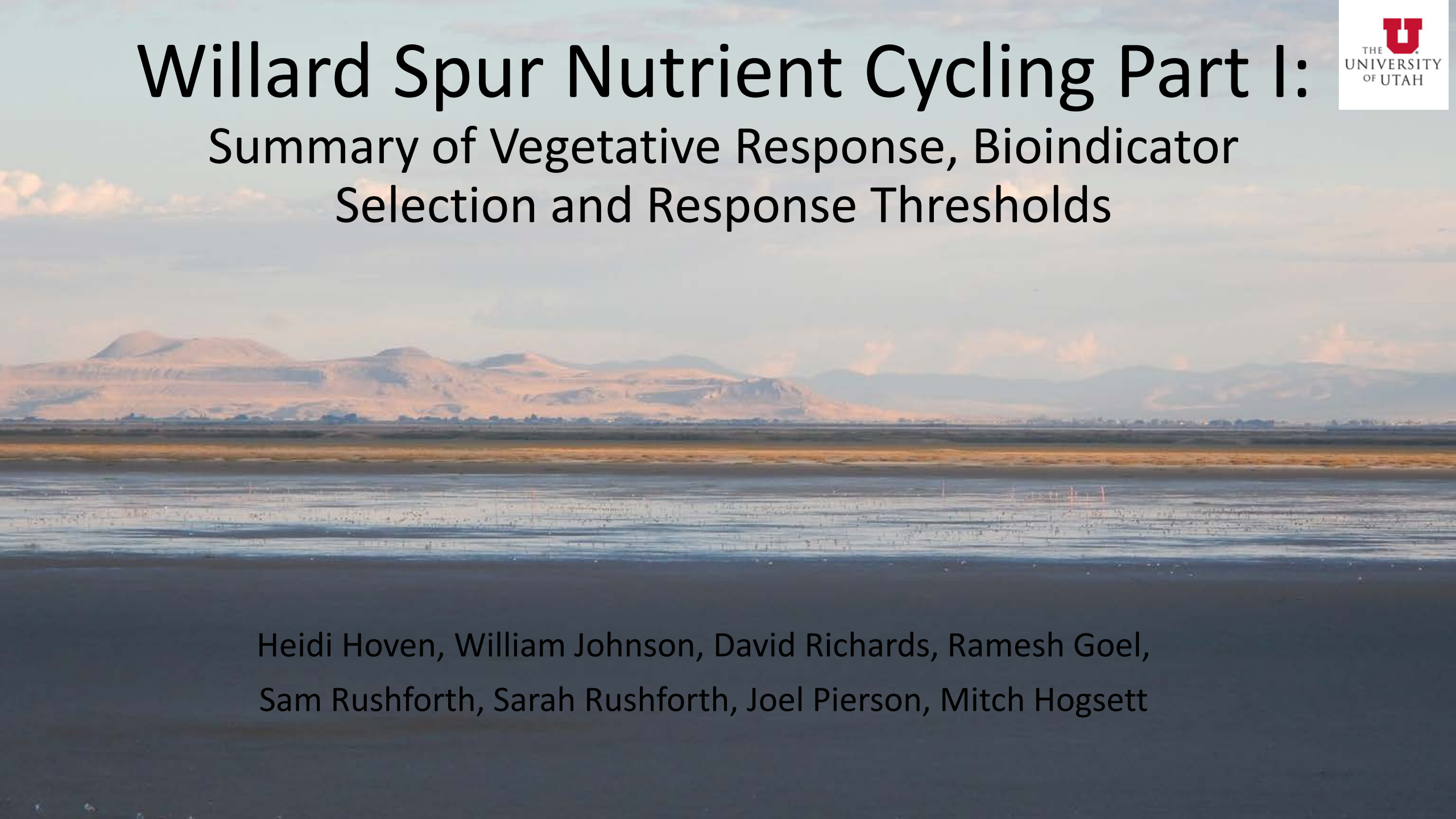
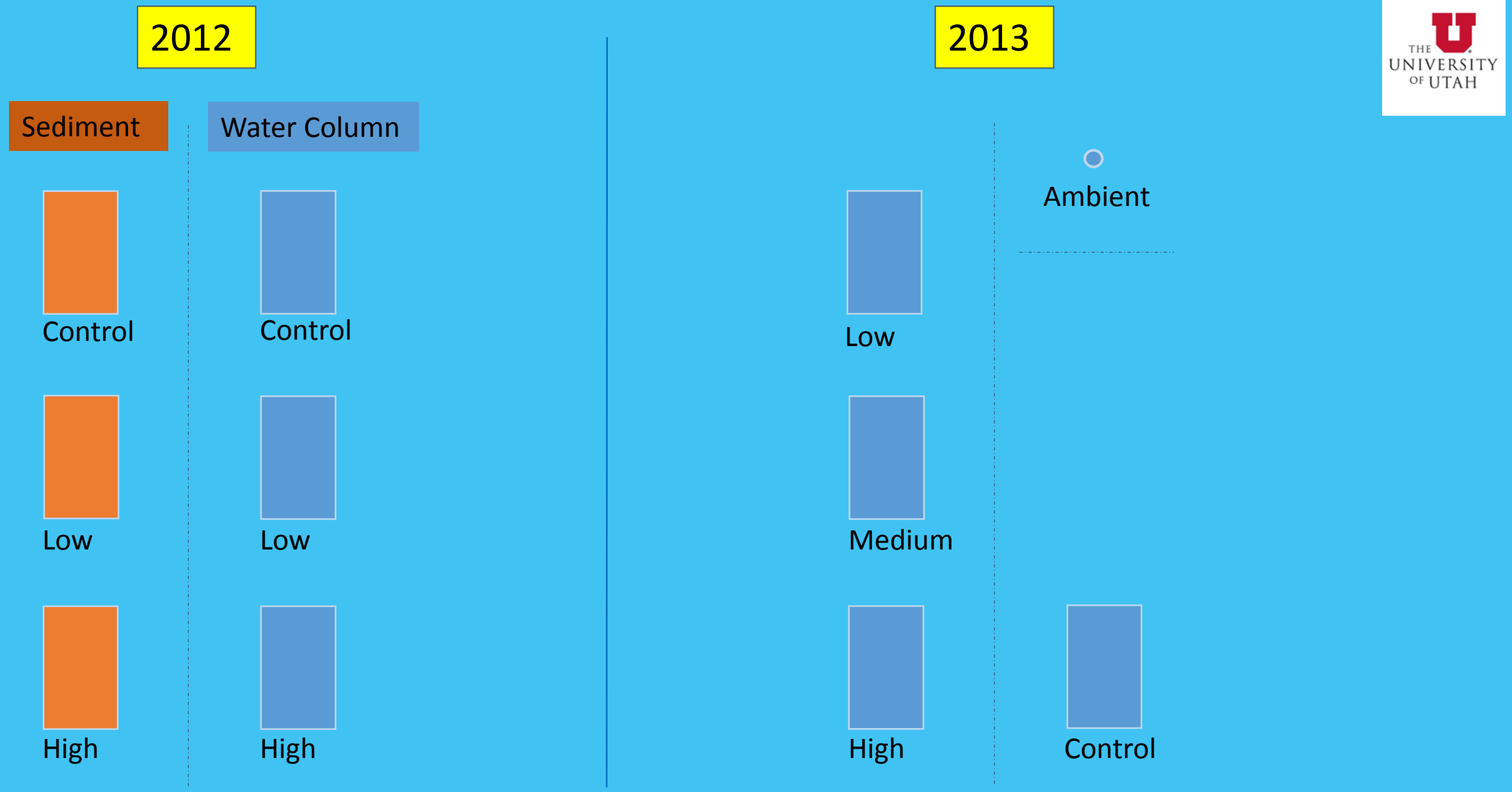
Willard Spur Nutrient Cycling Part I:

Summary of Vegetative Response, Bioindicator Selection and Response Thresholds



Heidi Hoven, William Johnson, David Richards, Ramesh Goel,

Sam Rushforth, Sarah Rushforth, Joel Pierson, Mitch Hogsett



Nutrient Amendment Experimental Design (not to scale)

Metrics used to Identify Bioindicators and Threshold Responses of Nutrient Enrichment in Willard Spur

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2012

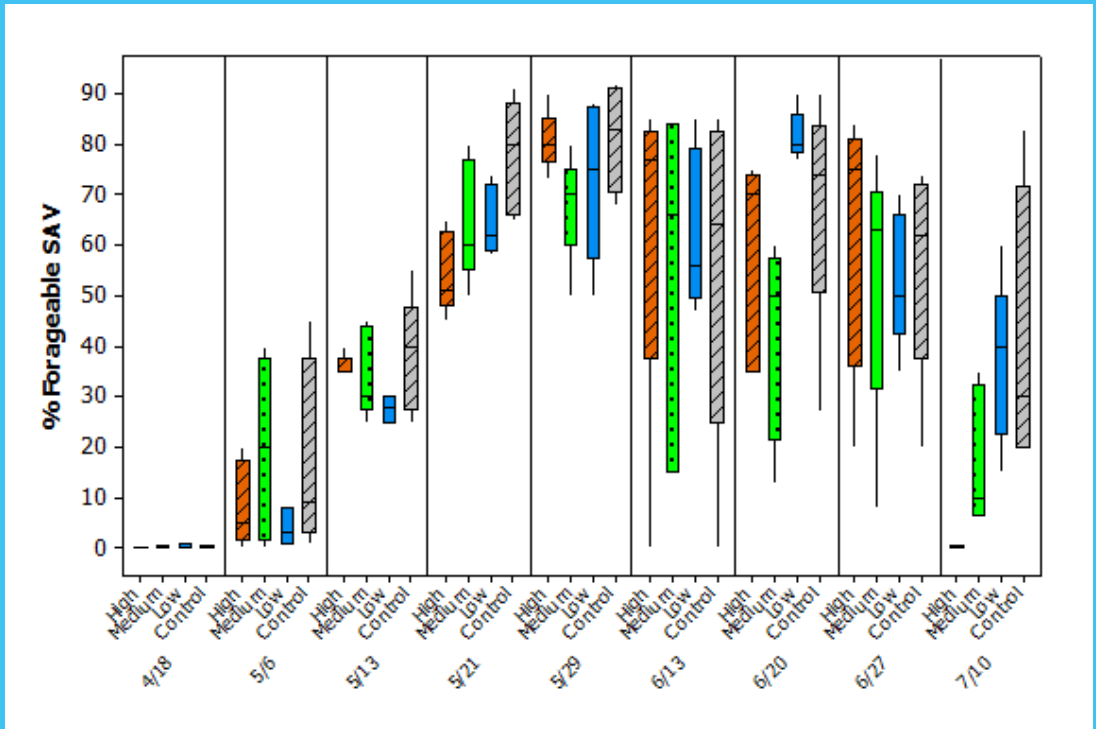
- **Percent cover Forageable SAV***
- Percent cover Total SAV
- **Branch Density***
- **Percent cover Algae on SAV***
- Percent cover BDS on SAV
- SAV Condition Index
- SAV Tuber and Drupelet Productivity
- Percent cover Surface Mat (algae, other)
- Phytoplankton Biomass (chl *a*)
- Phytoplankton Assemblages
- Periphyton Biomass
- Macroinvertebrate Density and Biomass
- Light penetration

2013

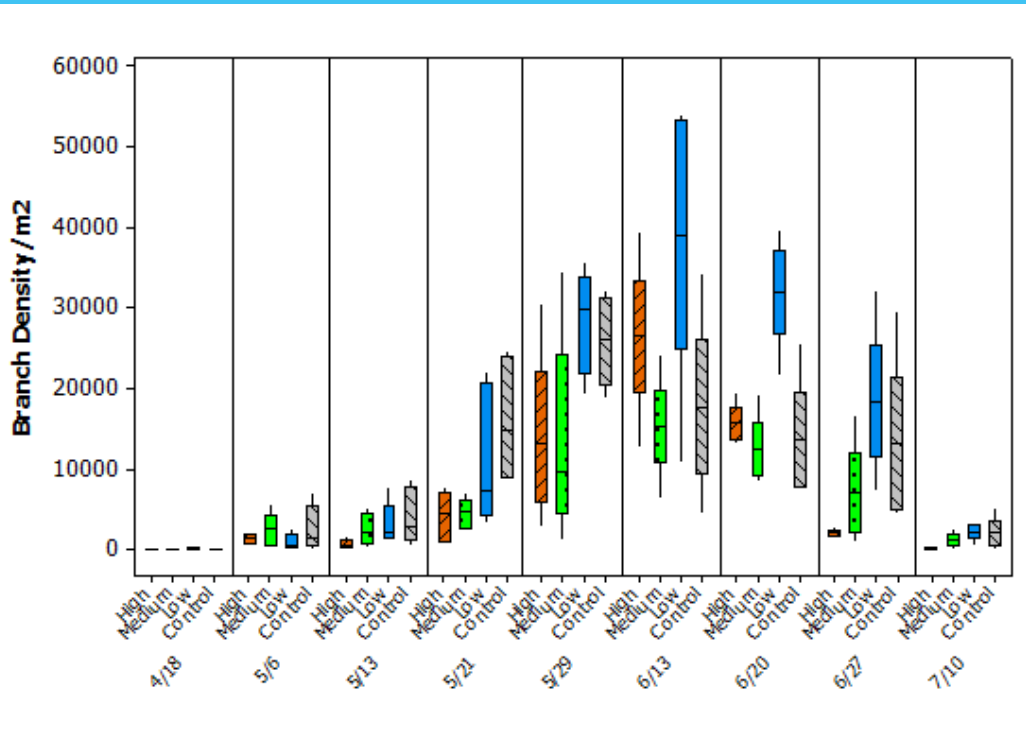
- Percent cover Forageable SAV
- Percent cover Total SAV
- Branch Density
- Percent cover Algae on SAV
- Percent cover BDS on SAV
- Percent cover Algae + BDS
- DWQ Condition Index
- Modified Condition Index
- Percent cover Surface Mat (algae, other)
- Light penetration

Natural, temporal (and treatment effect) changes that occur in Willard Spur submergent wetlands

2013



2013



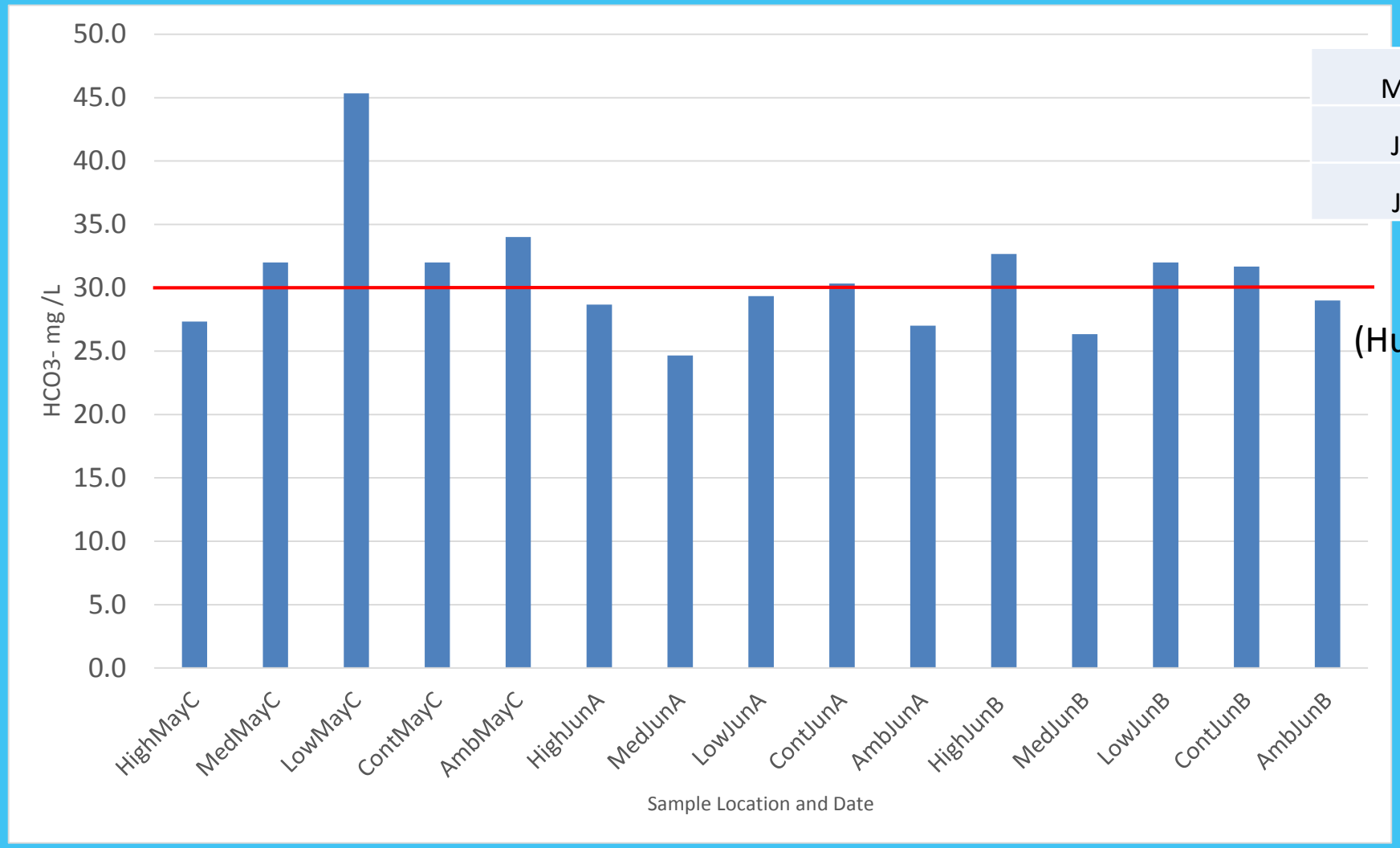
What factors drive the changes observed in the macrophyte community? (on a dry year)

- Spring inflow
  - Nutrients, dissolved, associated with particulates
  - Sediment / turbidity (not measured)
  - Dissolved organic material (not measured)
- pH / Alkalinity
- HCO_3^-
- Early through late summer natural impoundment

Water Column pH, 2013

May C	30-May
Jun A	13-Jun
Jun B	27-Jun

HCO_3^- Compensation Point (*S. pectinata*), 2013



May C	30-May
Jun A	13-Jun
Jun B	27-Jun

(Huebert & Gorham 1983)

How do natural variability in biological processes and productivity relate to nutrient cycling in Willard Spur?

Macrophytes (SAV)

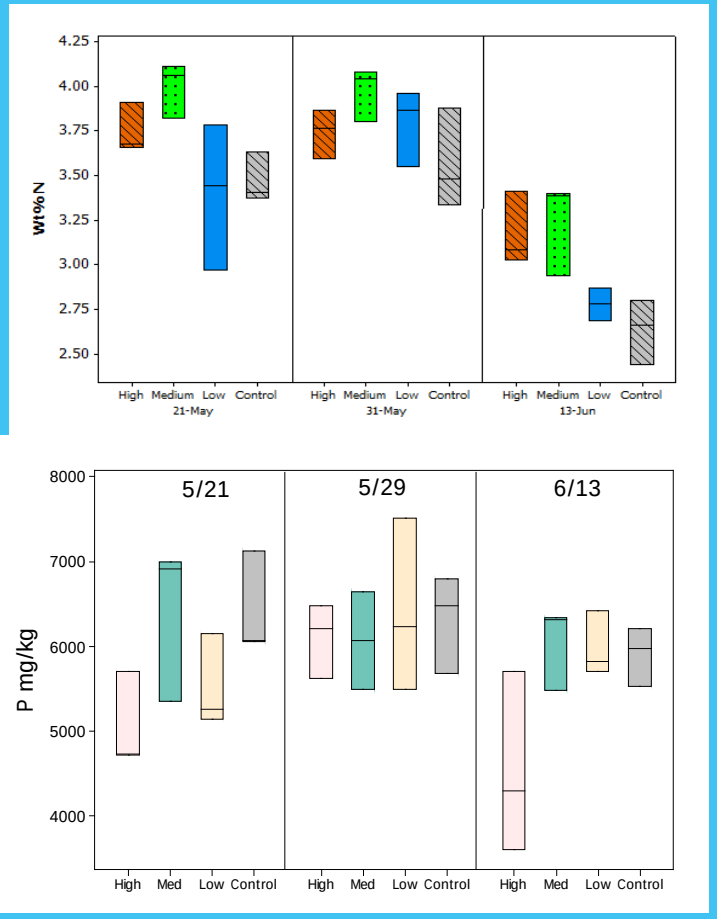
- Not P-limited
- Possibly N-limited
  - Optimal growth at 2013 Low Amendment

Filamentous Algae on SAV

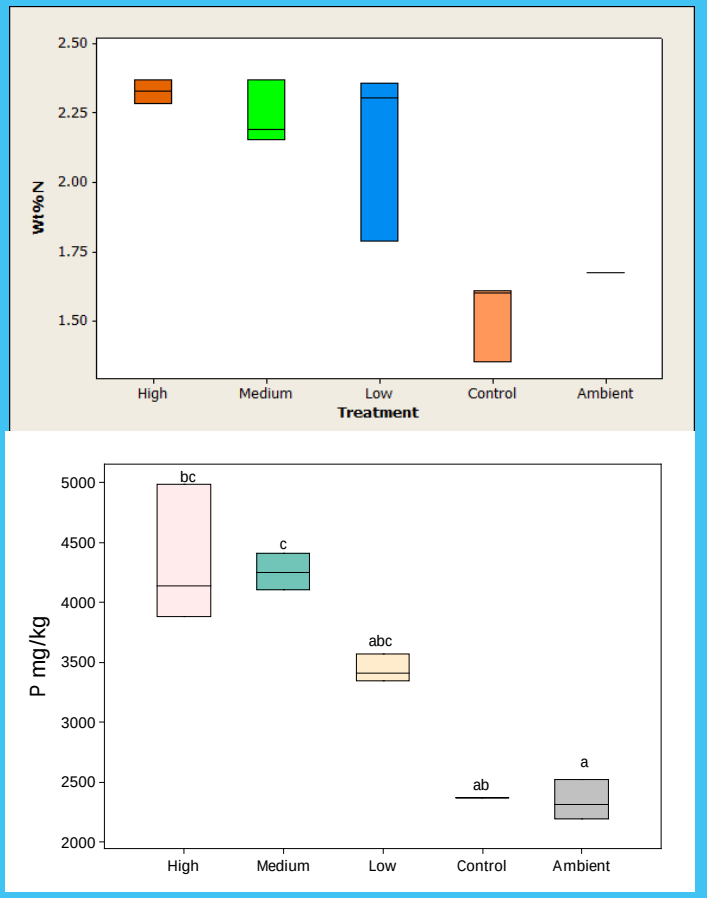
- Possibly P-limited
- Possibly N-limited

Tissue Nitrogen and Phosphorus content, 2013

S. filiformis leaf N and P



Algal N and P, June 13th



What constitutes a negative/unacceptable response to nutrients by the SAV, macroinvertebrate community, phytoplankton, macroalgae?

Macroalgal surface mats

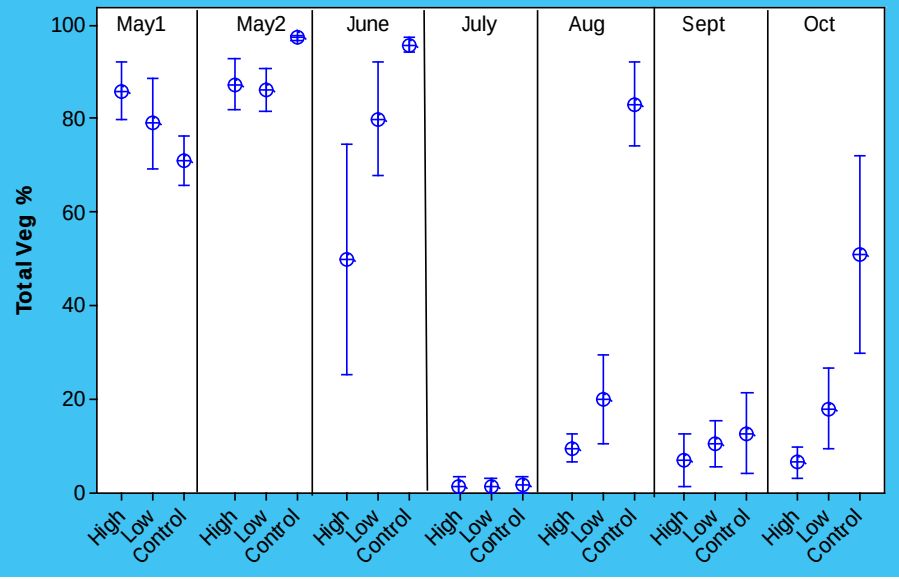
- Not able to stimulate a significant macroalgal surface mat response, although there was more macroalgae present during 2012 than 2013 (amendment and control); no significant nutrient enrichment response

Macroinvertebrates & Phytoplankton (2012)

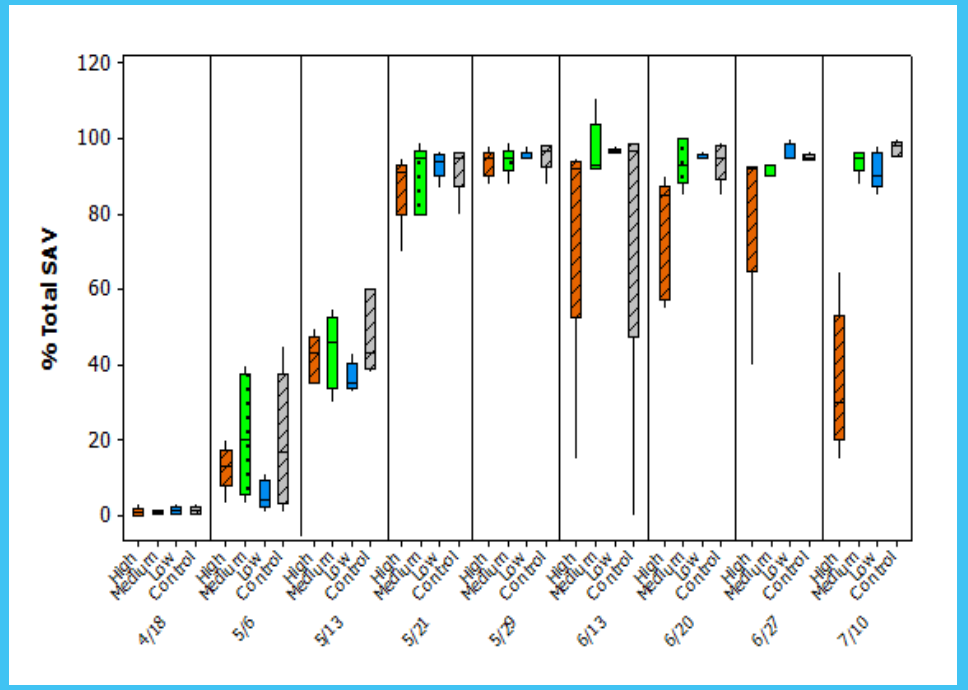
- Macroinvertebrate: no significant nutrient enrichment response
- Phytoplankton: no significant nutrient enrichment response

Trophic Shifts

- Early summer: High macrophyte species diversity (7+ species) and cover in (amendments and control)
  - Abundant foraging (birds and fish)
  - Abundant physical habitat (macroinvertebrates and juvenile fish)
- Mid-summer: Decline in macrophyte species diversity (1+ species), variable SAV cover (amendments* and control)
  - Loss of forageable SAV* (w/r/t waterfowl)
  - Patchy habitat for macroinvertebrates and related foraging
- Late summer: Onset of phytoplankton bloom, likely in response to nutrient release from decomposing plant material (2012, 2013)
- Late summer, early fall: Highest biomass macroinvertebrates (2012)
  - FFG = Scrapers (snails) in August
  - FFG = Collectors/gatherers (midges) (important for waterfowl) Sept / Oct*
  - Sampling technique likely biased against corixids (shorebirds observed feeding in shallow water throughout summer and early fall)



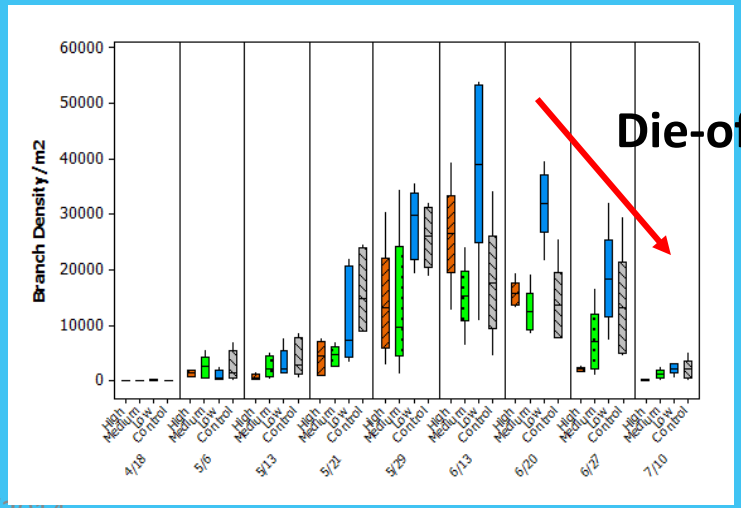
2012

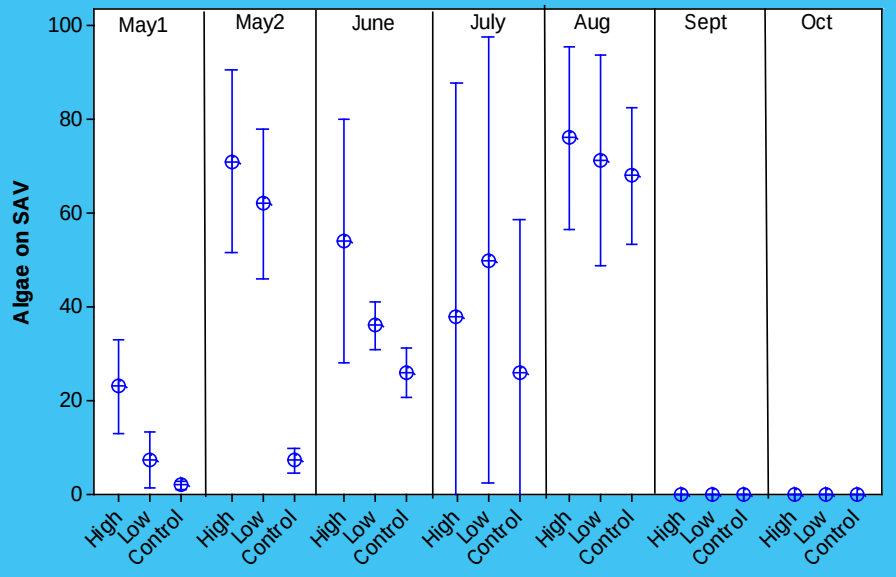


2013

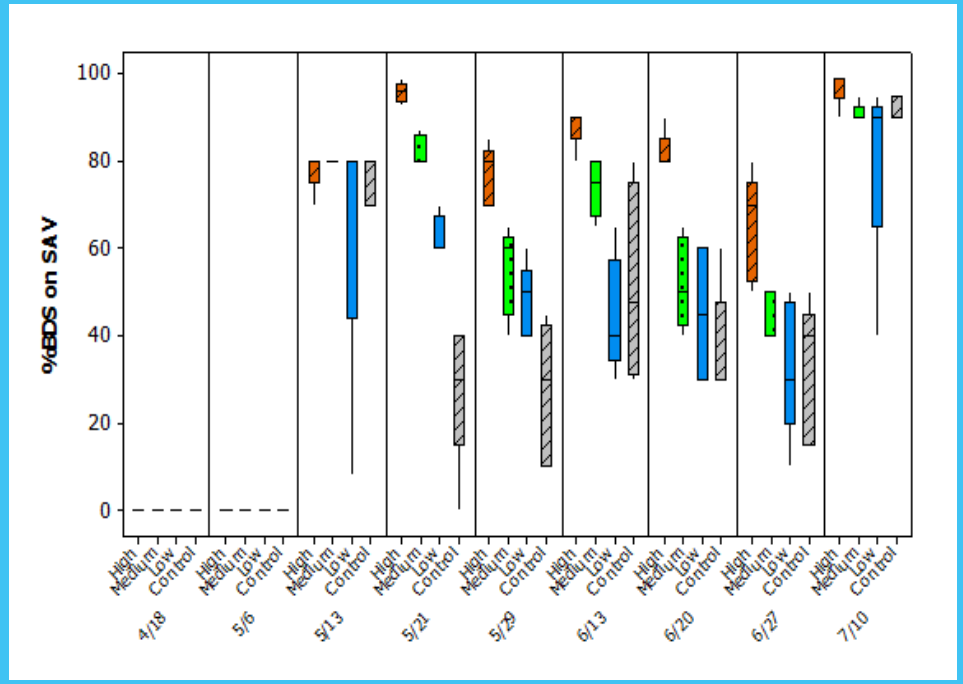
Trophic Shifts

- 2012: High filamentous algae (*Cladophora glomerata*) associated with SAV in amendments
  - Significant, positive response to N and P
- 2013: High BDS (biofilm/diatoms/sediment) on SAV in amendments
  - Significant, positive response to N and P
  - Responded to nutrient release from decomposing SAV





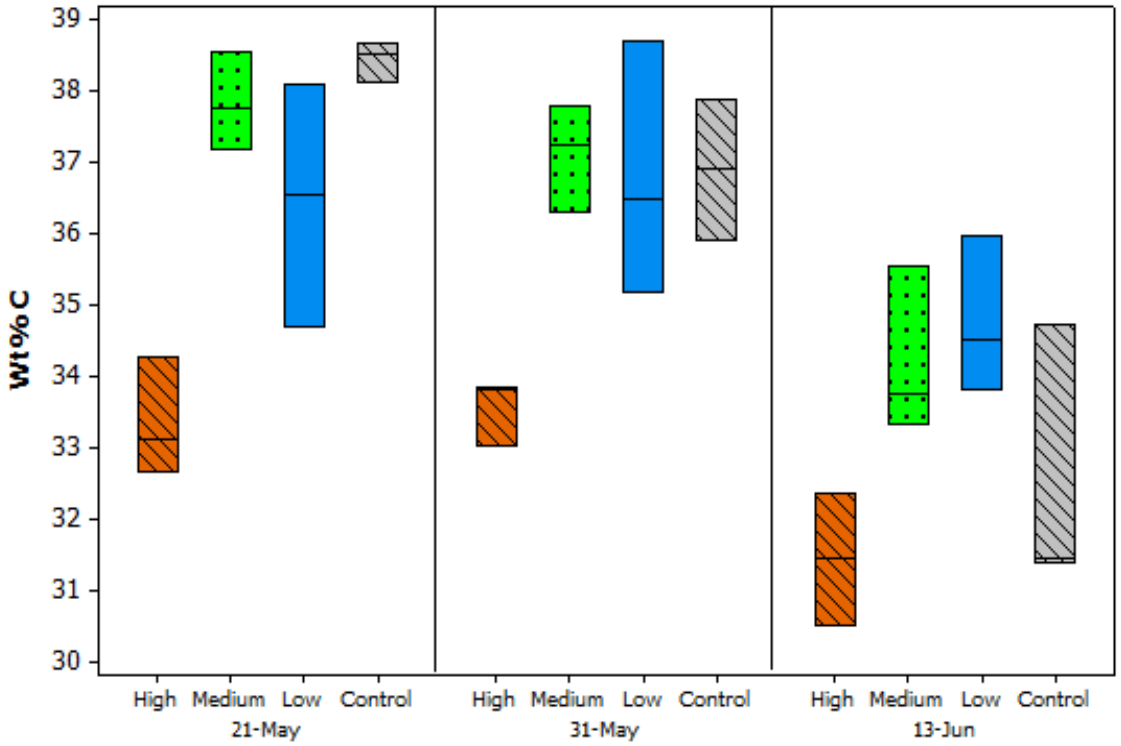
2012



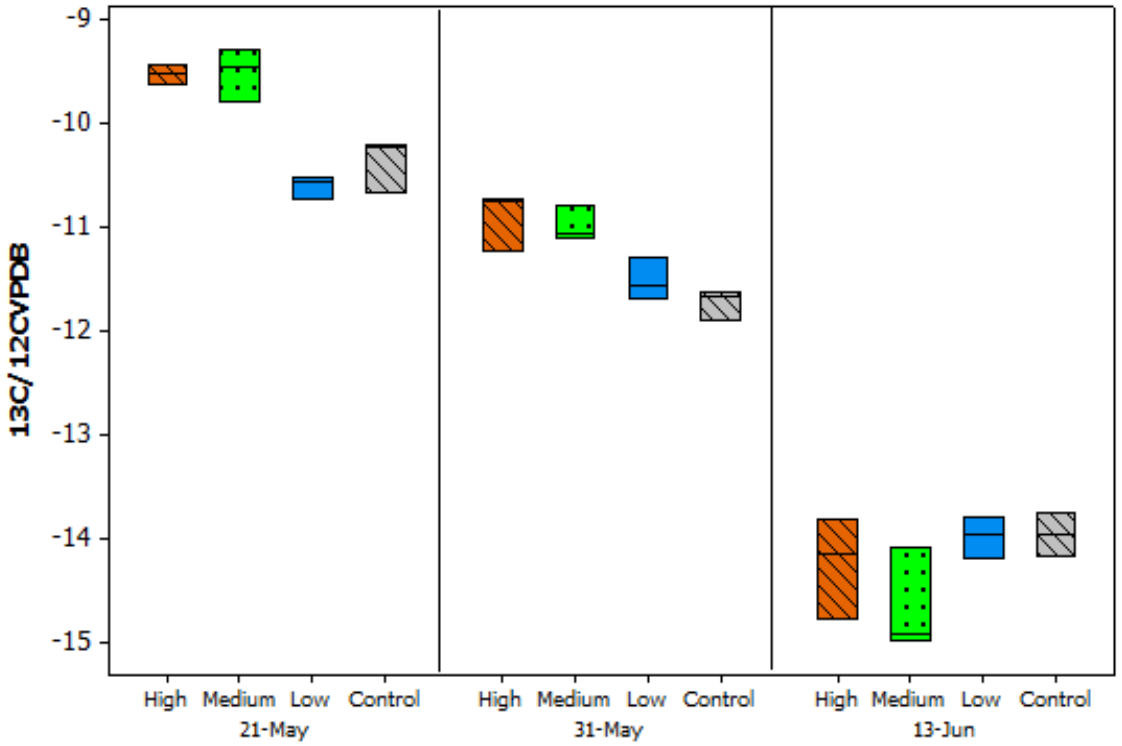
2013

Tissue Carbon content, 2013

S. filiformis leaf C



S. filiformis leaf $\delta^{13}C$ values



What constitutes a negative/unacceptable response to nutrients by the SAV, macroinvertebrate community, phytoplankton, macroalgae?

Premature SAV die-off

- High Amendments both years
  - 2012 die-off occurred up to one month prior to control SAV
  - 2013 die-off occurred 2 weeks prior to control

++ Algae and BDS associated with SAV

- Indirectly affect SAV
  - Impedes gas exchange
  - Raises local pH

- Stagnant conditions impede C diffusion
- WS at or below HCO_3^- compensation point: induces stress on SAV
  - Dependence on HCO_3^-, lower PS efficiency (Sand-Jensen 1982)
- Treatment effect on C assimilation by SAV

What triggers could be used to monitor for a negative/unacceptable response to nutrients?

1. Biondicator Selection: **Methods**

- 9 plant metrics evaluated (2013):
  - Branch Density
  - % Total SAV
  - % Total Mat
  - % Forageable SAV
  - % BDS on SAV
  - % Algae on SAV
  - % Algae and BDS on SAV
  - DWQ Condition Index, and
  - Modified Condition Index
- Evaluated using:
  - Box plots (median, 25th and 75th percentiles)
  - Non-parametric Kruskal-Wallis tests; factors = Julian weekly date and treatment.
  - Two-tailed test of multiple pairwise comparisons

What triggers could be used to monitor for a negative/unacceptable response to nutrients?

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1. Biondicator Selection: Kruskal-Wallis tests

Metric	Factor	DF	K (observed)	K (critical)	p-value
SAV					
Branch Density	Date	5	61.52	12.59	< 0.01
	Treatment	3	17.90	7.82	< 0.01
% Total SAV	Date	3	1.04	7.82	0.79
	Treatment	3	32.89	7.82	< 0.01
% Total Mat	Date	2	0.05	5.99	0.98
	Treatment	3	3.60	7.82	0.31
% Forageable SAV	Date	7	83.59	14.07	< 0.01
	Treatment	3	3.81	7.82	0.28
% BDS on SAV	Date	6	57.22	12.59	< 0.01
	Treatment	3	41.48	7.82	< 0.01
% Algae on SAV	Date	6	26.56	12.59	< 0.01
	Treatment	3	27.08	7.82	< 0.01
% Algae + BDS on SAV	Date	6	19.54	11.07	< 0.01
	Treatment	3	56.42	7.82	< 0.01
DWQ Condition Index	Date	2	44.15	7.82	< 0.01
	Treatment	3	9.93	7.82	< 0.01

1. Biondicator Selection

Multiple pairwise comparisons of four nutrient treatments (2013)

Metric	Treatment			
	High	Medium	Low	Control
SAV				
Branch Density/m^2	A	A	B	AB
% Total SAV	A	B	B	B
% Total Mat	A	A	A	A
% Forageable SAV	A	A	A	A
% BDS on SAV	A	B	C	C
% Algae on SAV	A	A	AB	B
% Algae + %BDS on SAV	A	B	C	D
Modified Condition Index	A	AB	B	AB
DWQ Condition Index	A	B	B	AB


“All models are wrong; but some are more useful than others”

What constitutes a negative/unacceptable response to nutrients by the SAV, macroinvertebrate community, phytoplankton, and macroalgae

2. Response Thresholds: Methods

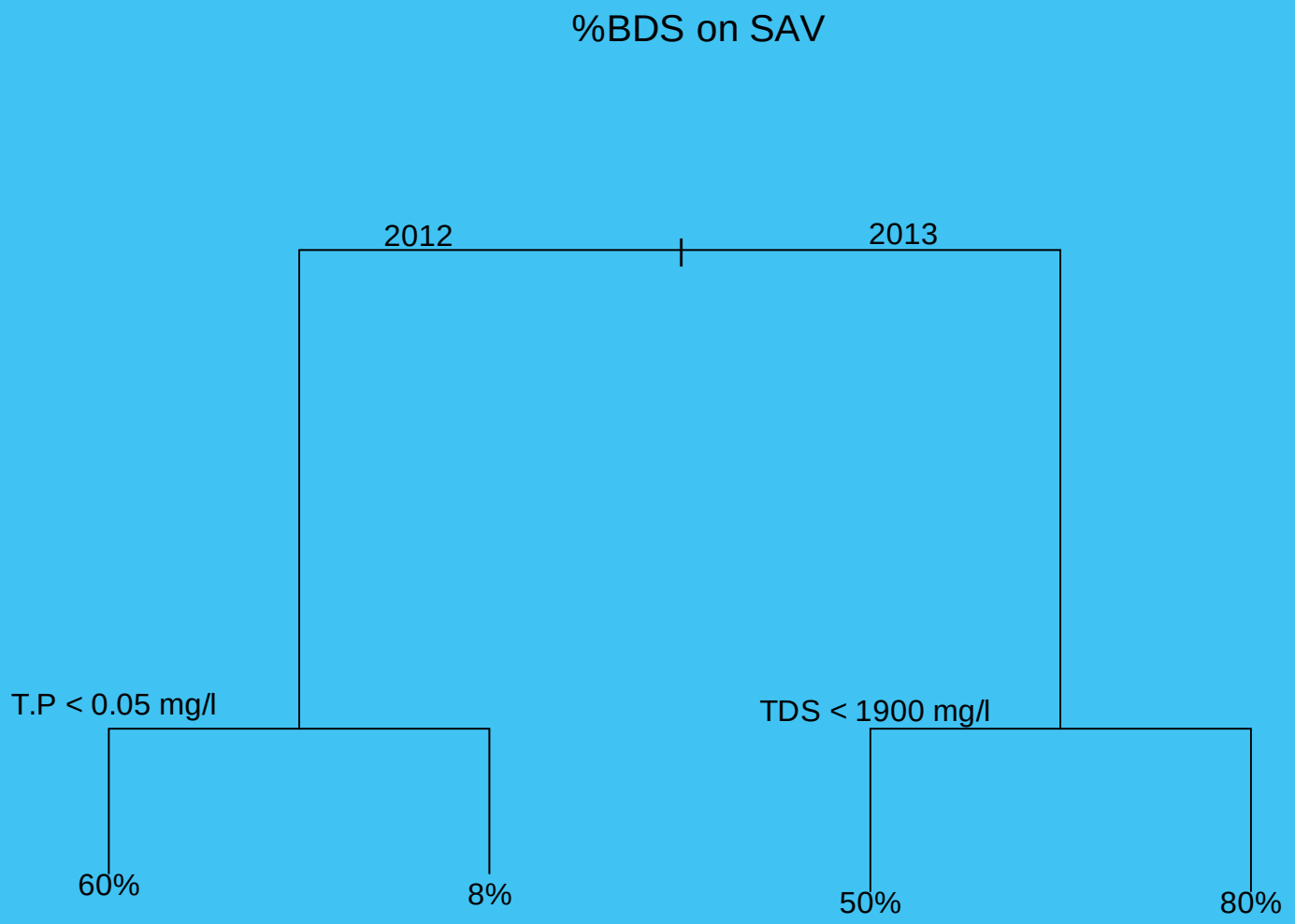
- Modeled relationships between relevant SAV metrics and environmental variables using **Classification and regression tree analyses (CART)**
- CART more powerful alternative to:
  - linear and additive regression models for *quantitative data*
  - linear and additive logistic models for *categorical data*
- Models fit by successively splitting the data to form homogeneous subsets

What constitutes a negative/unacceptable response to nutrients by the SAV, macroinvertebrate community, phytoplankton, macroalgae?

2. Response Thresholds: Methods

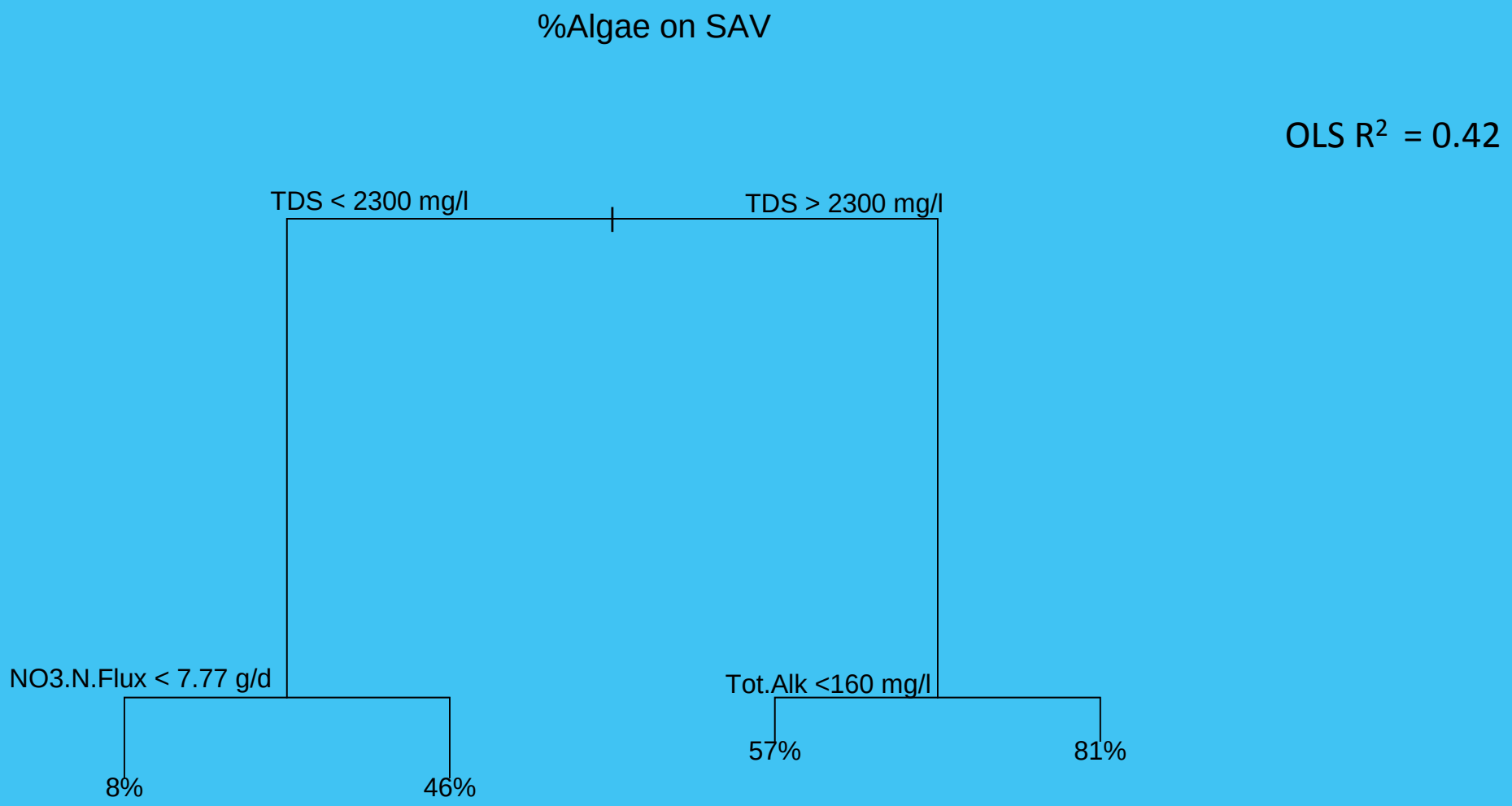
- Results were **hierarchical trees of decision rules** for **prediction/ classification** of plant metrics.
  - **Trees 'pruned'** using **cost-complexity pruning deviance and optimal recursive shrinking**
  - Cost complexity pruning determined the nested sequence of subtrees by recursively "snipping" off the least important splits
  - typically yielding trees of 4 to 5 branches
- OLS- multiple regressions conducted on CART variables to examine:
  - linear or additive responses

2. Approximate Response Thresholds



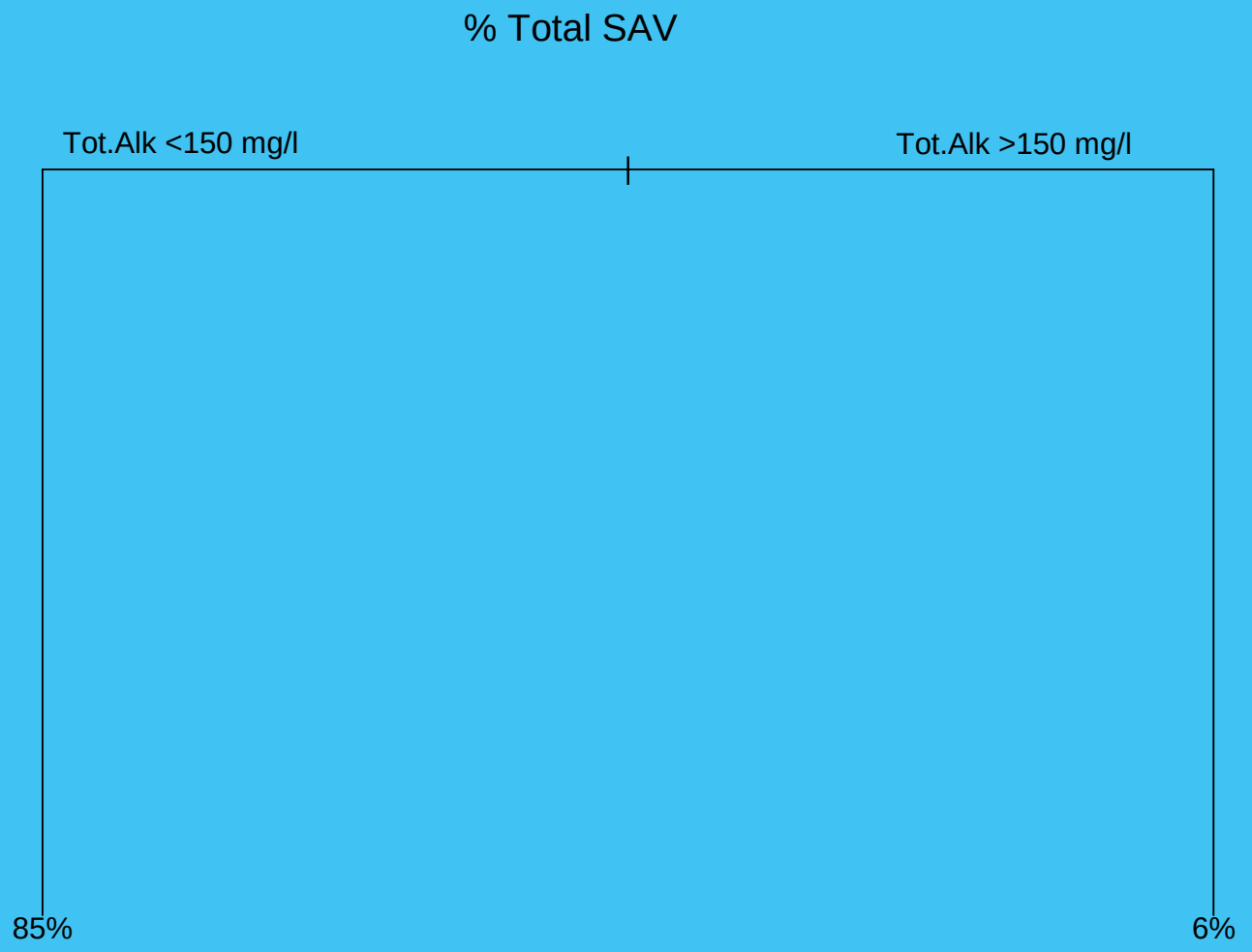
OLS R^2 = 0.40

2. Approximate Response Thresholds



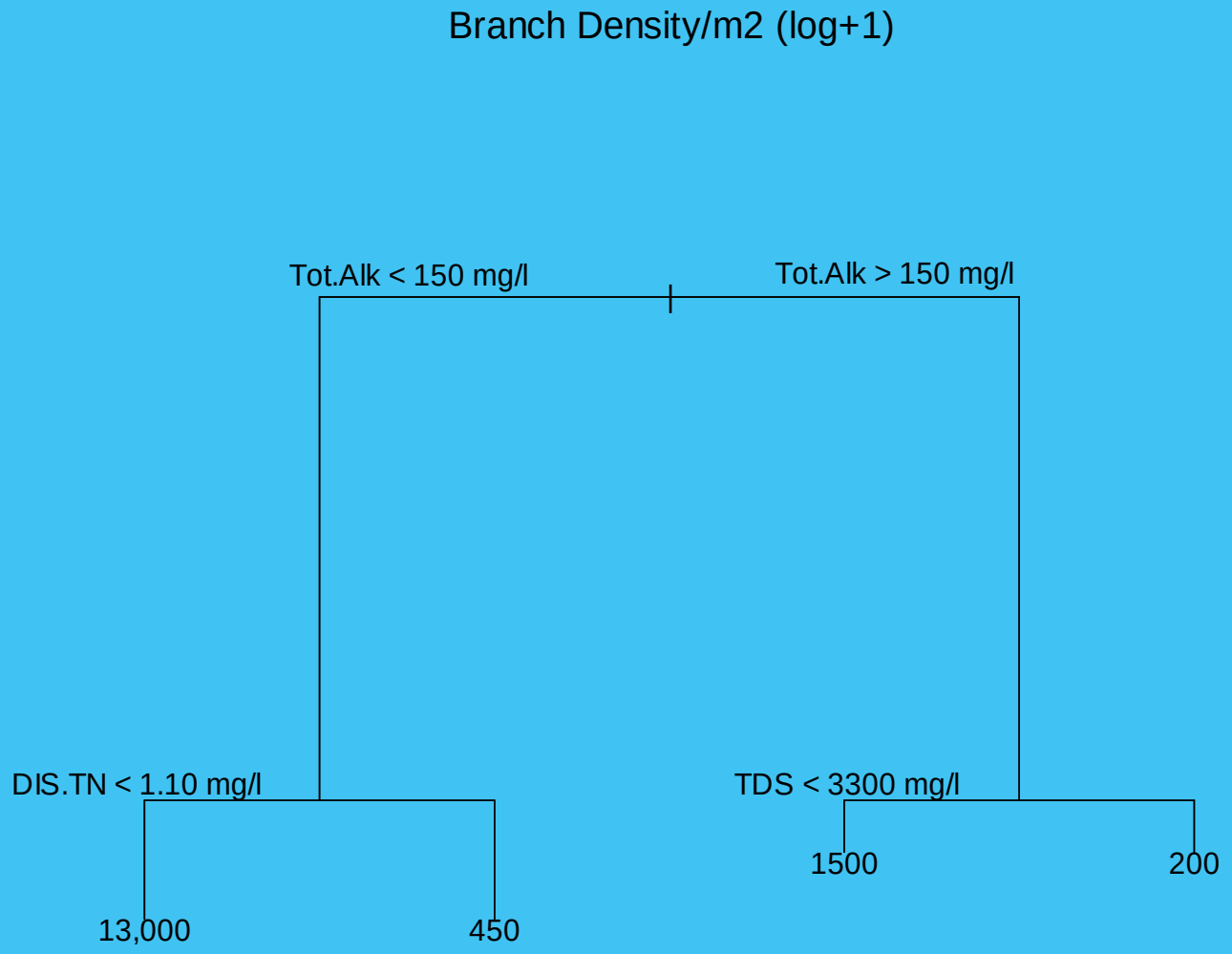
OLS R^2 = 0.42

2. Approximate Response Thresholds



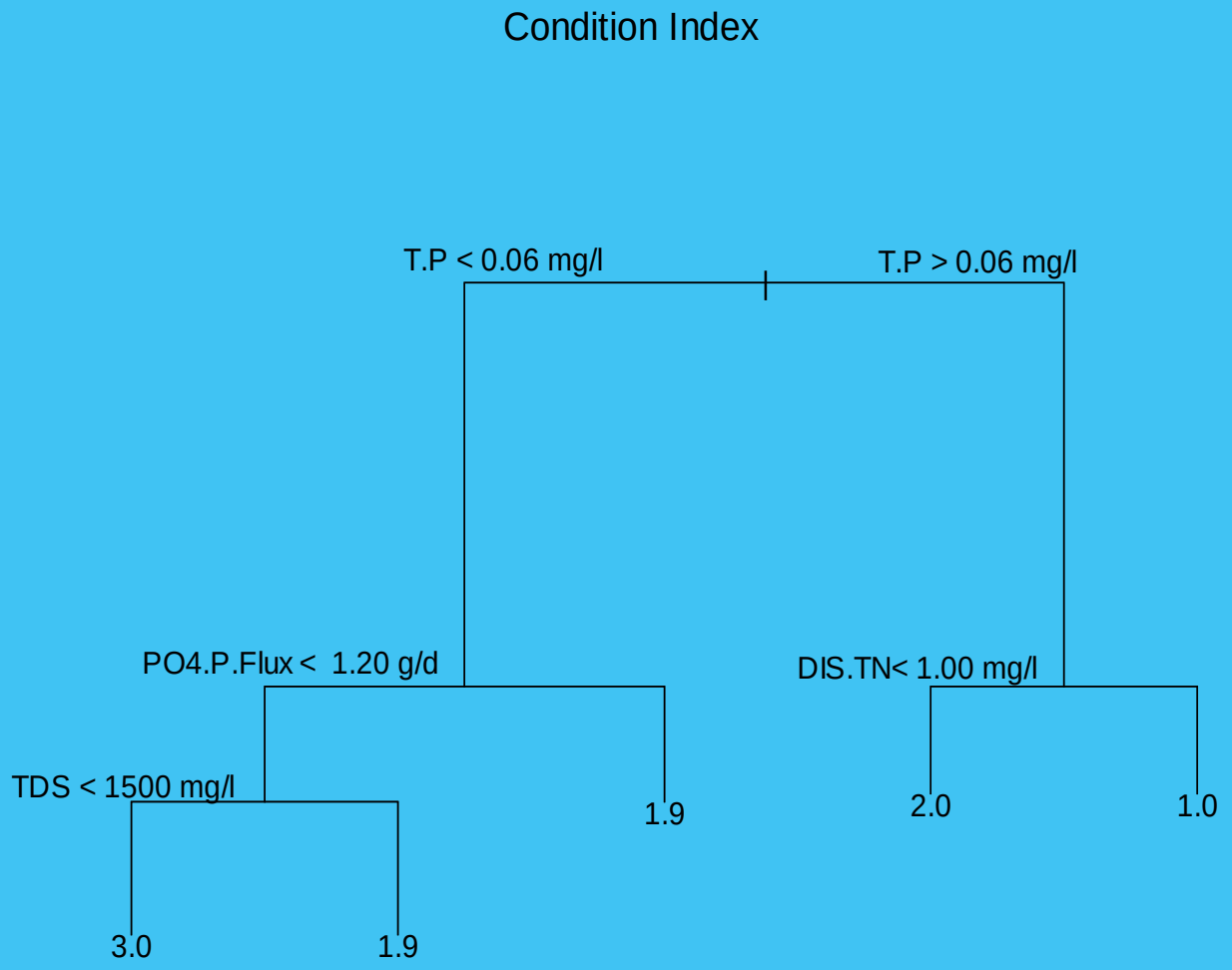
OLS R^2 = 0.45

2. Approximate Response Thresholds



OLS R^2 = 0.47

2. Approximate Response Thresholds



OLS R^2 = 0.68

Five proposed indicators

Indicator	Environmental Variables	Approximate Threshold Level	Direction
Branch Density (log+1)	1. Total Alkalinity	> 150 $mg \cdot L^{-1}$	Decrease
	2. Dissolved Total Nitrate	> 1.10 $mg \cdot L^{-1}$	Decrease
	3. Total Dissolved Solids	> 3300 $mg \cdot L^{-1}$	Decrease
% Total SAV	1. Total Alkalinity	> 150 $mg \cdot L^{-1}$	Decrease
% BDS on SAV	1.Year	2013	Increase
	2.Total Phosphorus	> 0.05 $mg \cdot L^{-1}$	Decrease
	3.Total Dissolved Solids	> 1900 $mg \cdot L^{-1}$	Increase
% Algae on SAV	1. Total Dissolved Solids	> 2300 $mg \cdot L^{-1}$	Increase
	2. NO3-N Flux	> 7.77 $g \cdot d^{-1}$	Increase
	3. Total Alkalinity	> 160 $mg \cdot L^{-1}$	Increase
Condition Index	1. Total Phosphorus	> 0.06 $mg \cdot L^{-1}$	Decrease
	2. PO4-P Flux	> 1.20 $g \cdot d^{-1}$	Decrease
	3 Total Dissolved Solids	> 1500 $mg \cdot L^{-1}$	Decrease
	4. Dissolved Total Nitrogen	> 1.00 $mg \cdot L^{-1}$	Decrease

Summary

- Negative response induced
- 5 proposed bioindicators
- Approximate response thresholds
  - Strongly suggest not using approximate threshold values in other wetland ponds
- In general, the high amendment (both years) had the most negative effect (Kruskal-Wallis)
  - CART showed varying responses to different environmental parameters (other factors besides nutrients have significant effect on biological responses)