Investigating the use of multispectral drones for identifying salt marsh condition

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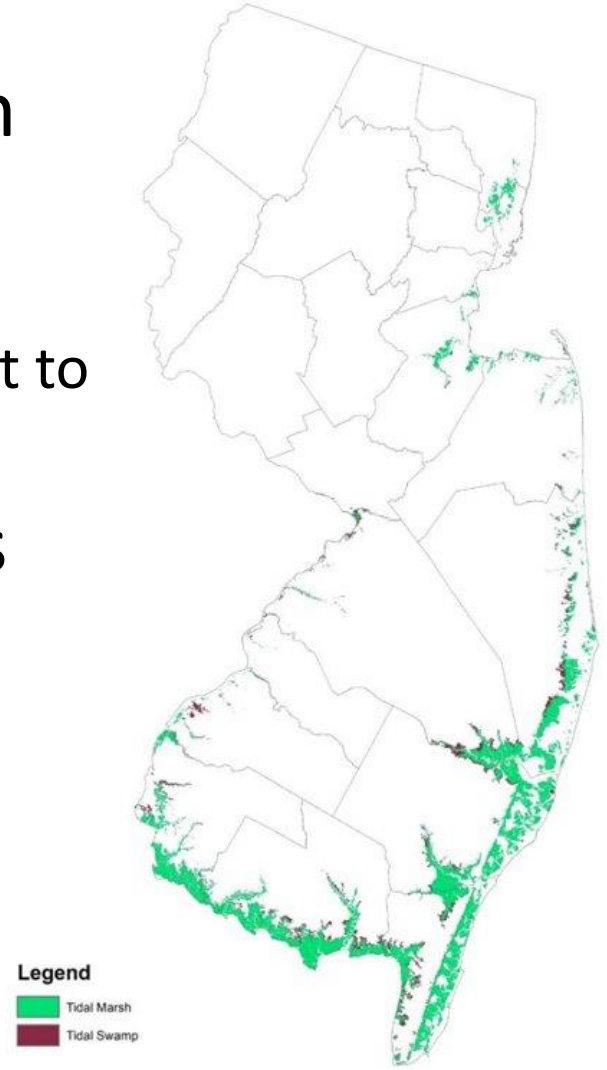
Overview

- Background & Goals
- 2022 Investigation
- 2023 Study Design
- Results & Take Aways

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

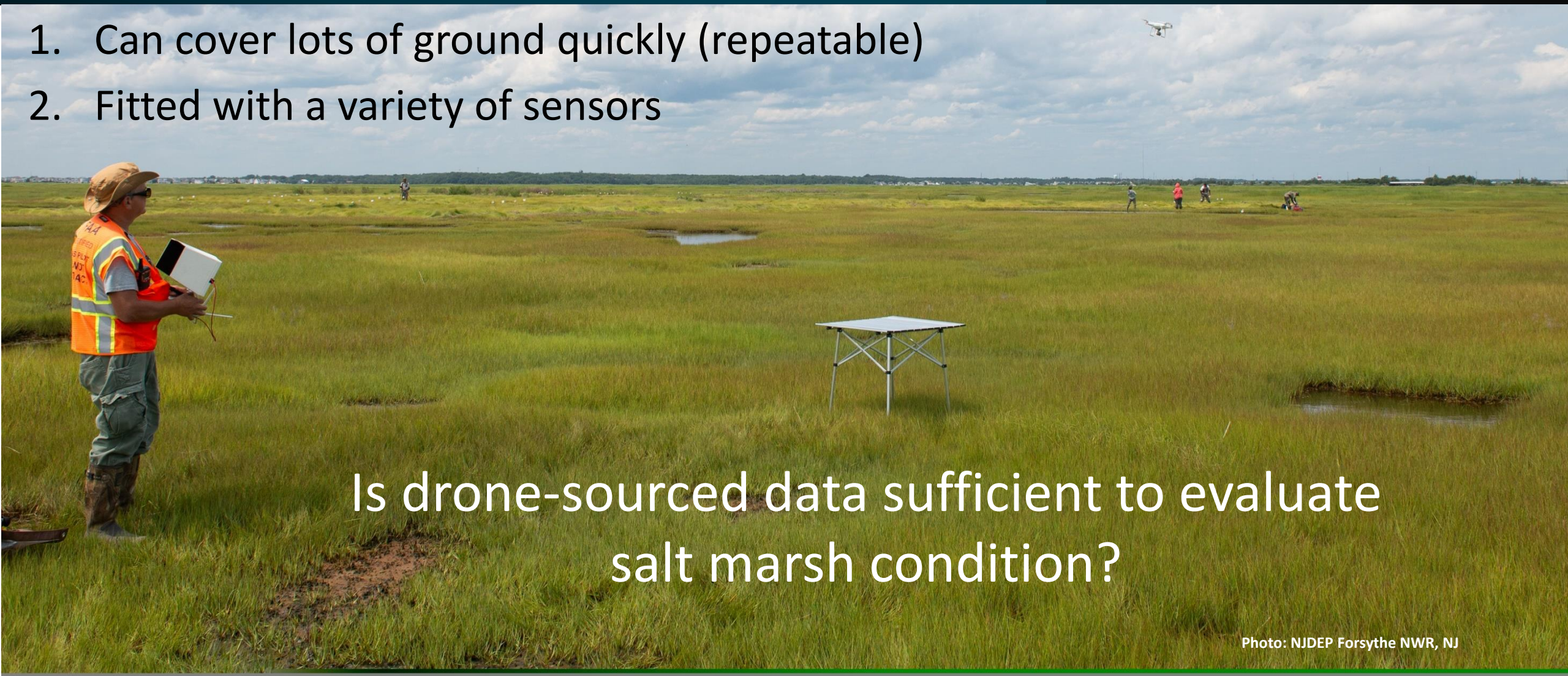
New Jersey is Rich with Coastal Wetlands

- 165,000 acres of coastal marsh
  - Many ecosystem services
  - Varying resilience
  - A predicted 19,000 acres may convert to open water by 2050 (1 ft SLR)
- Field-based Health Evaluations
  - Time consuming
  - Expensive



Potential Use of Drones

1. Can cover lots of ground quickly (repeatable)
2. Fitted with a variety of sensors

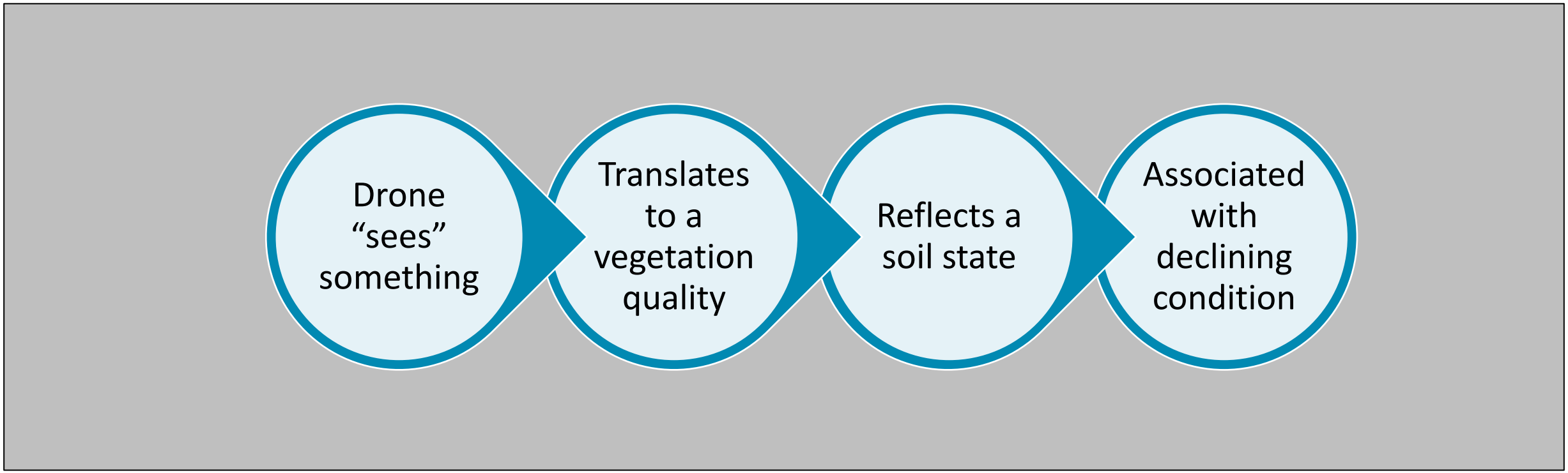


Is drone-sourced data sufficient to evaluate salt marsh condition?

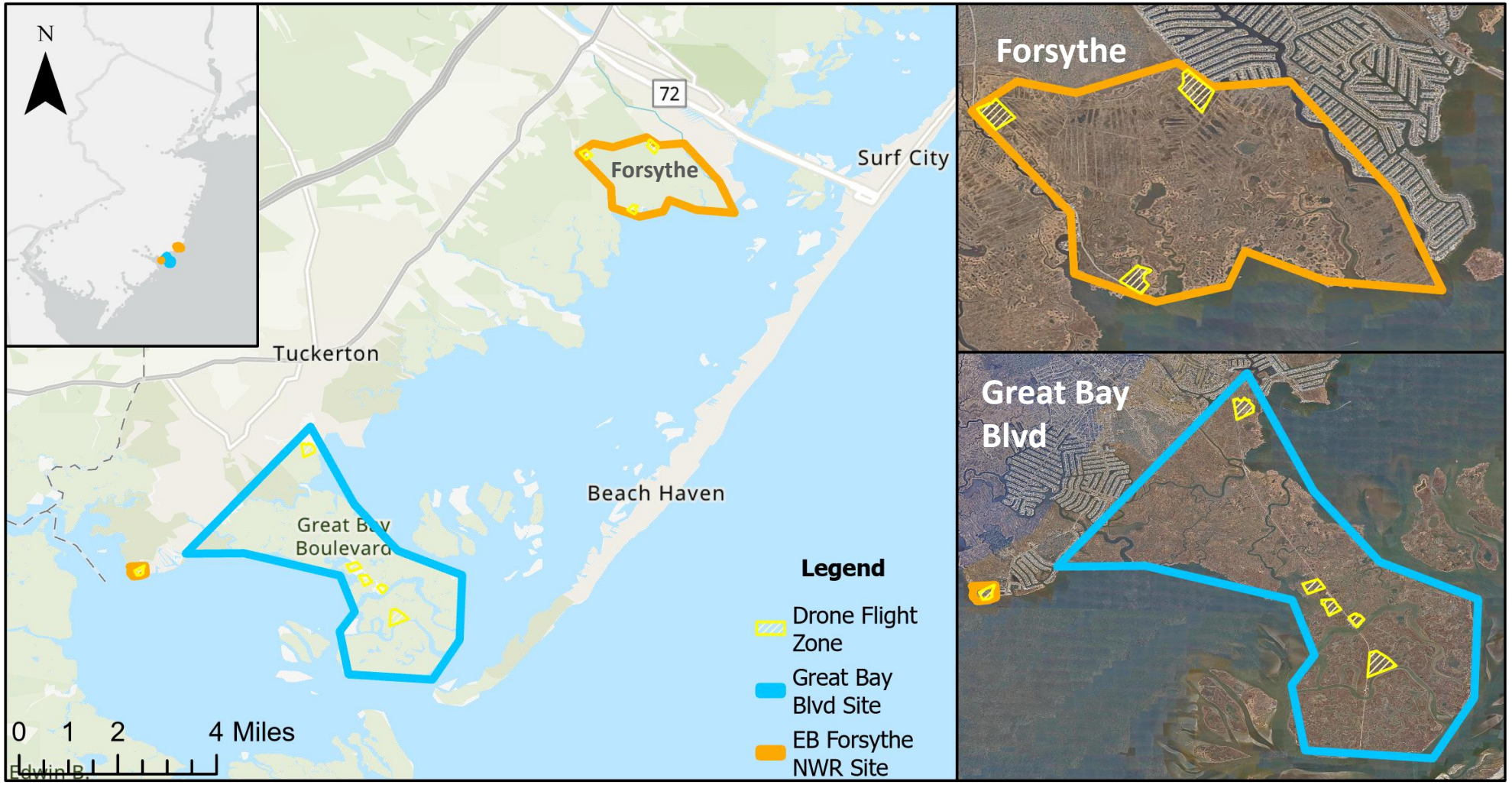
Photo: NJDEP Forsythe NWR, NJ

Project Goals & Objectives

Goal: To develop an efficient, drone-based methodology to identify areas of declining salt marsh condition



2022 Initial Investigation



2022 Initial Investigation

- Condition-based measurements
  - 100 m^2 plots of *Spartina alterniflora* (low marsh) or *Spartina patens* (high marsh)
  - Gave initial label of “healthy” or “unhealthy”
  - Drone flights around plots
    - RGB + Near Infrared + Red Edge
  - Followed by vegetation and soil chemistry analysis

2022 Initial Investigation

Orthomosaic Formation → Color-based Orthomosaic → Vegetation Indices → Zonal Summary Statistics of Plots

(preliminary)

Vegetation Index	Acronym of Index	Color Band Formula
Normalized Difference VI	NDVI	$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$
Green Normalized Difference VI	GNDVI	$GNDVI = \frac{(NIR - Green)}{(NIR + Green)}$
Normalized Difference Red-Edge Index	NDRE	$NDRE = \frac{(NIR - RE)}{(NIR + RE)}$
Non-Photosynthetic Vegetation Index	NPV	$NPV = \frac{(Blue - Green)}{(Blue + Green)}$

2022-23: Field Metrics

Soil & Porewater Chemistry: Dr. Charles Schutte, Rowan University

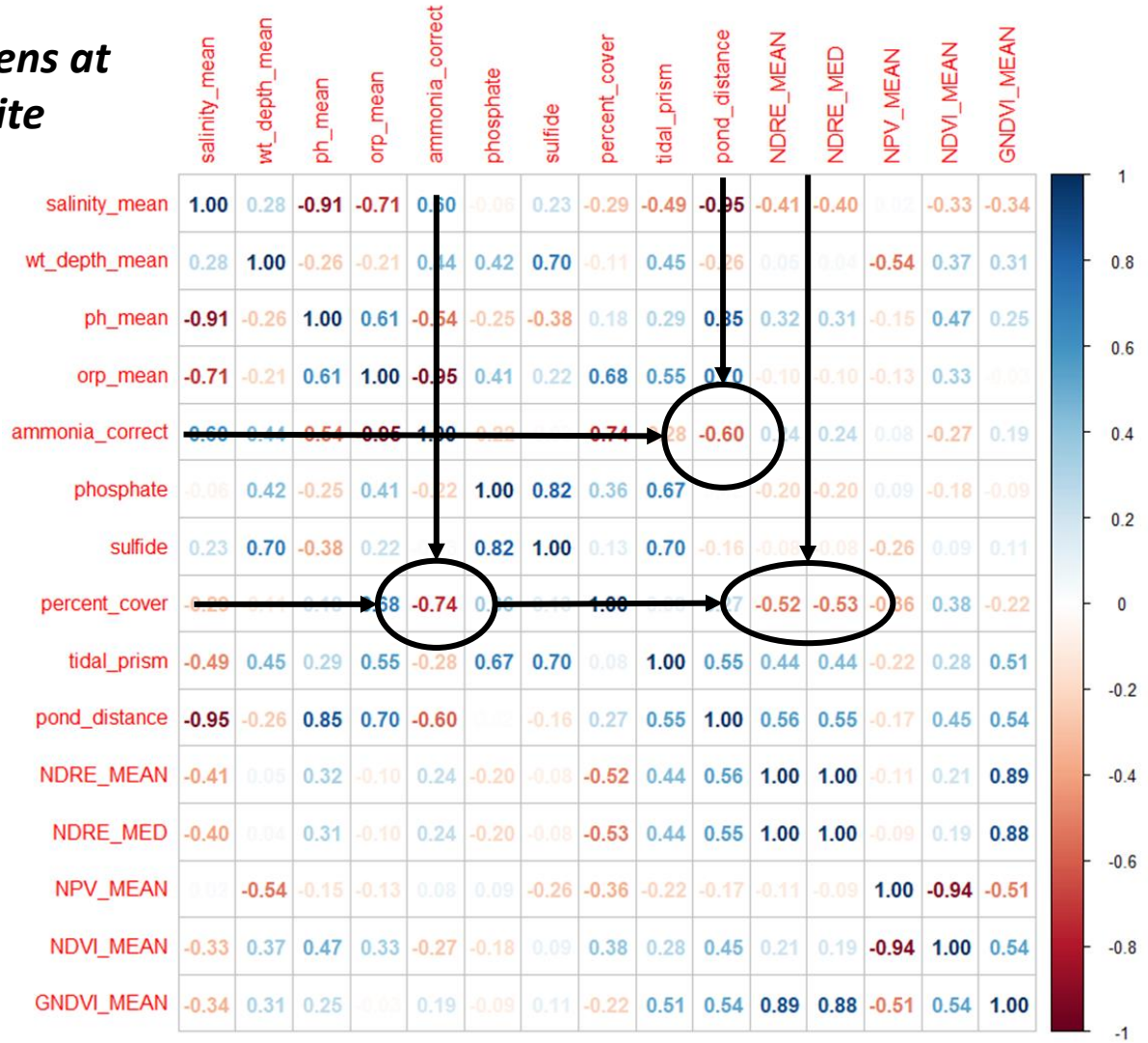
- Soils
  - pH
  - Oxidative Reduction Potential: nutrient availability/microbial activity
    - Low orp=anerobic conditions=favors methanogenic/sulfate reducing bacteria
- Porewater
  - Water Table Depth
  - Salinity
  - Sulfide, Sulfate, Sulfate Depletion
  - Ammonia
  - Chloride
  - Conductivity

Vegetation & Physical Metrics: NJ DEP Division of Science & Research

- Elevation
- Position in Tidal Prism
- Percent Cover: total and per vegetation type
- Vegetation Heights
- Bearing Capacity

2022 Initial Investigation Results

S. patens at GBB site



- *S. patens = strongest results*
- *S. alterniflora* results were confounding
- Site (factor) non-significant
- Clues towards relationships

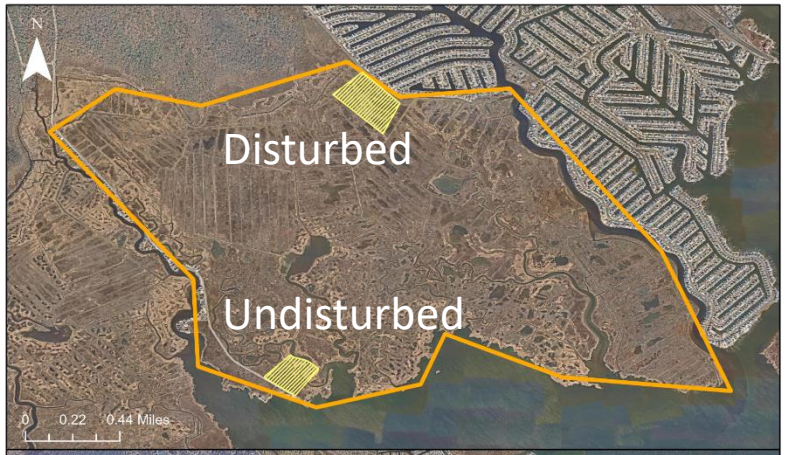
Response: NDRE_MED

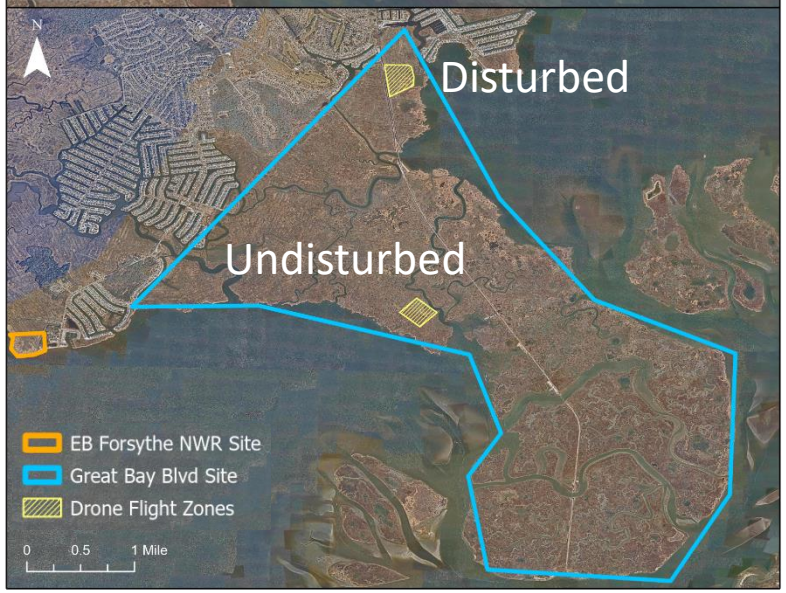
	Chisq	Df	Pr(>Chisq)
percent_cover	**5.7173**	**1**	**0.0168 ***
site	**0.1508**	**1**	**0.6978**
percent_cover:site	**2.2545**	**1**	**0.1332**

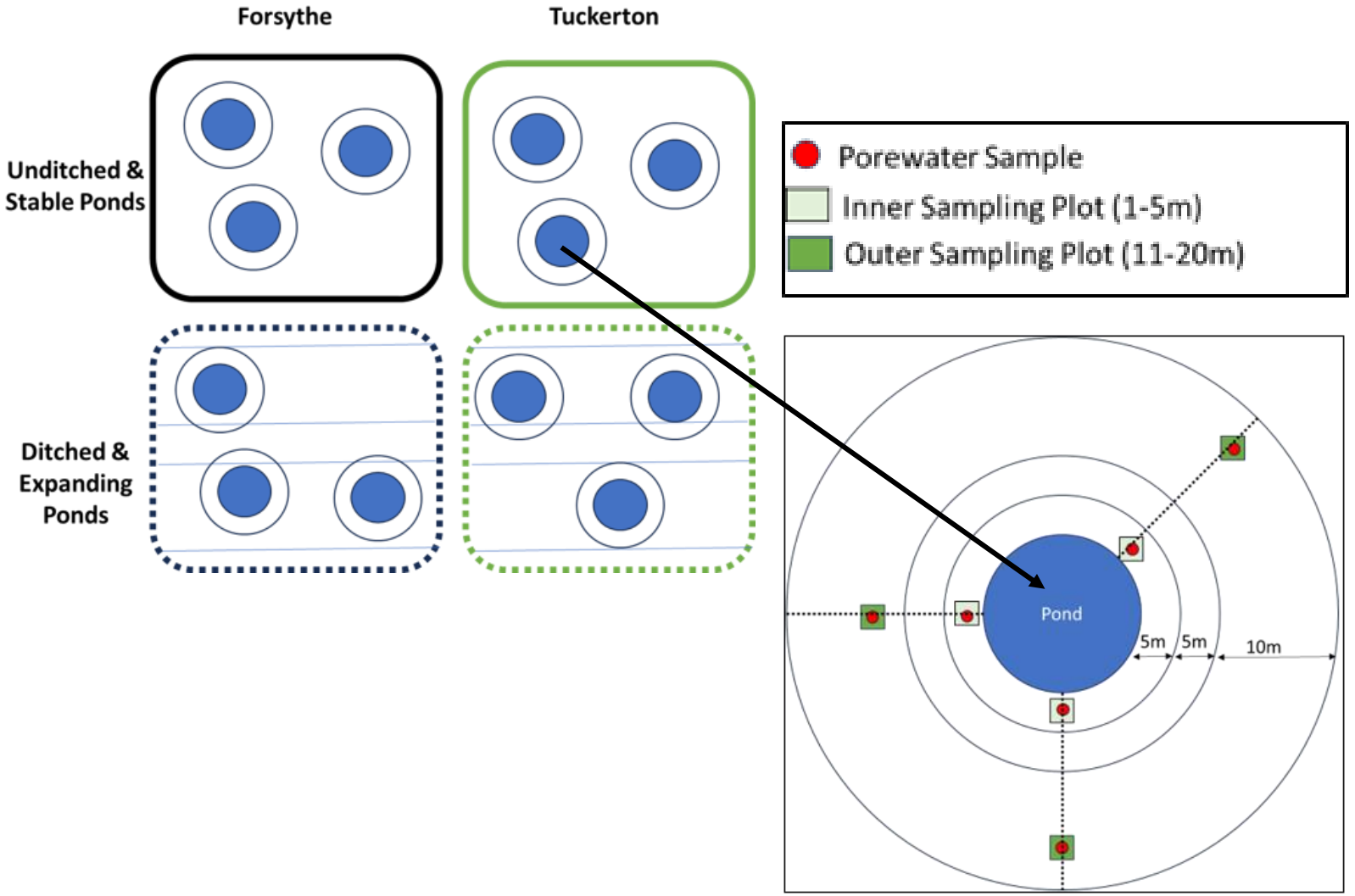
Response: percent_cover

	Chisq	Df	Pr(>Chisq)
ammonia_correct	**4.9529**	**1**	**0.02605 ***
site	**0.3514**	**1**	**0.55332**
ammonia_correct:site	**0.2391**	**1**	**0.62489**

2023 Study Design







2023 Analysis Methods

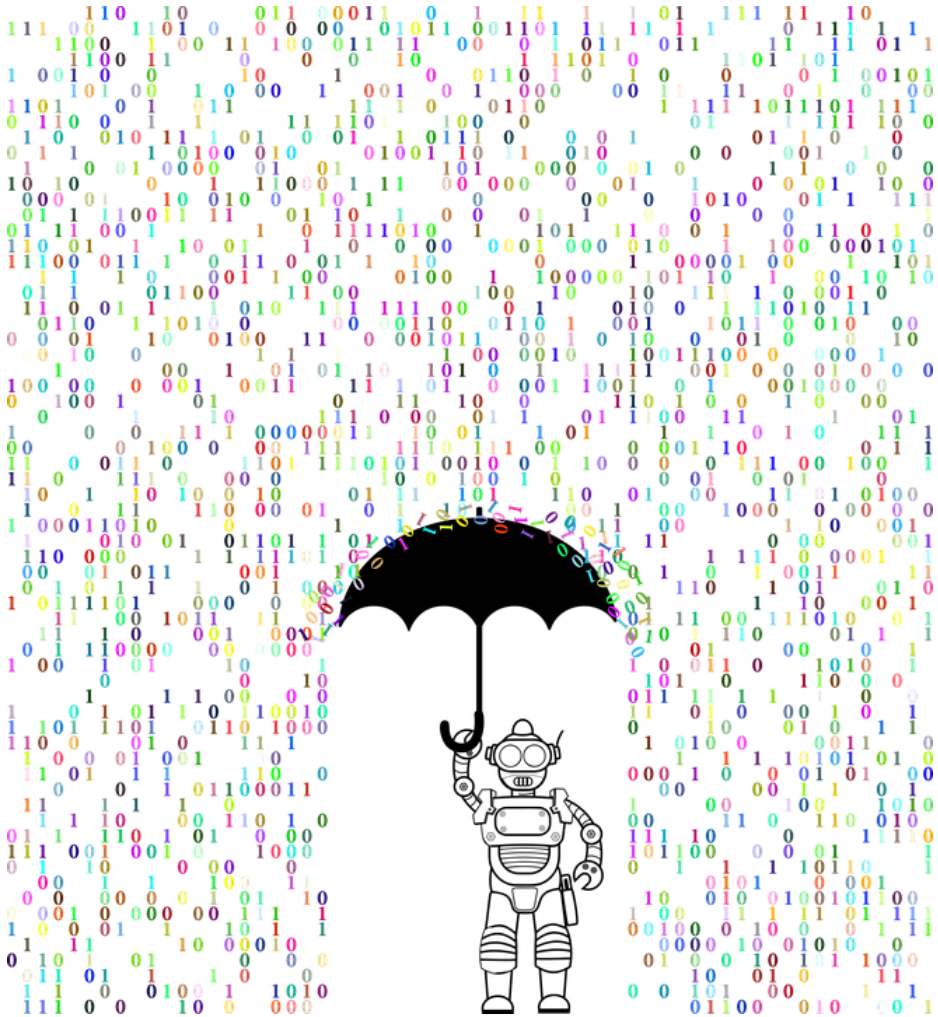
Multispectral Indices (MSIs) ~ Ecologic Status

1. Influence of Ditching, Site, Plot per metric: Kruskal-Wallace & Dunn post-hoc

2. Correlations between MSIs and ecologic variables: Spearman rank, non-parametric

3. Collinearity evaluation: Tolerance & VIF testing

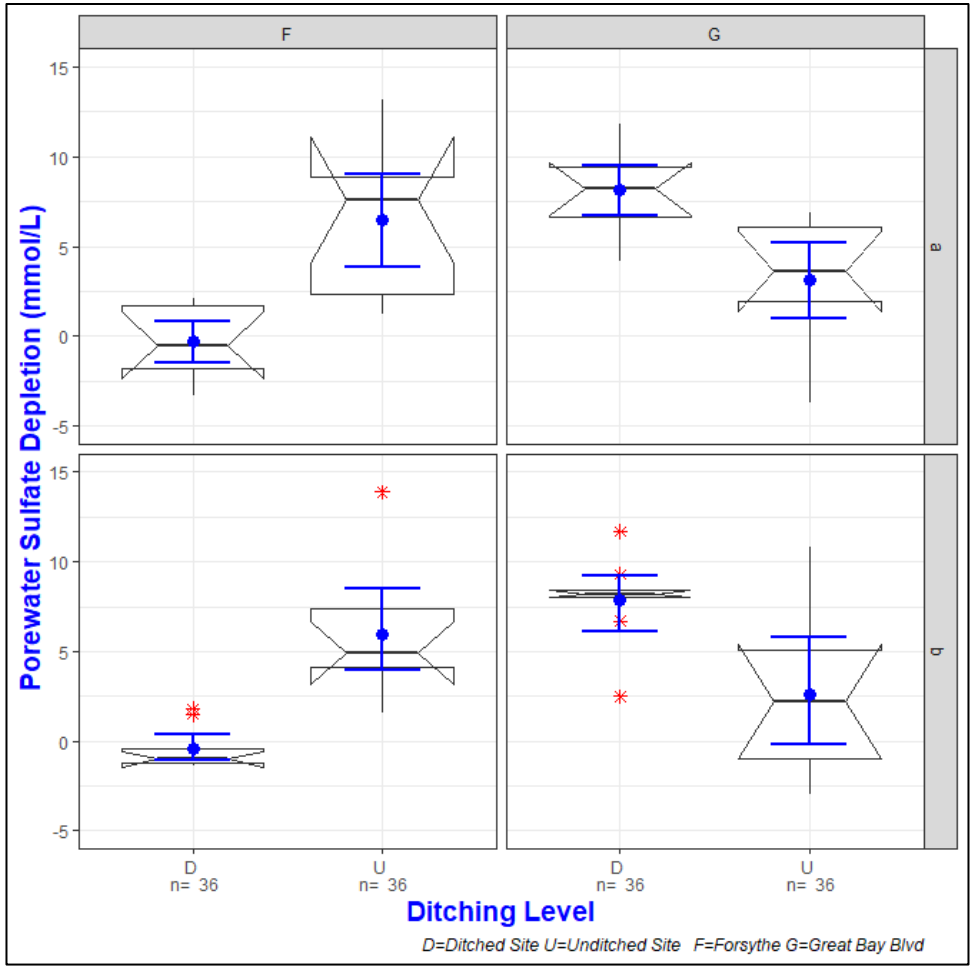
4. Mixed Effect Models: MSIs~ecologic variables, interactive, site=random, AIC scores

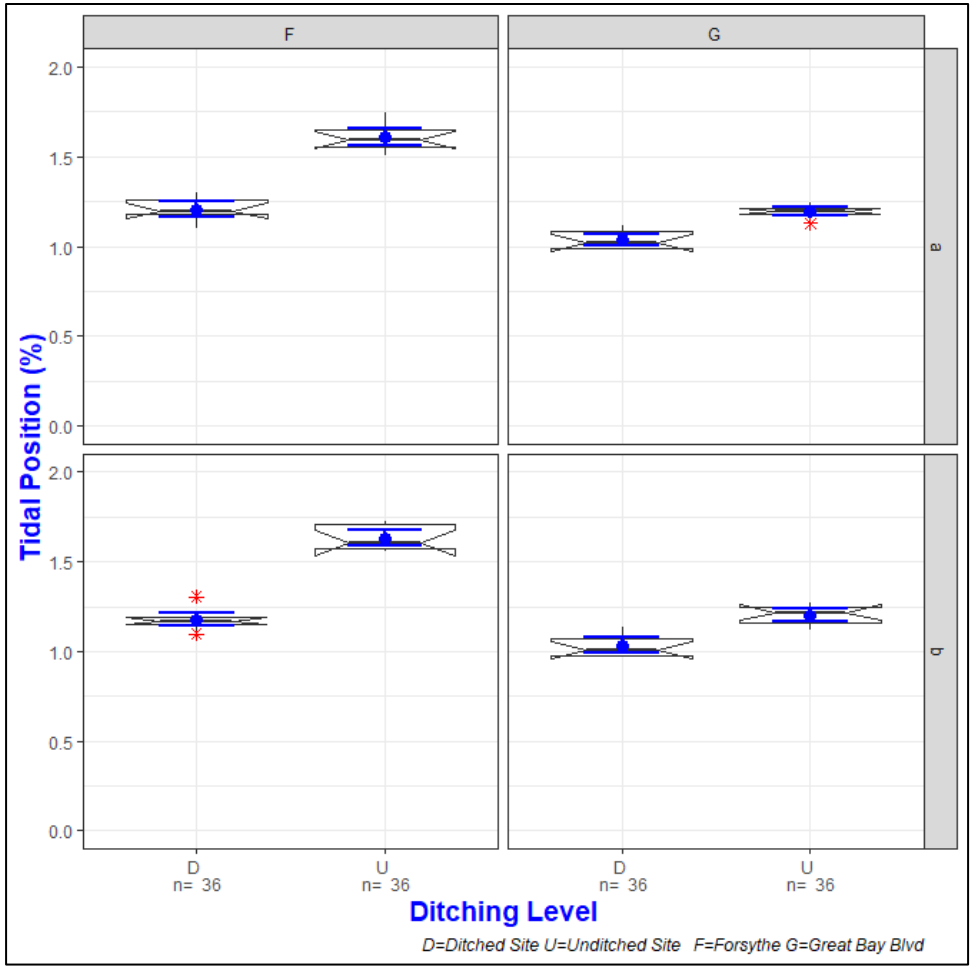


Results: Influence of Ditching, Site, & Plot

Most metrics showed no consistent evidence of factor-level influence

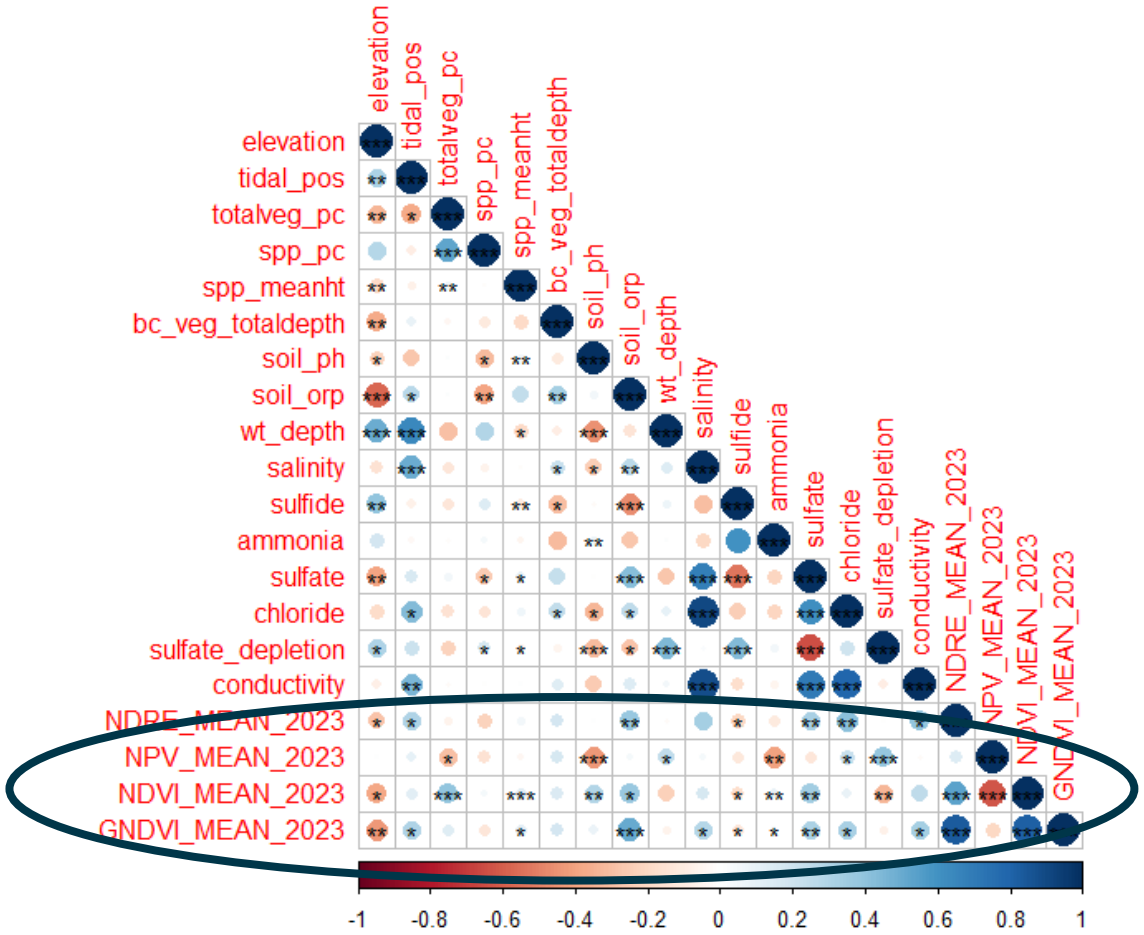
……except elevation and tidal position





Results: MSIs & Ecologic Variables

Step 1: Correlation Matrix



Step 2: Model Building: Tolerance & VIF Testing

a. GNDVI

Variables	Tolerance	VIF
S. patens Mean Height	0.99	1.01
Ammonia	0.98	1.02
Sulfate	0.97	1.03

b. NDRE

Variables	Tolerance	VIF
Tidal Position	0.94	1.06
Sulfate	0.94	1.06

c. NDVI

Variables	Tolerance	VIF
Elevation	0.84	1.19
S. patens Mean Height	0.96	1.04
Ammonia	0.96	1.04
Sulfate	0.87	1.15

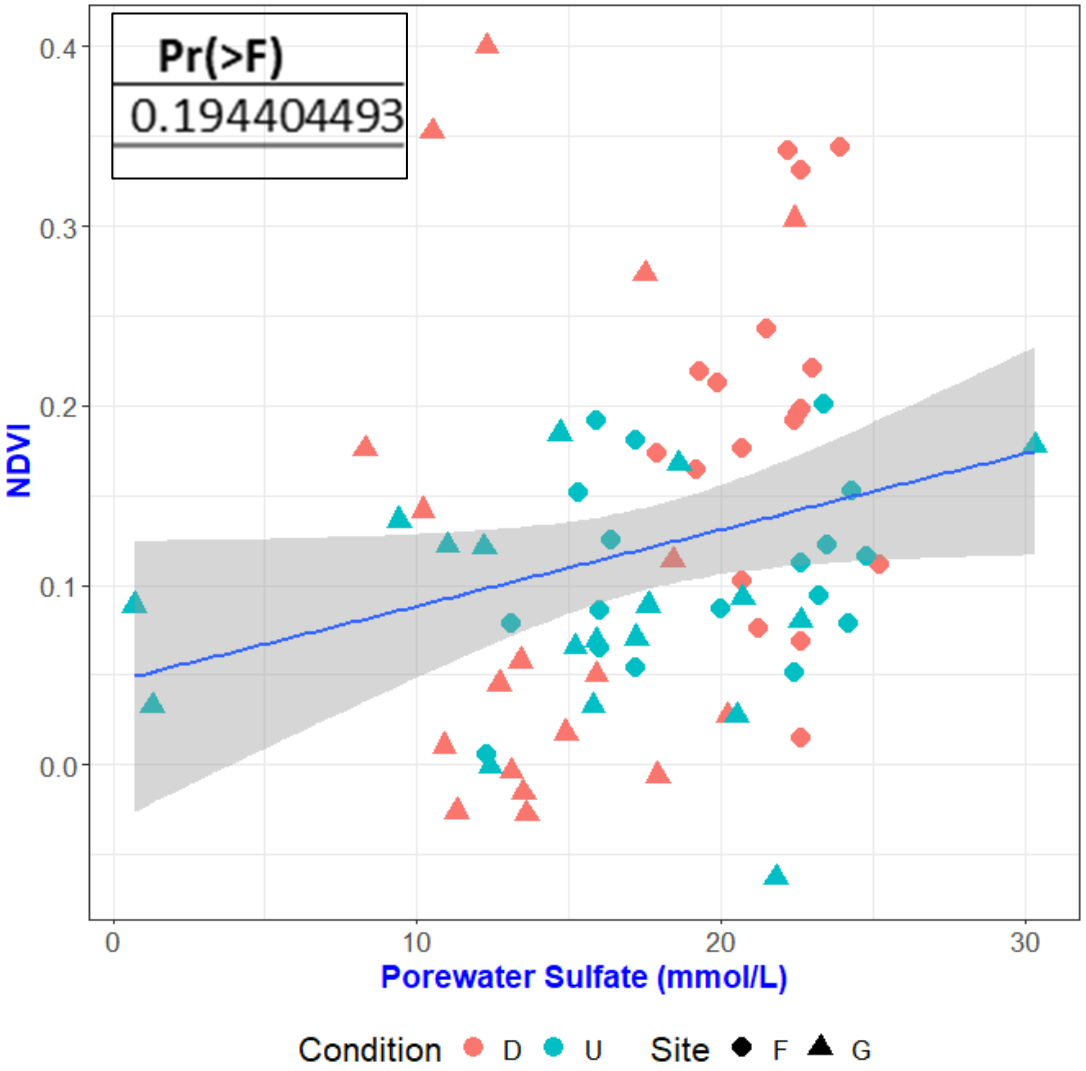
d. NPV

Variables	Tolerance	VIF
Total Vegetation Percent Cover	0.98	1.02
Ammonia	0.99	1
Sulfate Depletion	0.98	1.01

Results: Model Results

NDVI	npar	AIC	BIC	Chisq	Df	Pr(>Chisq)
Reduced	3	-124.426	-117.596	NA	NA	NA
Full	18	-140.159	-99.1791	45.7328	15	5.86E-05

Step Model	AIC
NDVI_MEAN_2023~1	*-331.23*
+Sulfate	-333.24
+<none>	**-333.24**
+Elevation	-332.81
+Ammonia	-331.65
+*S. patens* Mean Height	-331.62

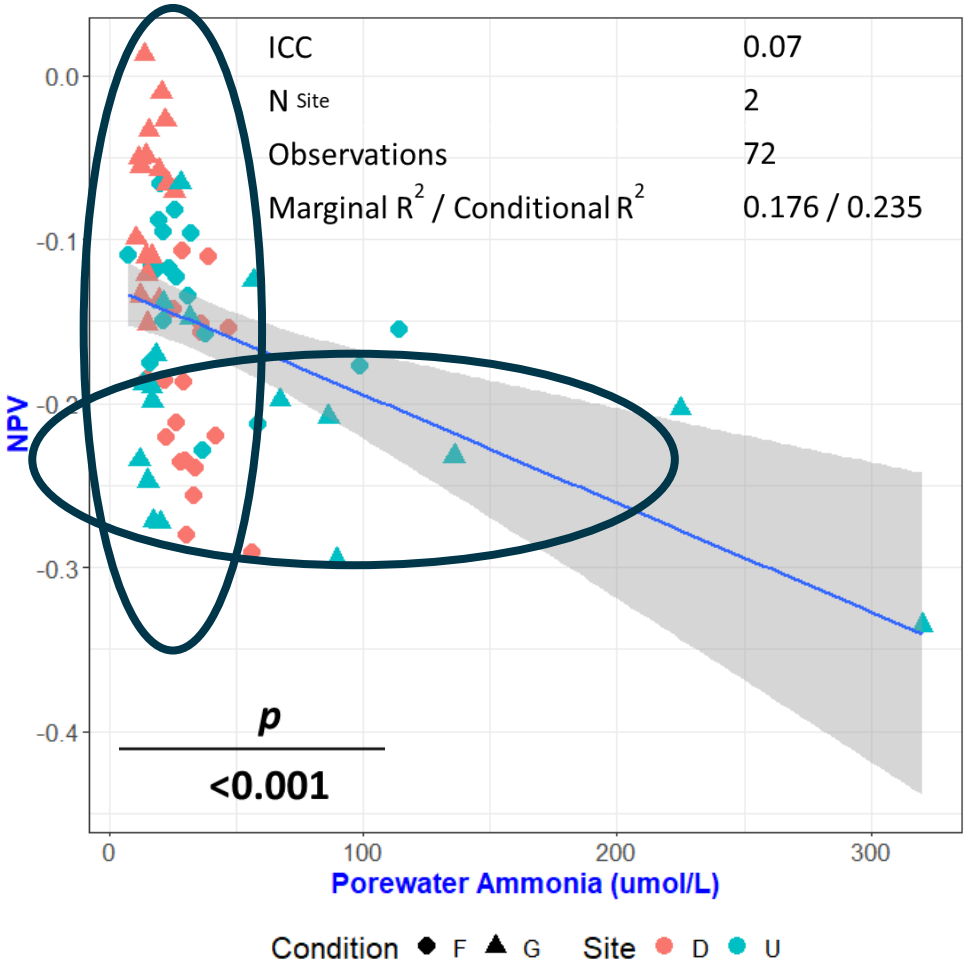


Results: Model Results

NPV	npar	AIC	BIC	Chisq	Df	Pr(>Chisq)
Reduced	3	-163.68	-156.85	NA	NA	NA
Full	10	-193.59	-170.82	43.91	7	2.22E-07

Step Model	AIC
NPV_MEAN_2023~1	*-372*
+Sulfate Depletion	-388.2
+Ammonia	-404.06
+Total Vegetation Percent Cover	-404.31
+Sulfate Depletion:Total Vegetation Percent Cover	-406.15
+<none>	**-406.15**
+Total Vegetation Percent Cover:Ammonia	-405.45
+Ammonia:Sulfate Depletion	-404.34

NPV	DenDF	F value	Pr(>F)
*totalveg_pc**	*67*	*5.91*	*0.018*
*ammonia****	*67*	*21.50*	*1.69E-05*
sulfate_depletion	67	1. 50	0.225
totalveg:sulfate_dep	67	3.67	0.060



Take Aways

1. Vegetation Community Delineation
   - Able to identify monocultures accurately, but issues with accurate mixed community identification
   - Could not be fully automated – varying levels of site-specific effort
2. Role of Ditching
   - Some scale issues, but some evidence that ditched marshes site lower than unditched counterparts (aeration, soil orp)
3. Relationships between MSI ~ Condition Variables
   - Nothing predictive, but may not be conclusive due to……
   - Sample size too small for measured variability
   - Scale of factors overwhelmed by geomorphic influence
4. Drone Considerations
   - Timing drone flights, took longer than expected, cross-plot similarity was difficult
     - Sun position – reflectance & shadowing
     - Water inundation – normalizing “wetness”

Questions & Discussion

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