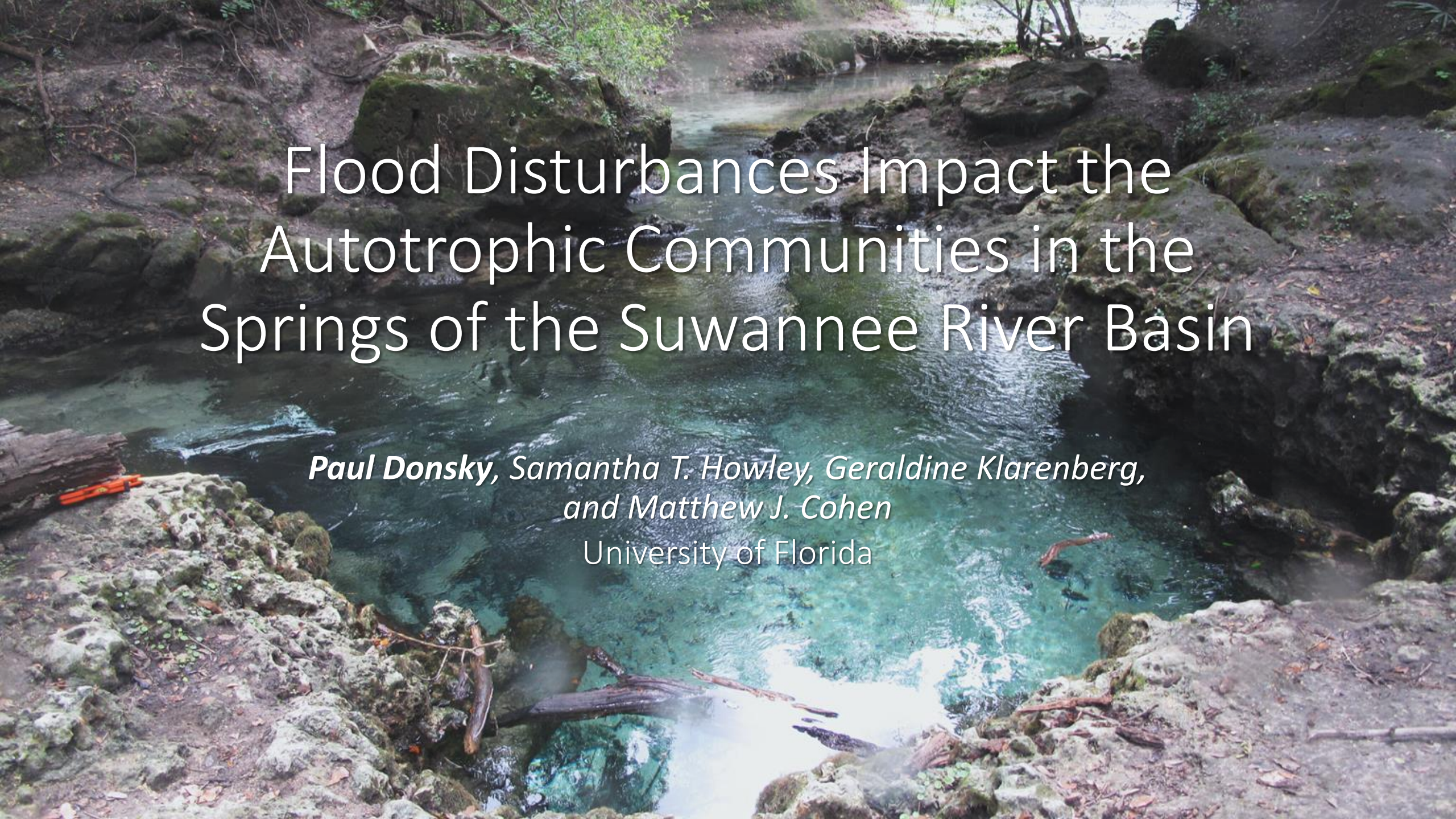

Flood Disturbances Impact the Autotrophic Communities in the Springs of the Suwannee River Basin

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Ecosystem State Change

- Pulse Disturbances: short duration, rapid shift
- Press Disturbances: long duration, gradual change
- Interactions: Press disturbances reduce resilience, priming a lasting state shift after a pulse disturbance
- Disturbance regimes are changing due to human impacts
- Entangled interactions complicate management

(Menge et al., 2021)

https://springseternalproject.org/

Then & Now: SAV gone in most springs, often replaced by algae

What are the underlying causes?

What are the roles of press and pulse disturbances?

Press disturbances in springs

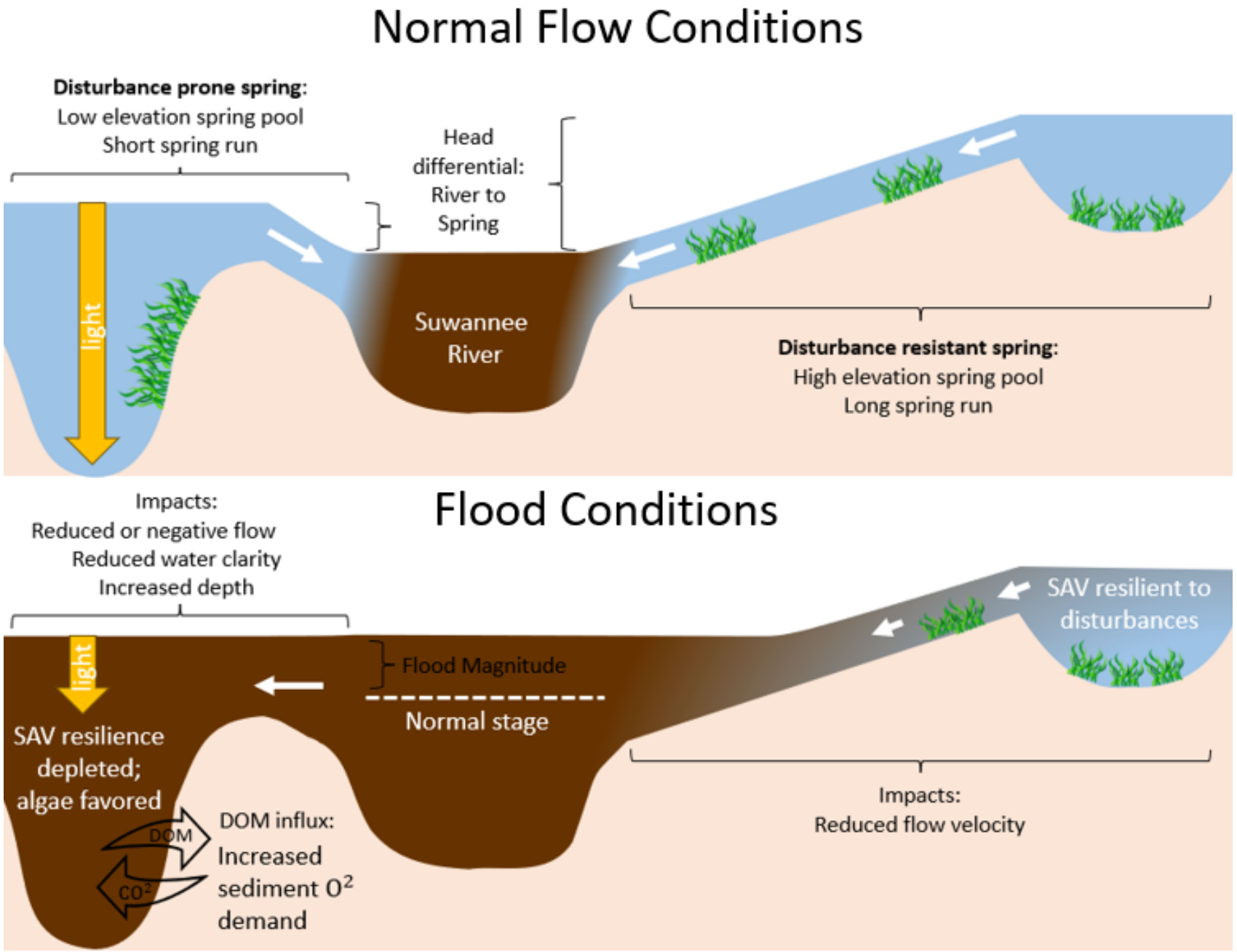
- Much more frequently studied and cited factors
  - Flow reductions
  - Nutrient pollution
  - Clarity
  - Recreation
  - Dissolved Oxygen

Pulse disturbances in springs

- Ecological impacts completely unstudied
- River Intrusion Events (RIEs): Surface waters flood into springs
  - Flow reversals: surface water completely displaces groundwater, spring becomes a sink
  - Brownout: surface waters mix with groundwater in spring pool
- Reduction in light availability: potential effect on autotrophs

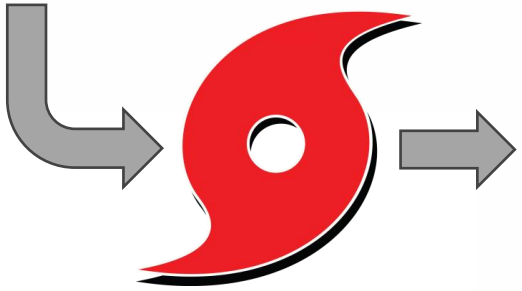
RIE Cross Section

- River stage ≥ aquifer stage
- Increased depth and decreased clarity
- Introduce DOM, trigger respiration, reducing oxygen
- Springs higher above river more resistant to RIEs



Case study: Gilchrist Blue Springs

- Santa Fe River rose 4 meters and covered Gilchrist Blue Springs for several weeks
- *S. kurziana* was the dominant SAV Species
- Most SAV gone after flood
- Some recovery but *S. kurziana* remains scarce
- Similar events in Crystal River and the St. Johns River



Hurricane Irma

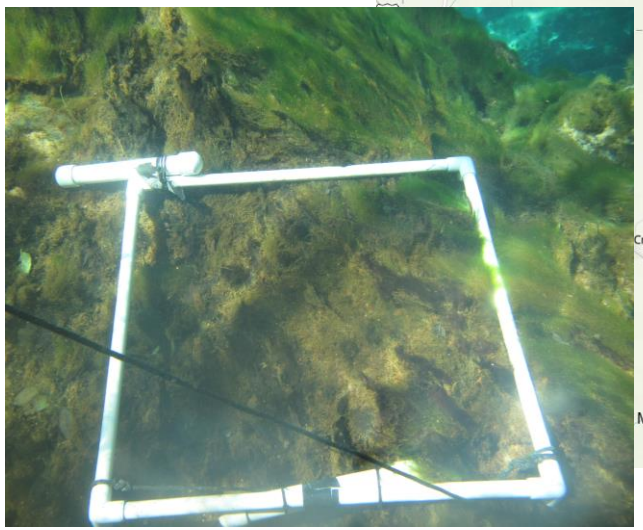
(Adler et al. 2018)

Hypothesis

- Autotrophic community structure in springs is controlled by disturbance regimes
- Specifically: springs with more frequent disturbances will be less likely to support SAV and exhibit higher prevalence of algae through reduced competition

Study Site and Survey Methods

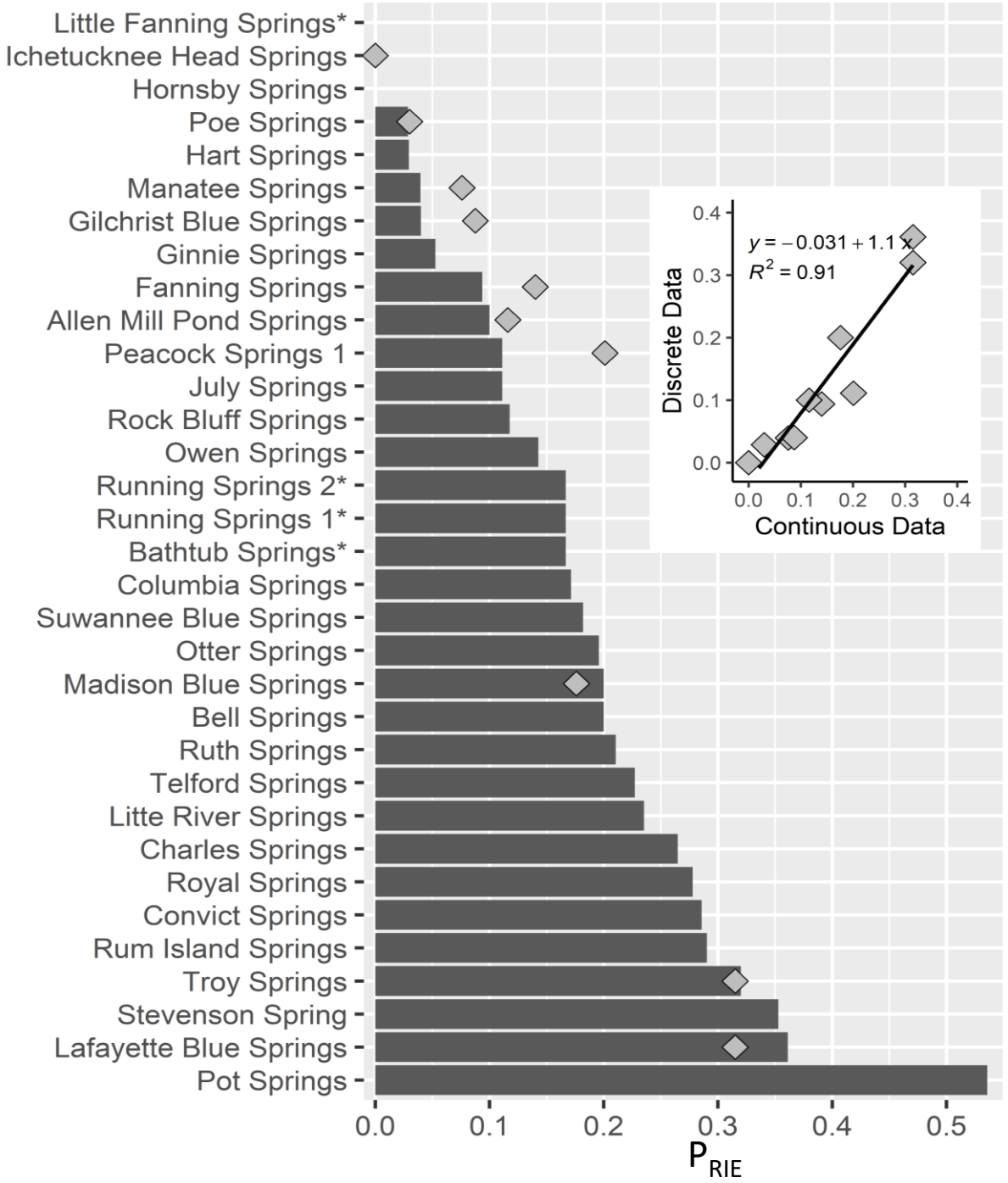
- Suwannee River Basin
- 62 springs sampled from May 2022 to April 2023
- Quadrat survey: measured % cover of algae and SAV within a $0.5\mathrm{m}^2$ area in haphazardly selected locations
  - n samples based on the size of spring
- Dissolved oxygen (DO) and Specific Conductance (SpC) measured in spring vent



Disturbance Frequency (P_{RIE}) Distribution

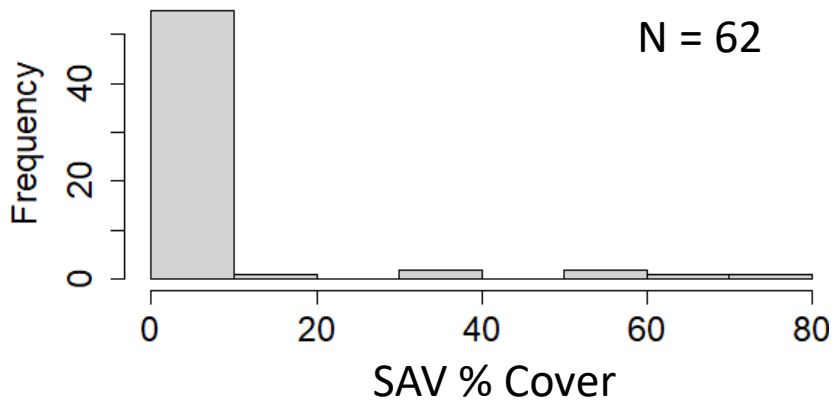
- Determined using water quality data, mainly specific conductivity (2014-2022)
  - SpC: high in GW, low in surface water
- Bars: frequencies from discrete sample method
- Points: frequencies from continuous data method
  - Discrete observations accurately capture pulse disturbance frequency

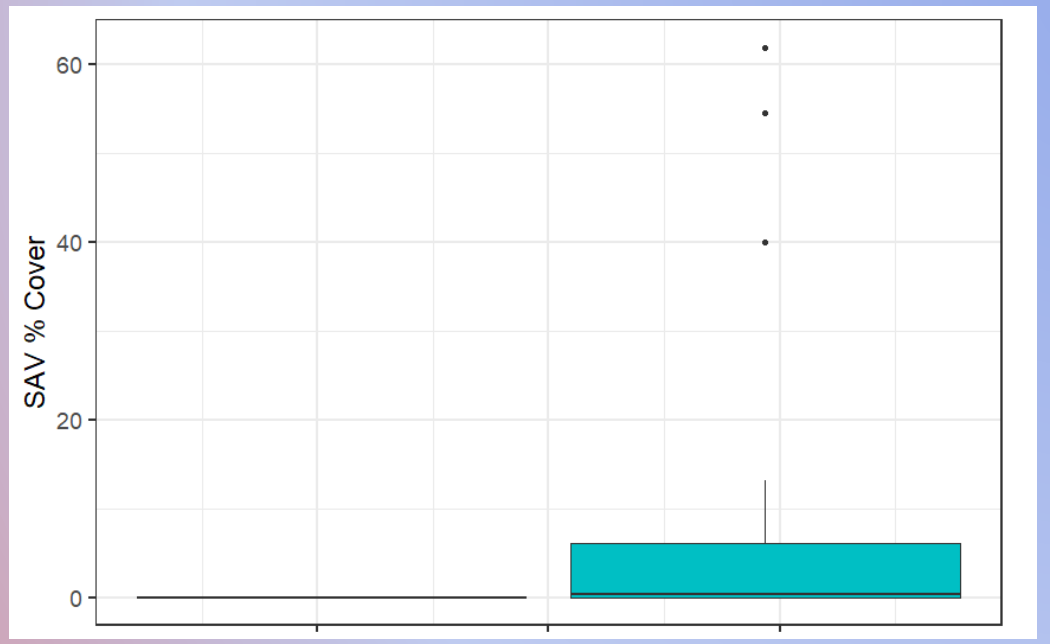
- Average frequency for Suwannee Springs = 0.17

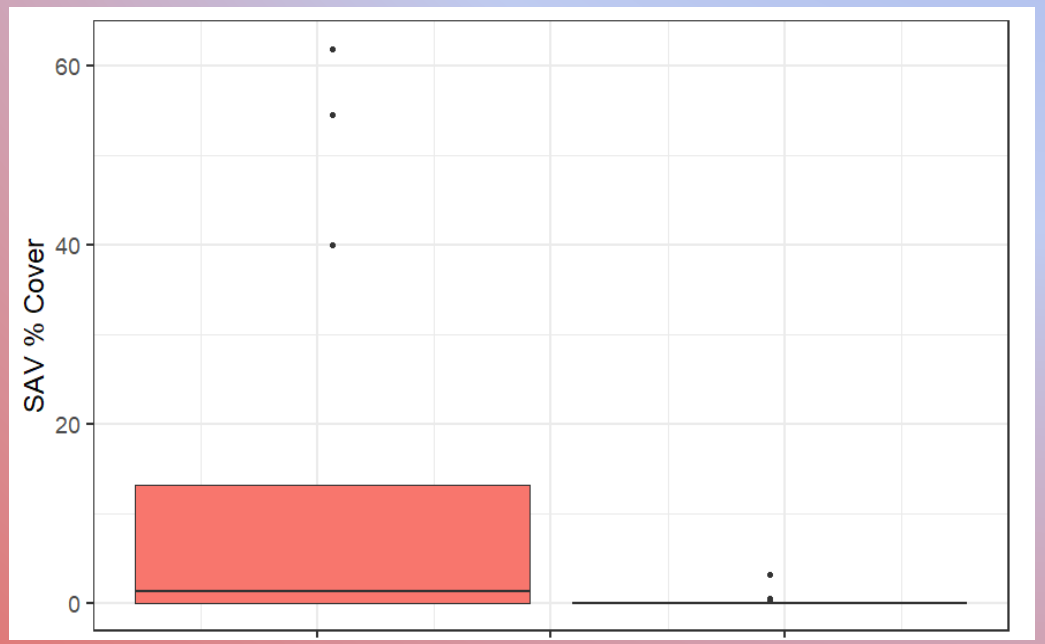


Results – SAV % Cover

- Heavily skewed distribution: all models non-significant
- Visual data exploration revealed thresholds
  - Tested with Mann-Whitney U test
- P_{RIE}: 0.2 ($p = 0.004$)
- DO: 2 mg/L ($p < 0.01$)







Floridastateparks.org

Ginniespringsoutdoors.com

SAV Growth Requirements

- Minimum light requirements for freshwater SAV: 10% surface irradiance[a]
- Ichetucknee River: average percent-transmittance = 53% at 1m[b]
- Santa Fe River = 1-23%; probably on the lower end during floods
  - % Transmittance to bed probably < 10%
- What are the effects of a two-month long RIE?

[a]Kemp et al., 2004
[b]Florida Springs Institute, 2020

Results – Algae % Cover

- On its own, P_{RIE} is not a significant predictor of algal cover

	Variable	Relationship	p-value
Model 1	P_{RIE}	Negative	0.72
Pseudo-R^2 = 0.04			

Results – Algae % Cover

- On its own, P_{RIE} is not a significant predictor of algal cover
- Significance emerges in multivariate models
- Model 1a: Interaction effect between P_{RIE} and DO
  - Observed in previous research (Hensley and Cohen, 2017)

	Variable	Relationship	p-value
Model 1	P_{RIE}	Negative	0.72
Pseudo-R^2 = 0.04			
Model 1a	P_{RIE}	Negative	**0.007**
Pseudo-R^2 = 0.35	DO	Negative	**<0.001**
	P_{RIE} * DO	Positive	**0.006**

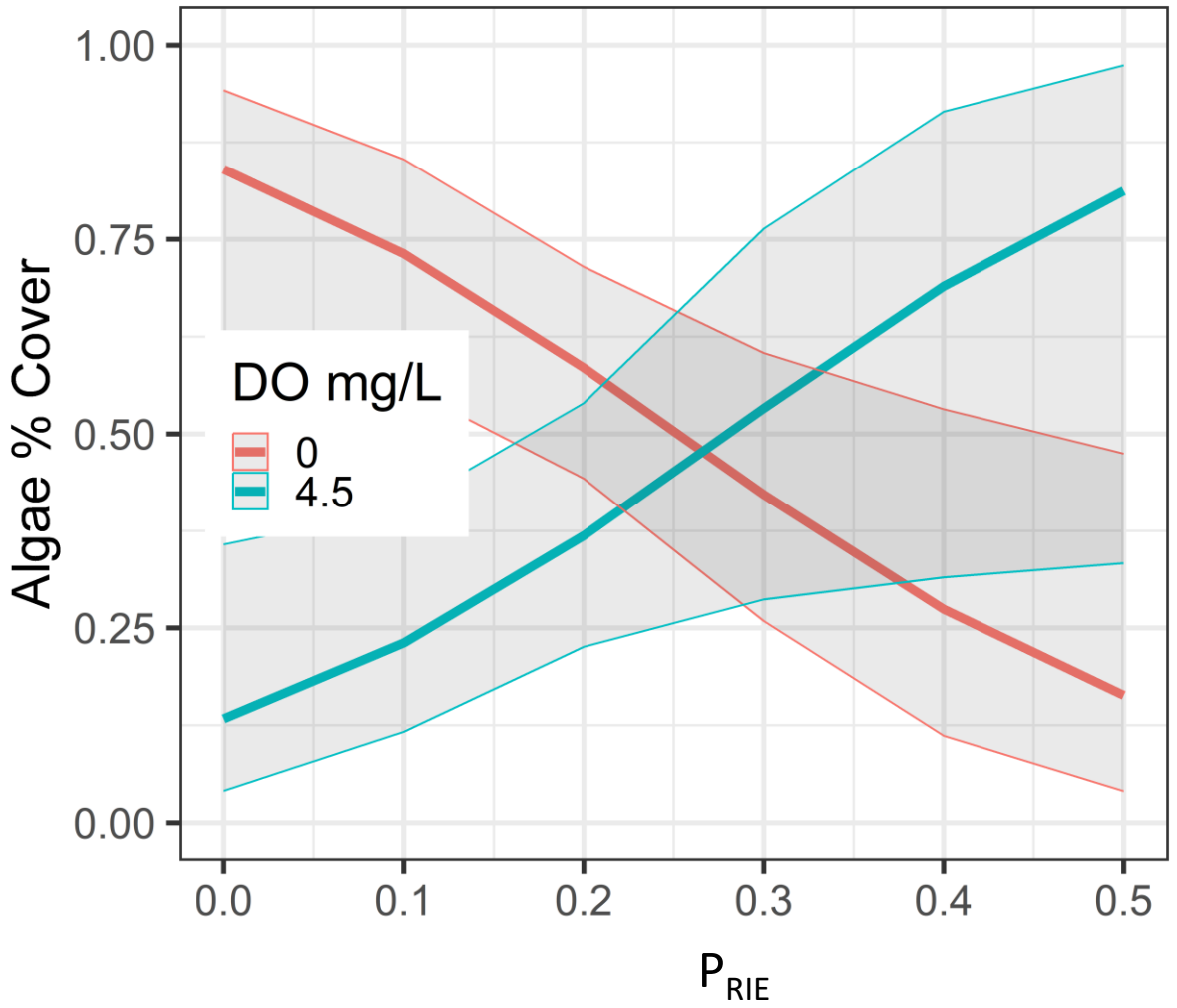
Results – Algae % Cover

- On its own, P_{RIE} is not a significant predictor of algal cover
- Significance emerges in multivariate models
- Model 1a: Interaction effect between P_{RIE} and DO
  - Observed in previous research (Hensley and Cohen, 2017)
- Best selected model also includes Recreation, depth (stdev), and Total Phosphorous (TP)
  - TP: best univariate predictor of algae cover ($p = 0.026$, Pseudo-$R^2 = 0.15$, $df = 32$)
    - No relationship observed with Nitrate

	Variable	Relationship	p-value
Model 1	P_{RIE}	Negative	0.72
Pseudo-R^2 = 0.04			
Model 1a	P_{RIE}	Negative	**0.007**
Pseudo-R^2 = 0.35	DO	Negative	**<0.001**
	P_{RIE} * DO	Positive	**0.006**
Model 1b	P_{RIE}	Negative	**<0.001**
Pseudo-R^2 = 0.54	DO	Negative	**0.003**
	P_{RIE} * DO	Positive	**0.002**
	Recreation	Negative	**0.023**
	Depth (stdev)	Positive	**0.002**
	Total Phosphorous	Positive	**0.099**

DO x RIE Interaction

- Evidence that RIEs increase algal cover by reducing competition with SAV
- In springs with no DO (no SAV) increased RIEs inhibit algae



Oxygen and ecosystem state

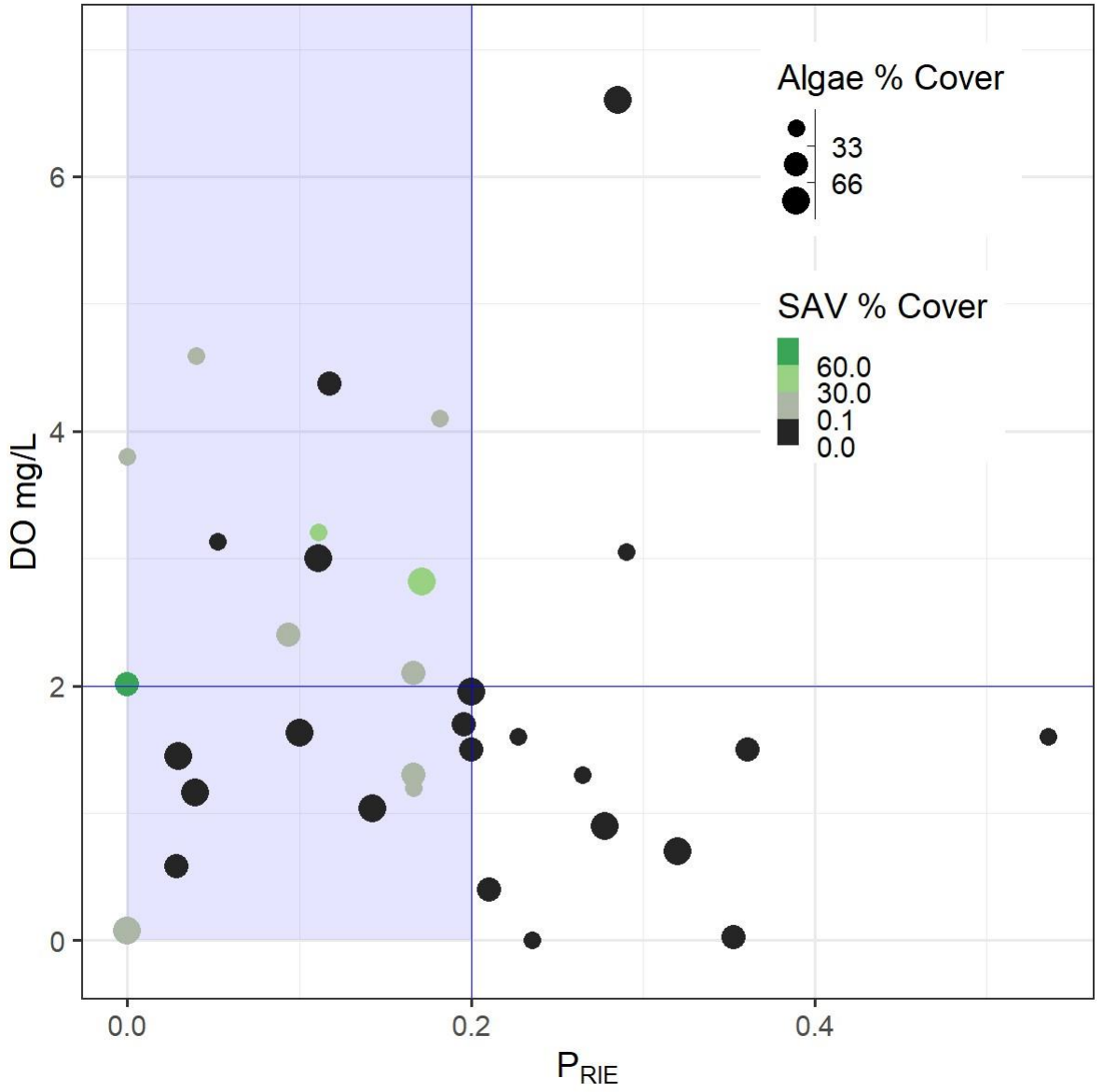
- Springs with high P_{RIE} (>0.20) exclusively support algae
- Intermediate P_{RIE} (0 to 0.20): SAV distributed along DO gradient
- SAV produces oxygen and needs it to grow
  - Possible negative feedback loops

➢ Disturbances stress SAV communities

➢ Sediment hypoxia

➢ SAV recovery prevented

➢ Algae-dominated stable state



Major Takeaways

1. RIEs are associated with both SAV loss and algal proliferation
   - 20% disturbance threshold for SAV survival has implications for springs protection plans (MFLs) and SAV restoration projects
2. Oxygen is a critical covariate with autotrophic community structure
   - Negative feedback loops could play a role in maintaining algae-dominated states, inhibiting SAV recovery
3. Disturbance regime is predictable based on hydrologic properties
   - Further sources of variation should be investigated, including the degree of anthropogenic influence

Future Research

- Long-term studies: Direct observations on effects of disturbances of different sizes and recovery patterns
- Mesocosm studies: Disentangle interaction effects with DO and nutrients