Investigating the use of multispectral drones for identifying salt marsh condition

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Background & Goals



2022 Investigation



2023 Study Design



Results & Take Aways





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

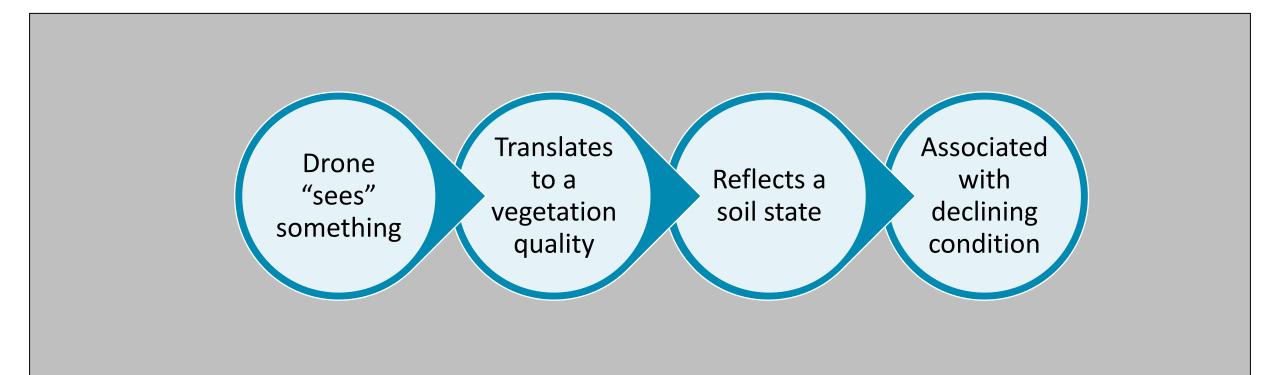
Is drone-sourced data sufficient to evaluate salt marsh condition?



Project Goals & Objectives



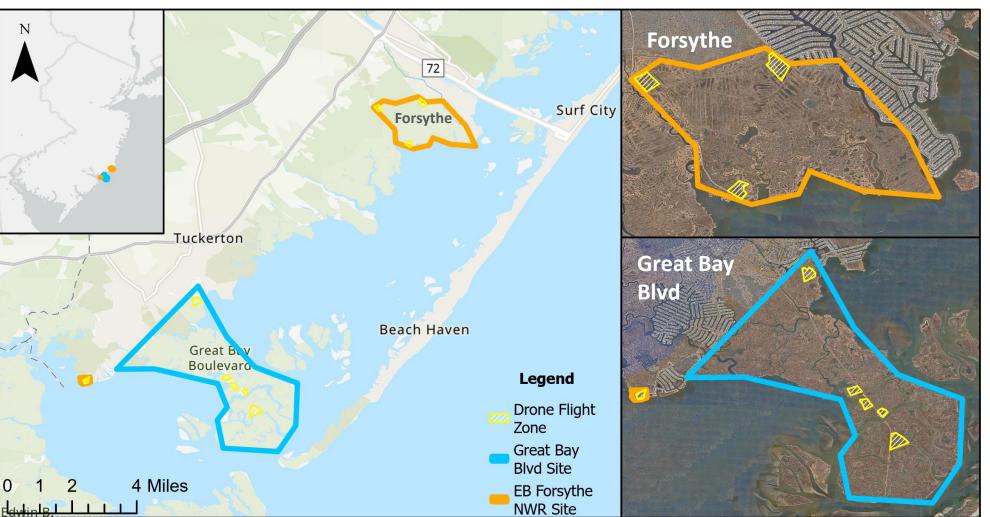
Goal: To develop an efficient, drone-based methodology to identify areas of declining salt marsh condition





2022 Initial Investigation







2022 Initial Investigation



- Condition-based measurements
 - 100 m² 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 Orthomosaic	Vegetation Indices	Z	Zonal Summary Statistics of Plots	
	Vegetation Index	Acronym of Index	Color Band Formula	
Per transmission and the second secon	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	$NDRE = \frac{(NIR - RE)}{(NIR + RE)}$	
(preliminary)	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	salinity_mean	wt_depth_mean	ph_mean	orp_mean	ammonia_correct	phosphate	sulfide	percent_cover	tidal_prism	pond_distance	NDRE_MEAN	NDRE_MED	NPV_MEAN	NDVI_MEAN	GNDVI_MEAN
salinity_mean	1.00	0.28	- <mark>0.9</mark> 1	-0.71	0.60	-0.06	0.23	-0.29	-0.49	-0.95	-0.41	-0.40		-0.33	-0.34
wt_depth_mean	0.28	1.00	-0.26	-0.21	0.14	0.42	0.70		0.45	-0.26	0.05	0.04	-0.54	0.37	0.31
ph_mean	-0.91	-0.26	1.00	0.61	-0.54	-0.25	-0.38	0.18	0.29	0.85	0.32	0.31	-0.15	0.47	0.25
orp_mean	-0.71	-0.21	0.61	1.00	-0.95	0.41	0.22	0.68	0.55	070	-0:10	-0.10	-0.13	0.33	-0.03
ammonia_correct	0.60	0.44	0.54	0.05	1.90	0.22		0.74	► <u>2</u> 8	-0.60	0.24	0.24	0.08	-0.27	0.19
phosphate	-0.06	0.42	-0.25	0.41	-0.22	1.00	0.82	0.36	0.67	_	-0.20	-0.20	0.09	-0.18	-0.09
sulfide	0.23	0.70	-0.38	0.22		0.82	1.00	0.13	0.70	-0.16	-0.08	0.08	-0.26	0.09	0.11
percent_cover	-0.20	0.11	0.10	₿.68	-0.74	0.)=	0.10	1.00	0.00	+(-0.52	-0.53	-0 86	0.38	-0.22
tidal_prism	-0.49	0.45	0.29	0.55	-0.28	0.67	0.70	0.08	1.00	0.55	0.44	0.44	-0.22	0.28	0.51
pond_distance	-0.95	-0.26	0.85	0.70	-0.60	0.02	-0.16	0.27	0.55	1.00	0.56	0.55	-0.17	0.45	0.54
NDRE_MEAN	-0.41	0.05	0.32	-0.10	0.24	-0.20	-0.08	-0.52	0.44	0.56	1.00	1.00	-0.11	0.21	0.89
NDRE_MED	-0.40	0.04	0.31	-0.10	0.24	-0.20	-0.08	-0.53	0.44	0.55	1.00	1.00	-0.09	0.19	0.88
NPV_MEAN	0.02	-0.54	-0.15	-0.13	0:08	0.09	-0.26	-0.36	-0.22	-0.17	-0.11	-0.09	1.00	-0.94	-0.51
NDVI_MEAN	-0.33	0.37	0.47	0.33	-0.27	-0.18	0.09	0.38	0.28	0.45	0.21	0.19	-0.94	1.00	0.54
GNDVI_MEAN	-0.34	0.31	0.25	-0.03	0.19	-0.09	0.11	-0.22	0.51	0.54	0.89	0.88	-0.51	0.54	1.00

- S. patens = strongest results
- S. alterniflora results were confounding

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- 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 E	Of Pr(>Chisq)
ammonia_correct	4.9529	1 0.02605
site	0.3514	1 0.55332
ammonia_correct:s	ite 0.2391	1 0.62489

-1

-0.8

1

0.8

0.6

0.4

0.2

0

-0.2

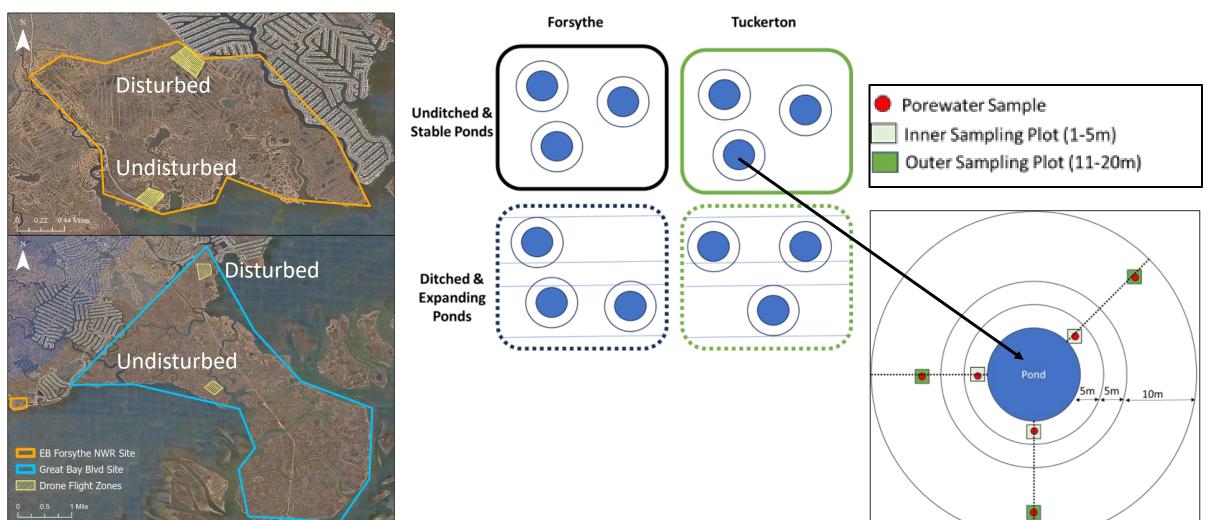
-0.4

-0.6



2023 Study Design





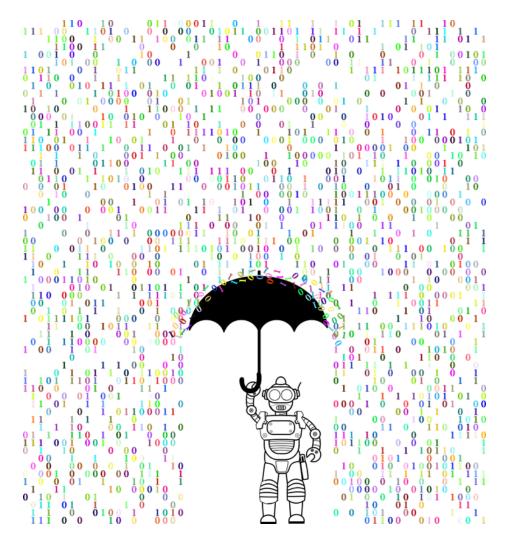


2023 Analysis Methods



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



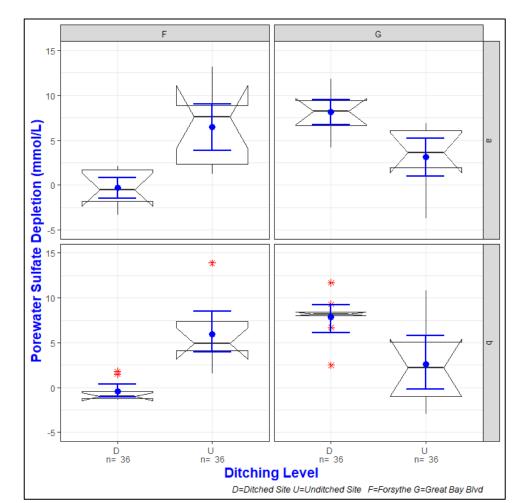


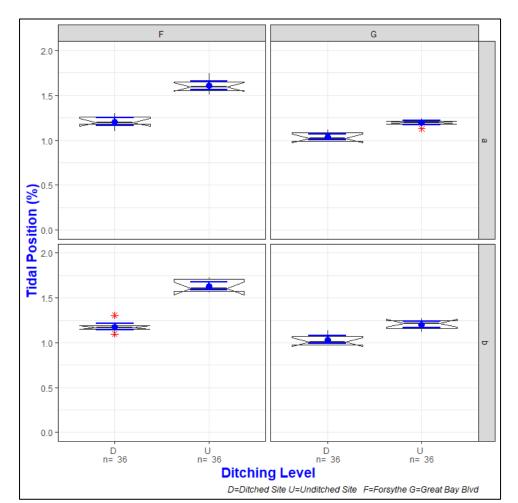
Results: Influence of Ditching, Site, & Plot



Most metrics showed no consistent evidence of factor-level influence

.....except elevation and tidal position



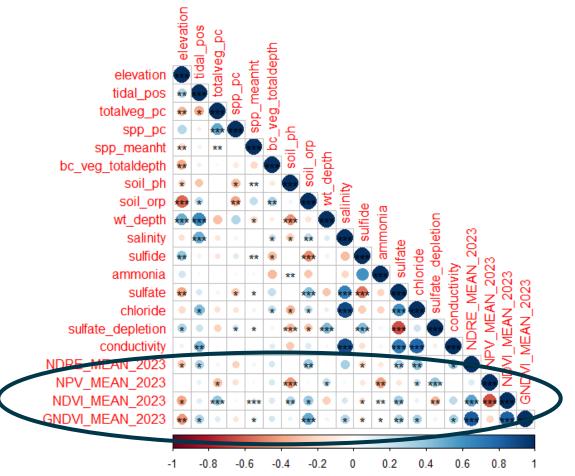




Results: MSIs & Ecologic Variables



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

0.98

1.01

Sulfate Depletion



Results: Model Results



NDVI	npar	AIC	BIC	Chisq	Df	Pr(>Chisq)	0.4-	Pr(>F)
Reduced	3	-124.426	-117.596	NA	NA	NA		0.194404493
Full	18	-140.159	-99.1791	45.7328	15	5.86E-05		
Step Model		AIC					0.3-	
NDVI_MEAN_2023	3~1	-331.23						
	+Sulfate	-333.24					0.0	
	+ <none></none>	-333.24					0.2-	
	+Elevation	-332.81					z	
	+Ammonia	-331.65					0.1-	
+S. patens N	Mean Height	-331.62						
							0.0-	
							l	0 10 20 30 Porewater Sulfate (mmol/L)

Condition ● D ● U Site ● F ▲ G



Results: Model Results



NPV	npar	AIC	BI	С	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	0.0	ICC	0.07
				ALC				0.0	N Site	2
Step Model				AIC					Observations	72
NPV_MEAN_2023~1				-372					Marginal R ² / Conditional	R ² 0.176 /
	+Sul	lfate Depletion		-388.2				-0.1		
		+Ammonia		-404.06					•	
+T(otal Vegetation	Percent Cover		-404.31						
+Sulfate Depletion:To	otal Vegetation	Percent Cover		-406.15)
		+ <none></none>		-406.15						2
+Total Vegeta	ation Percent C	over:Ammonia		-405.45				-0.3		
	+Ammonia:Sul	fate Depletion		-404.34						
NPV	Den	DF Fva	lue	Р	r(>F)				2	
totalveg_pc*	67	7 5.	91	0	.018			-0.4	<i>p</i>	
ammonia***	67	7 21	50	1.6	59E-05)		<	:0.001	
sulfate_depletion	67	7 1.	50	0	.225			Ó	100 20 Porewater Ammonia (
totalveg:sulfate_o	dep 67	7 3.	67	0	.060	_				ie 🔍 D 🔍 U





- 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

NEW JERSEY DEPARTMENT C **ENVIRONMEN** PROTECTION

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