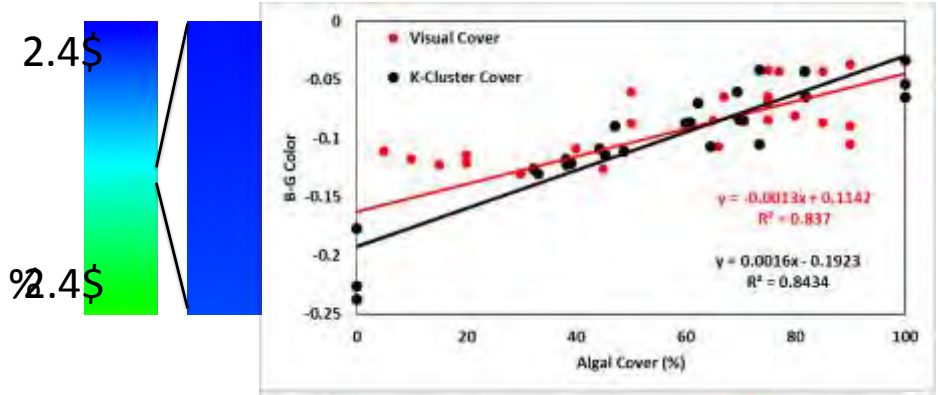
BG Color = -0.0117

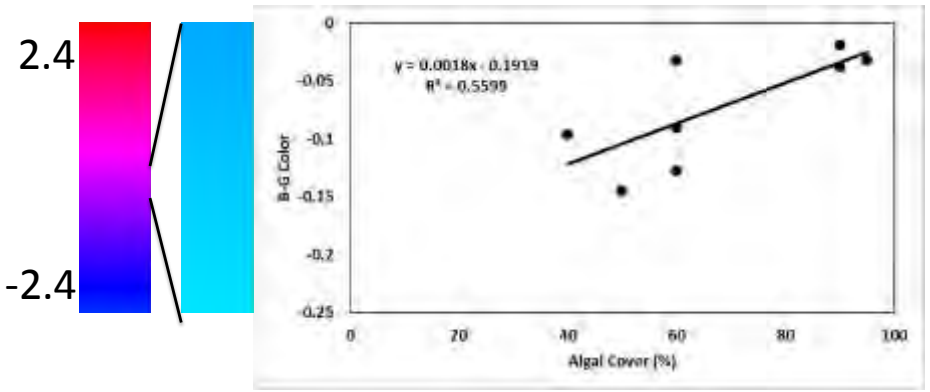


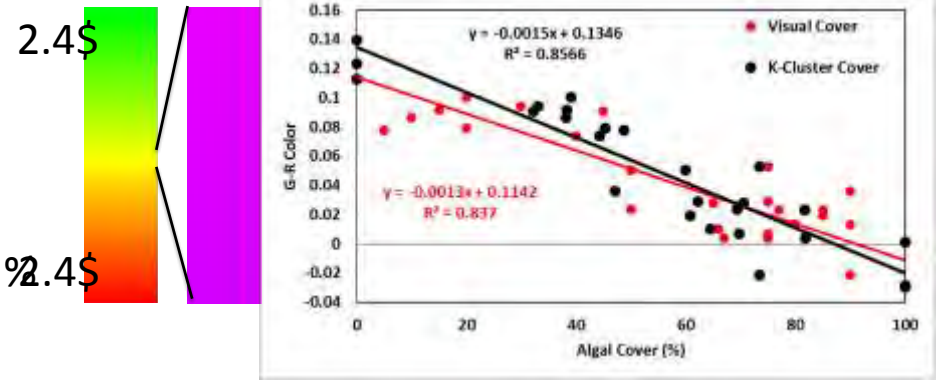
2. Critical Velocity – Initial Results

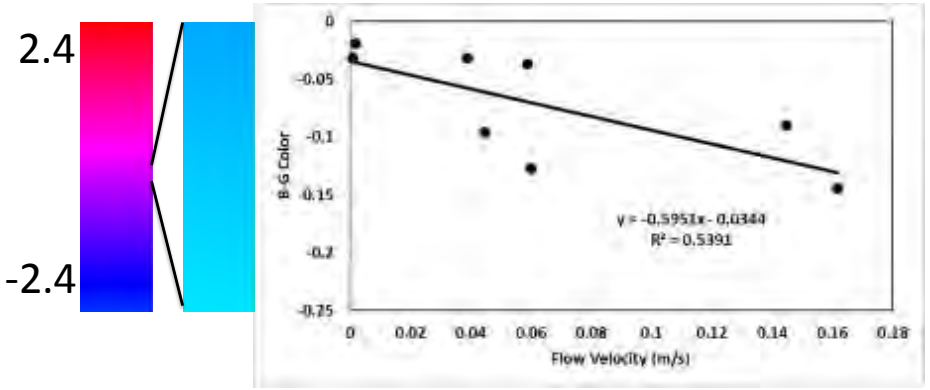
B1. Average Image Color Shift

- Good correlation with both BG and GR
- Training image and field data: similar slope
- Both B-G color and algal cover ~ velocity









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3. River-Scale Veg-Flow Interactions

Apparent shift in stage-discharge relationship in Silver River:

1. Increased spatial coverage of submersed aquatic vegetation?
2. Expansion of hydrilla in the lower Silver and Ocklawaha?
3. Reconfiguration of vegetation under low discharge?

Figure by Ed Carter

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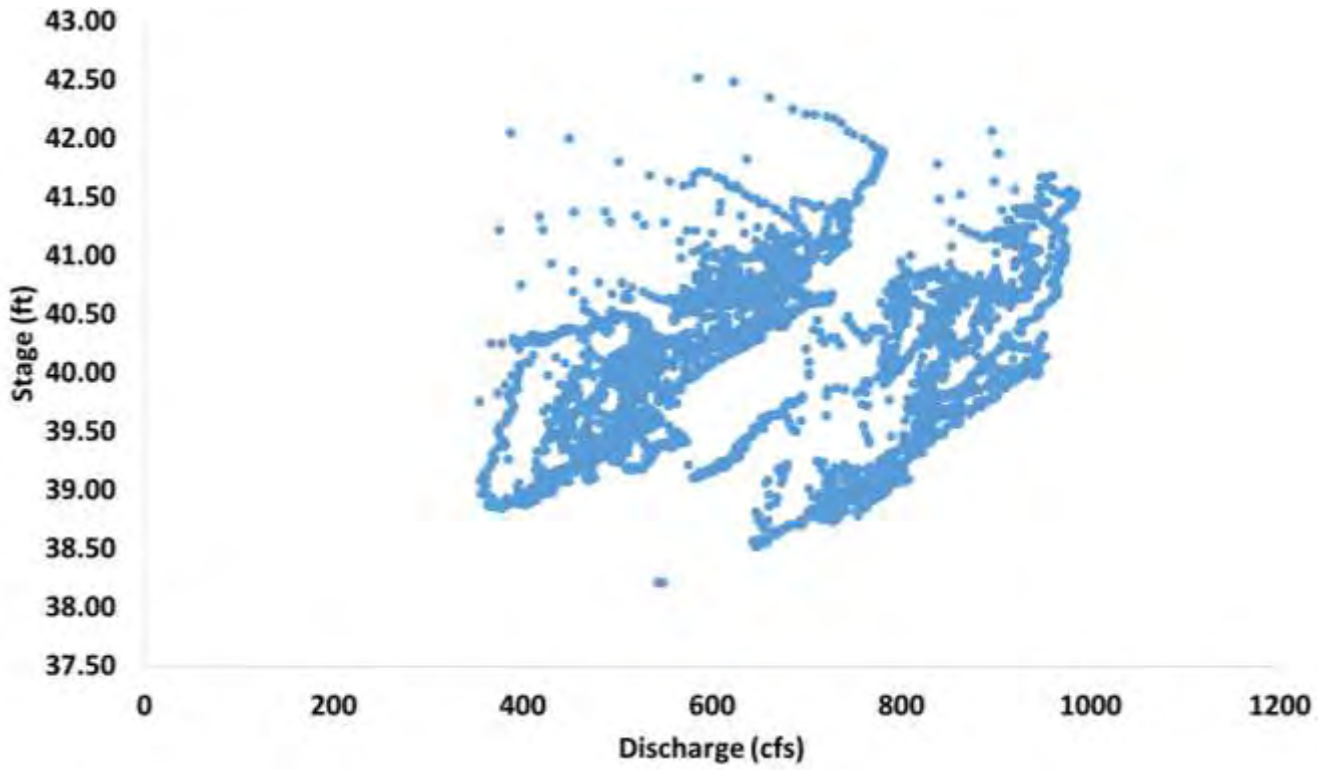
Data:

2/7/67 - 6/30/72

11/21/03 - 6/30/15



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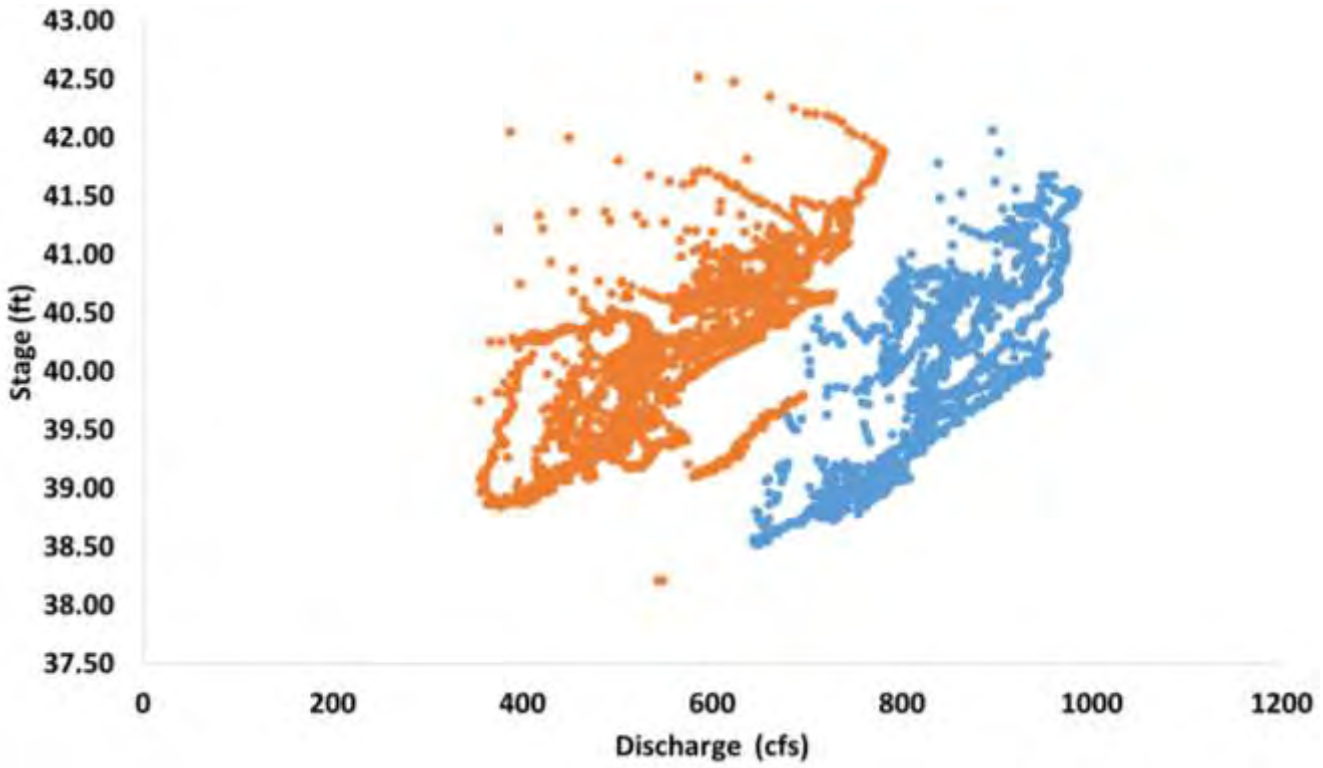
2/7/67 - 6/30/72

11/21/03 - 6/30/15



3. River-Scale Veg-Flow Interactions

Apparent shift in stage-discharge relationship in Silver River:

1. Increased spatial coverage of submersed aquatic vegetation?
2. Expansion of hydrilla in the lower Silver and Ocklawaha?
3. Reconfiguration of vegetation under low discharge?

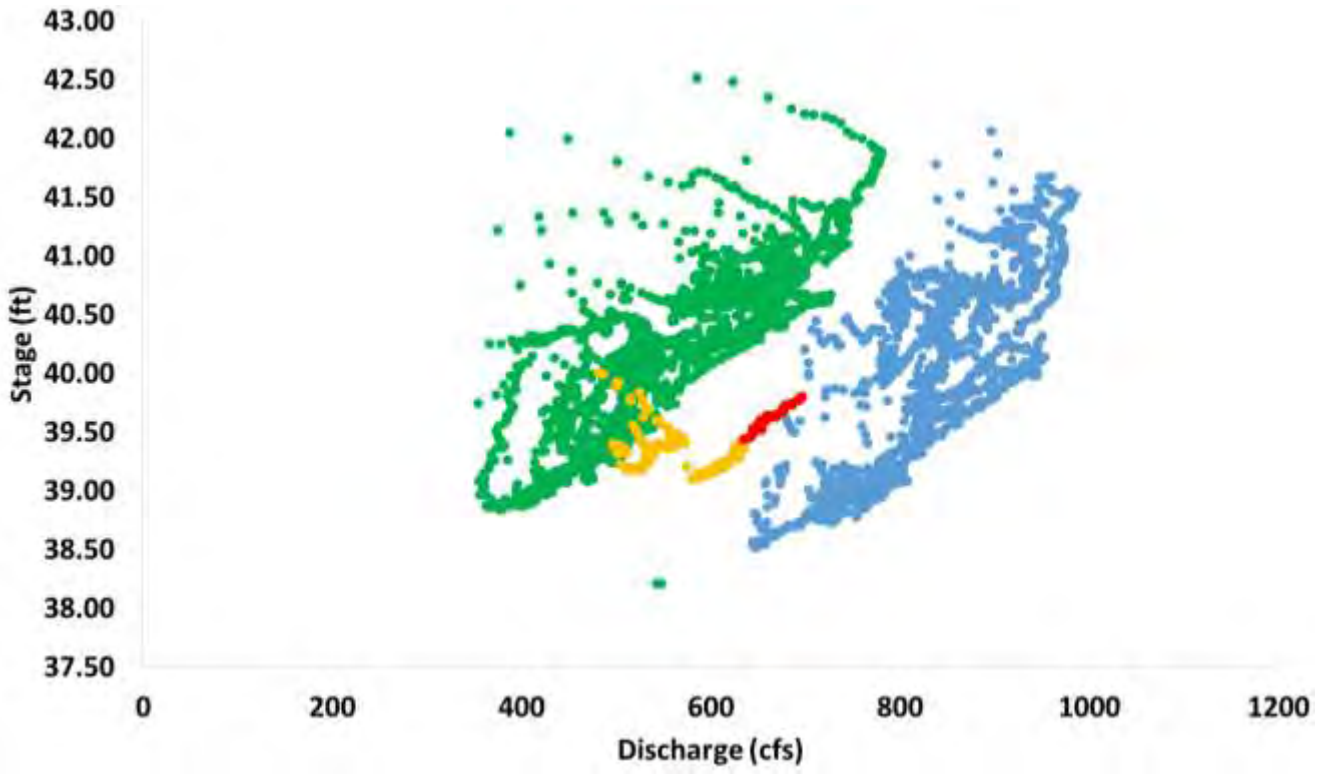
Data:

2/7/67 - 6/30/72

11/21/03 - 12/31/03

1/1/04 - 6/30/04

7/1/05 - 6/30/15



3. River-Scale Veg-Flow Interactions

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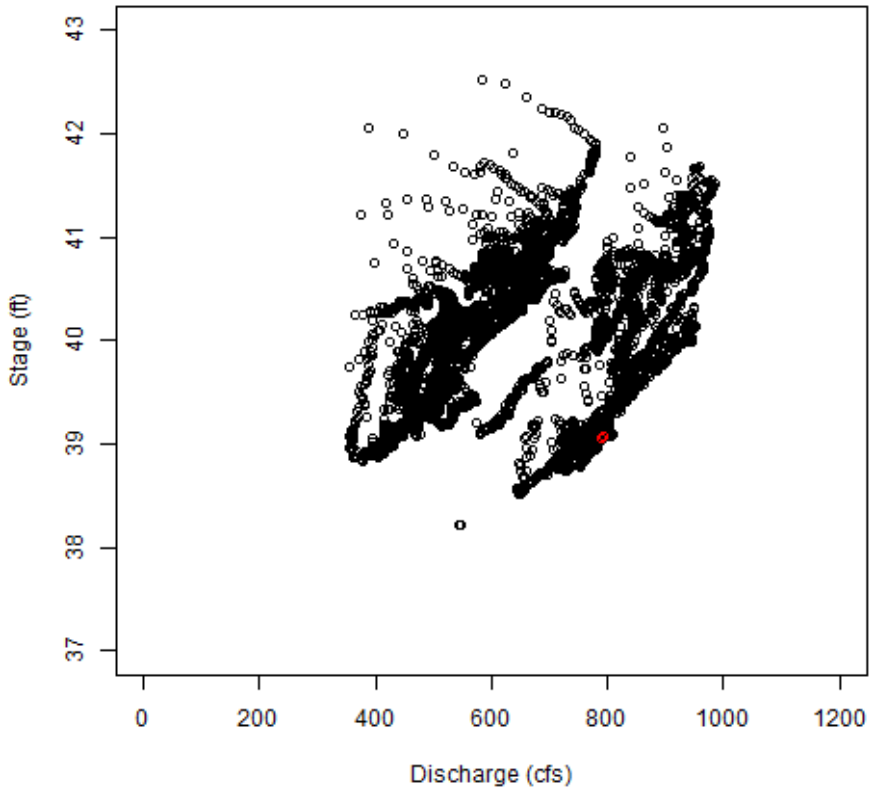
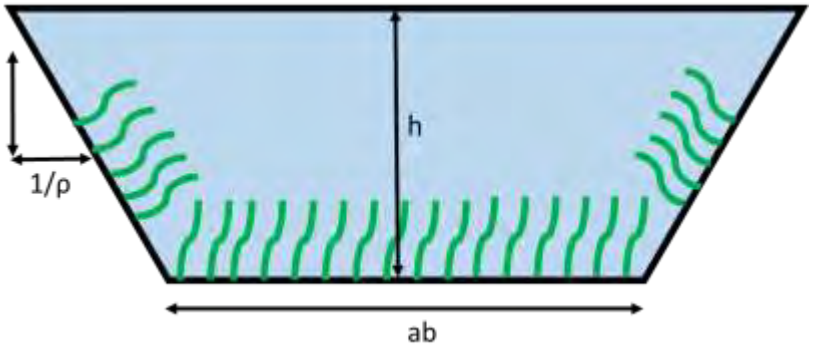
- Evidence for 2004 transition
- Alternative stable (?) state?
- Unstable intermediate state?
- A reasonable mechanism?



3. River-Scale Veg-Flow Interactions

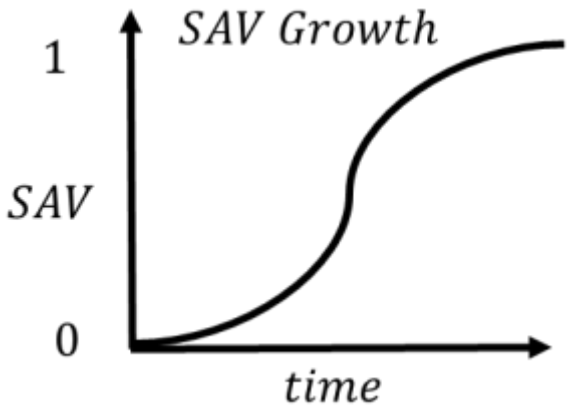
Can we induce such a shift in a (simplified) modeled system?

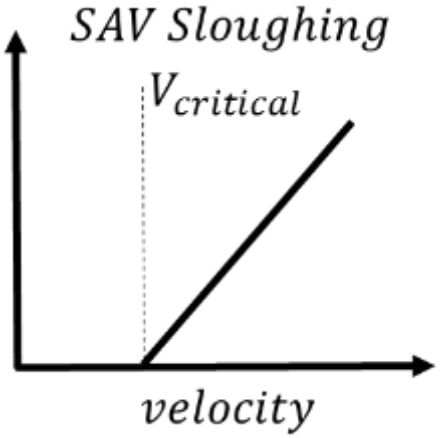
$$Q = \frac{k}{n}\left(\frac{A}{P}\right)^{\frac{2}{3}}(S)^{\frac{1}{2}}A \qquad \longleftarrow h \longrightarrow$$

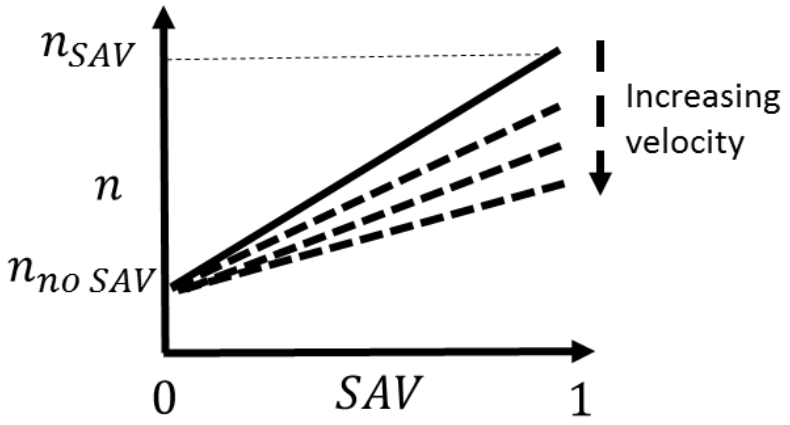


$$v = \frac{Q}{A}$$

$$n = n_{no\ SAV} + \left(\frac{n_{SAV} - n_{no\ SAV}}{1-0} - [N_v V \Phi(V) + (n_{saturated} - N_v V)\Phi(V - V_{sat})]\right) SAV$$







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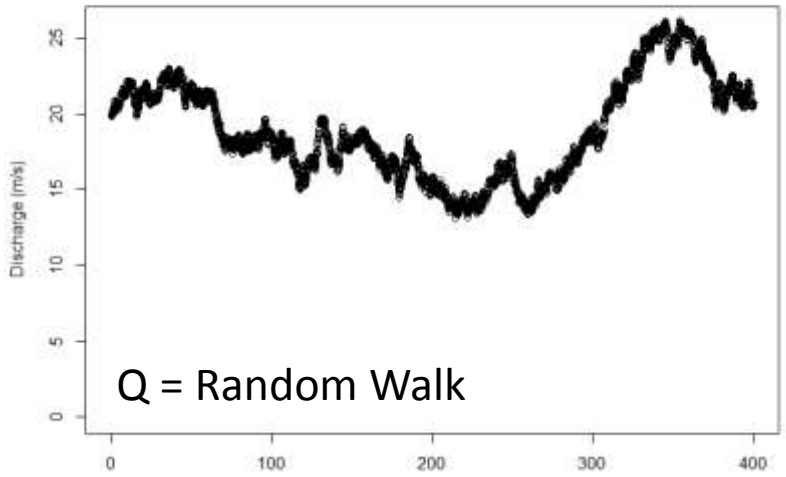

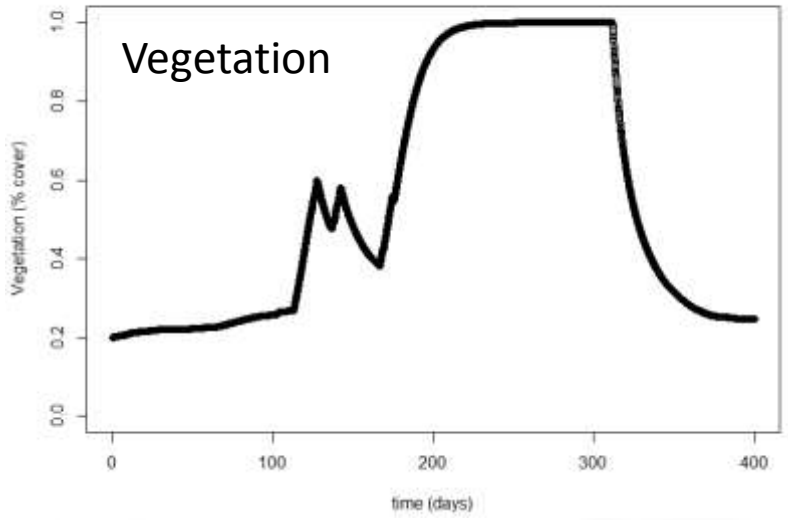

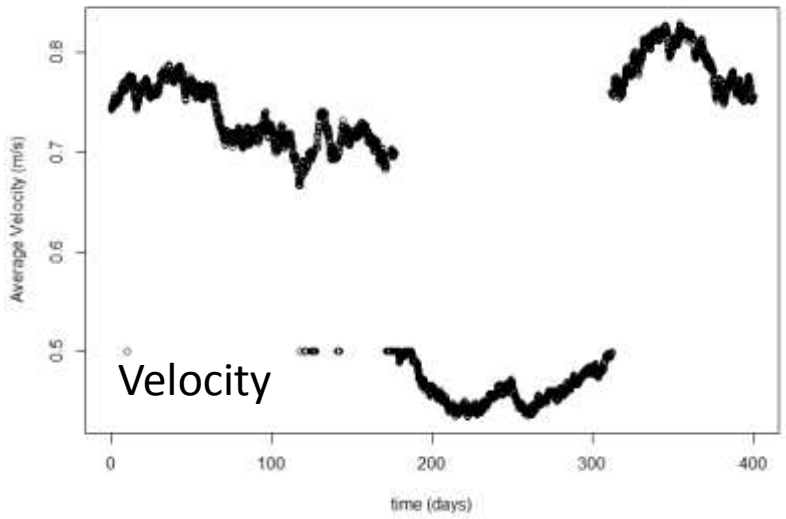

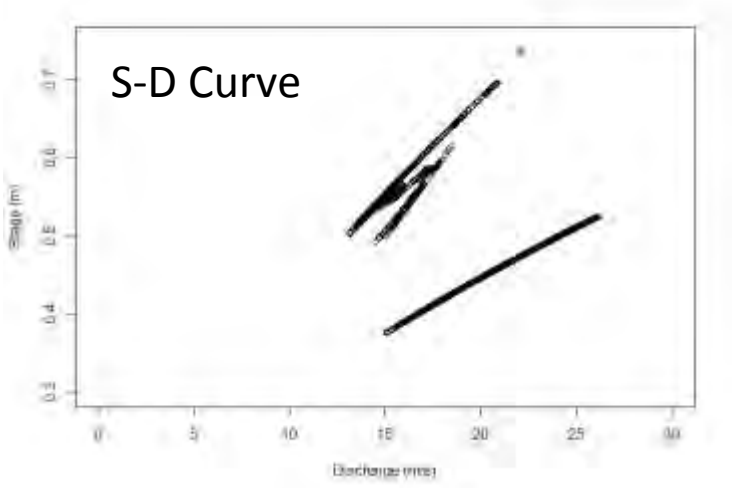

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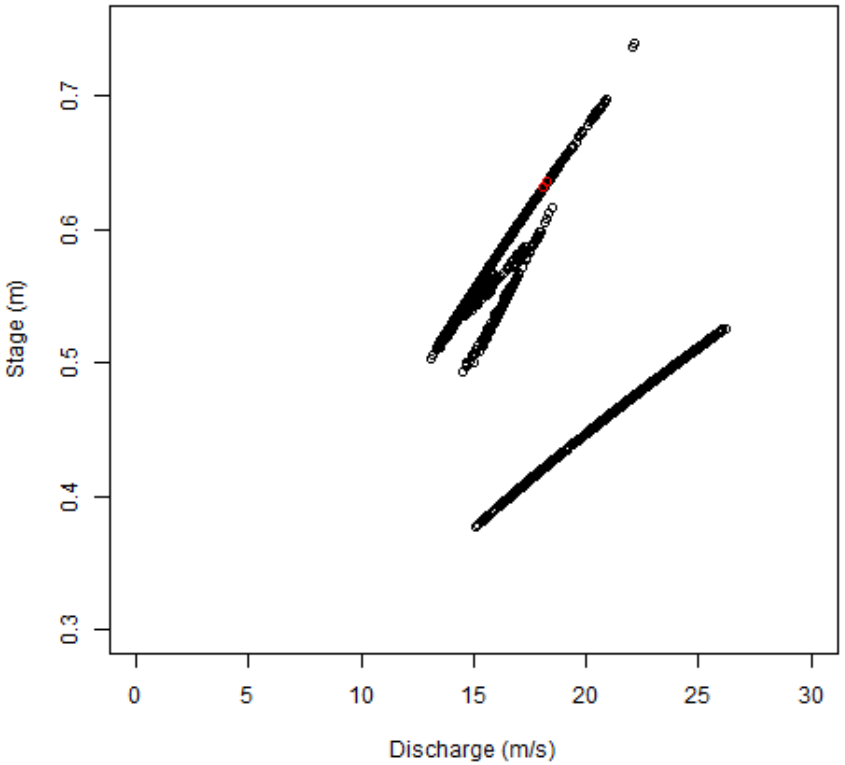
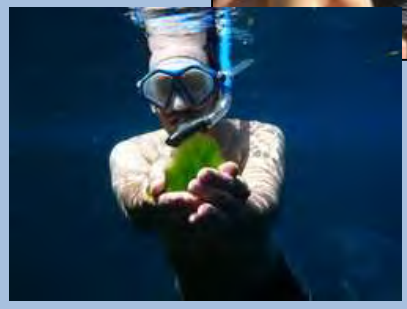


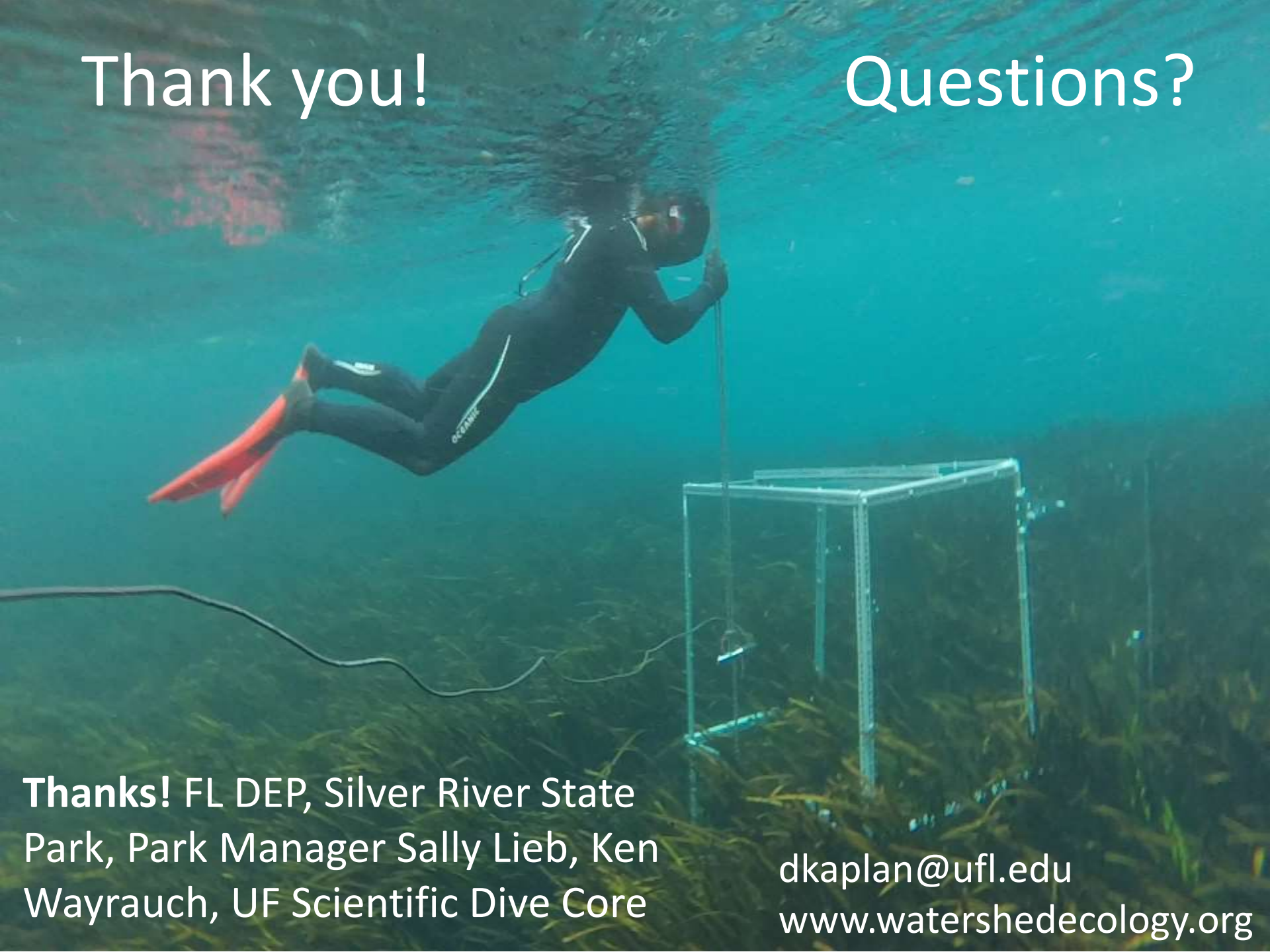
H & H Objective (simplified)

SJRWMD Team

"…determine whether velocity is an important non-nitrate factor influencing the community structure and function of primary producers in the system."*

UF Team




Thank you!
Questions?
Thanks! FL DEP, Silver River State Park, Park Manager Sally Lieb, Ken Wayrauch, UF Scientific Dive Core
dkaplan@ufl.edu
www.watershedecology.org