



How vulnerable are South Carolina's marshes?

How do we decide?



South Carolina (SC) has ~350,000 acres of salt marsh, largely dominated the annual, native marsh grass *Spartina alterniflora* (saltmarshguide.org). The salt marsh ecosystem is a highly productive coastal habitat which provides a wealth of ecosystem services.

Increasing rates of sea level rise (SLR) have raised concerns regarding the resilience of marshes in SC and their ability to keep pace with the high rate of observed SLR.

Although there has never been a long-term, coast-wide marsh monitoring program in SC, North Inlet-Winyah Bay (NI-WB) and ACE Basin (ACE) National Estuarine Research Reserves are well-studied, and reserve staff have been monitoring the salt marsh at their high salinity Wetland and Water Level (WWL) sites for 20 years. Both reserves have plot level vegetation and elevation data - including surface elevation tables (SETs) - and high-resolution drone imagery from their ongoing monitoring efforts.

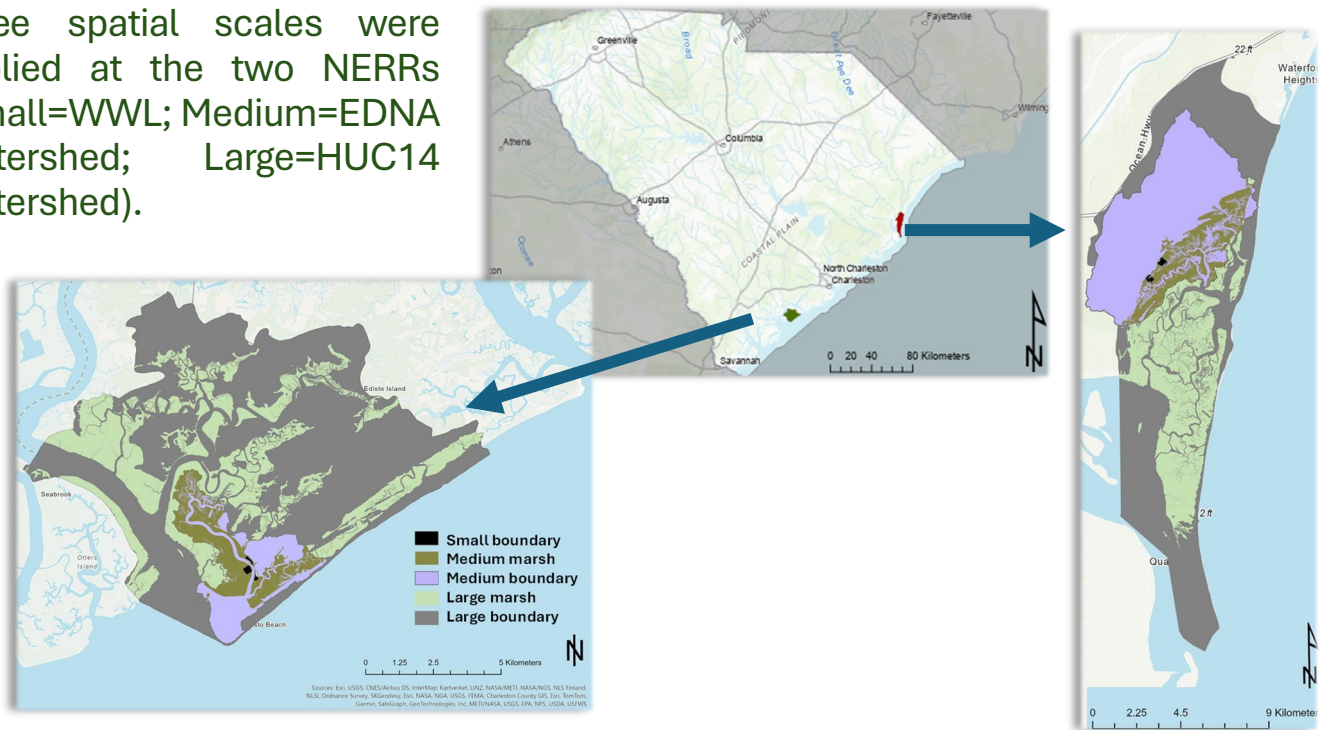
Despite differences in tidal range and sediment loads, neither location has shown significant loss of the marsh vegetation over the last two decades. These two locations provide long-term datasets to assess the applicability of existing marsh vulnerability metrics to validate if they are reliable for SC marshes.



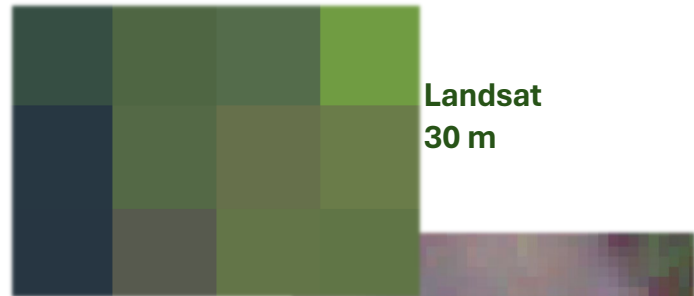
Study Goal & Methods

To assess applicability of a suite of existing marsh resilience estimates and metrics at the intensively studied NI-WB and ACE WWL sites across differing spatial scales and image resolutions.

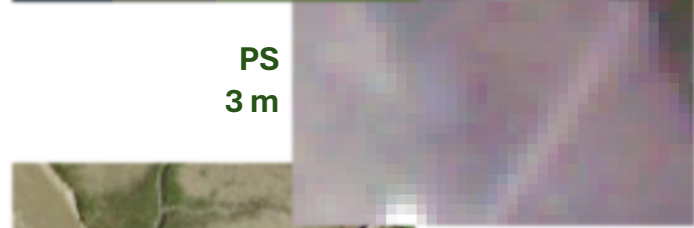
Three spatial scales were applied at the two NERRs (Small=WWL; Medium=EDNA Watershed; Large=HUC14 Watershed).



USGS created the Unvegetated to Vegetated Ratio (UVVR)¹ and % Vegetated National Products (NP) available at a 30 m resolution (pixel size) using Landsat satellite imagery (all tides). These NPs were evaluated for NI-WB and ACE at the three scales.



USGS proposed a national threshold of UVVR < 0.15 (or > 87% vegetated cover) as resilient and > 0.15 (or < 87% veg.) as vulnerable, primarily based on data from mid-Atlantic and west coast.



USGS UVVR methodology was applied to National Agriculture Imagery Program aerial imagery (NAIP, known tide) and Planet Scope satellite imagery (PS, low tide only) with Drone imagery (low tide) used for calibration to develop NERR-derived UVVR, % Vegetated, as well as Normalized Difference Vegetation Index (NDVI) at three scales.




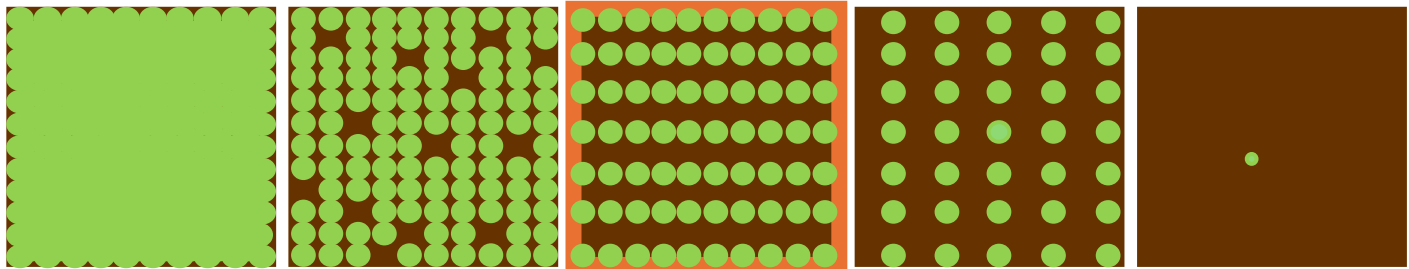
¹ Ganju et al. 2017

A Tale of Many Metrics

The suite of metrics assessed include 1 m² plot level data, WWL level data from Marsh Resilience to Sea-Level Rise (MARS), and basin level data. Each metric assesses slightly different aspects of marsh health. Thereby, ensuring marsh health is assessed across a range of metrics and not just one.


Plot Level: Percent Cover Metric


 Percent vegetative cover in ACE and NI-WB averages ~ 50% for areas with *S. alterniflora*, and this has been stable or increasing since monitoring began. This translates to a Unvegetated to Vegetated Ratio (UVVR) of 1.

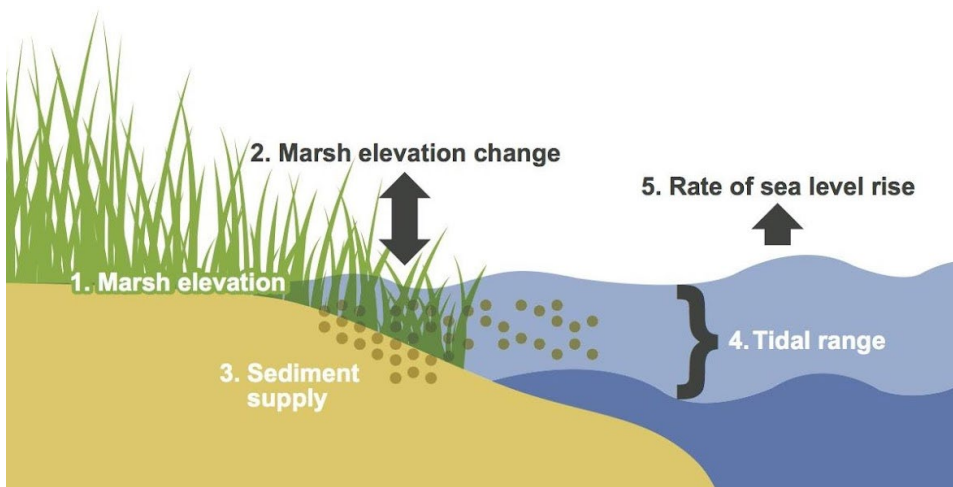


Vegetated:	100%	75%	50%	25%	0.01%
UVVR:	0	0.3	1	3	99

WWL Level: Marsh Resilience to Sea-Level Rise (MARS) Metrics

 NI-WB WWL marsh ranges from moderate to vulnerable using the MARS² metrics. In particular, this marsh is not vertically gaining relative to SLR (Metric 2 – Marsh elevation change).

 ACE WWL marsh ranges from moderate to resilient using the MARS metrics. In particular, this marsh is vertically gaining relative to SLR (Metric 2 – Marsh elevation change).

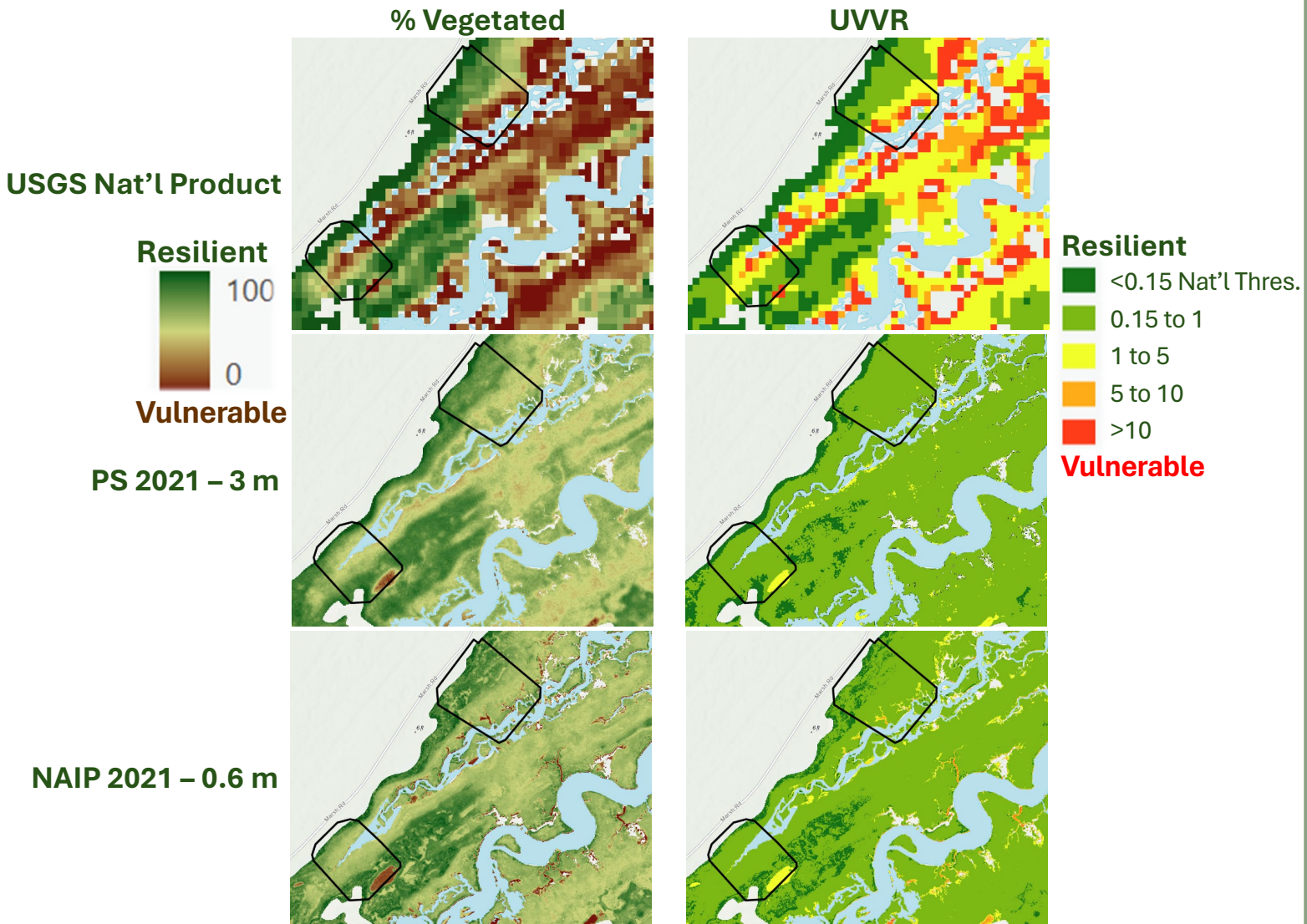


Metric	NI-WB	ACE
1.	Yellow	Light Green
2.	Red	Dark Green
3.	Orange	Yellow
4.	Yellow	Light Green
5.	Yellow	Yellow

² Raposa et al. 2016

Basin Level: UVVR & % Vegetated Metrics

Only areas with mixed plant communities near upland edges achieve the < 0.15 UVVR national threshold (equates to $> 87\%$ vegetated) as resilient for either the NP or NERR-derived data. NERR-derived UVVR indicate the marsh is more resilient if a UVVR < 1 (50% vegetated, average plot data) threshold is used.



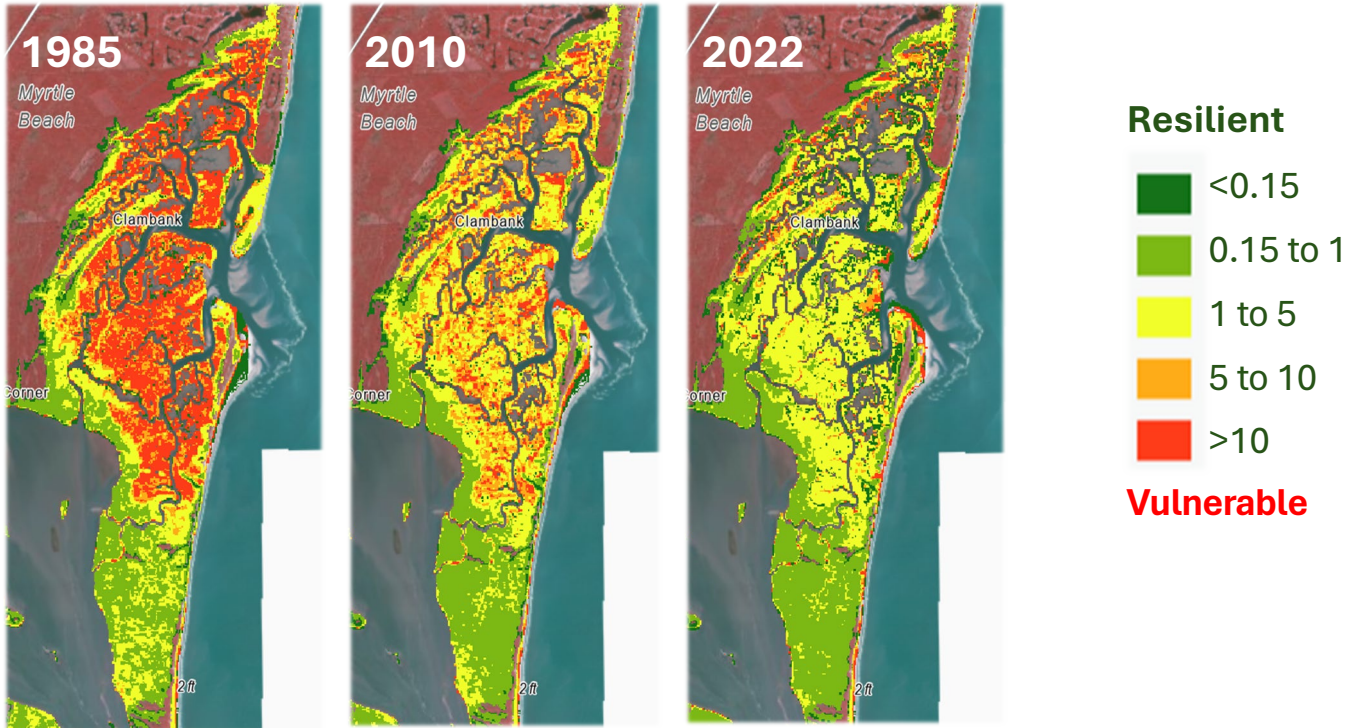
The % Vegetated and UVVR for NI-WB and ACE ranges for the small scale and three imagery resolutions. Percent vegetated cover is higher and UVVR is lower in NI-WB compared to the ACE. This indicates NI-WB is more resilient; however, the MARS metrics indicate the ACE is more resilient.

Metric	Source	Imagery	Resolution	NI-WB	ACE
Vegetated (%)	Nat'l Prod	Landsat	30 m	36-61	31-43
	NERR	PS	3 m	70-82	35-60
	NERR	NAIP	0.6 m	68-76	48-56
UVVR	Nat'l Prod	Landsat	30 m	0.6-1.7	1.4-2.3
	NERR	PS	3 m	0.2-0.4	0.7-1.9
	NERR	NAIP	0.6 m	0.3-0.5	0.8-1.1

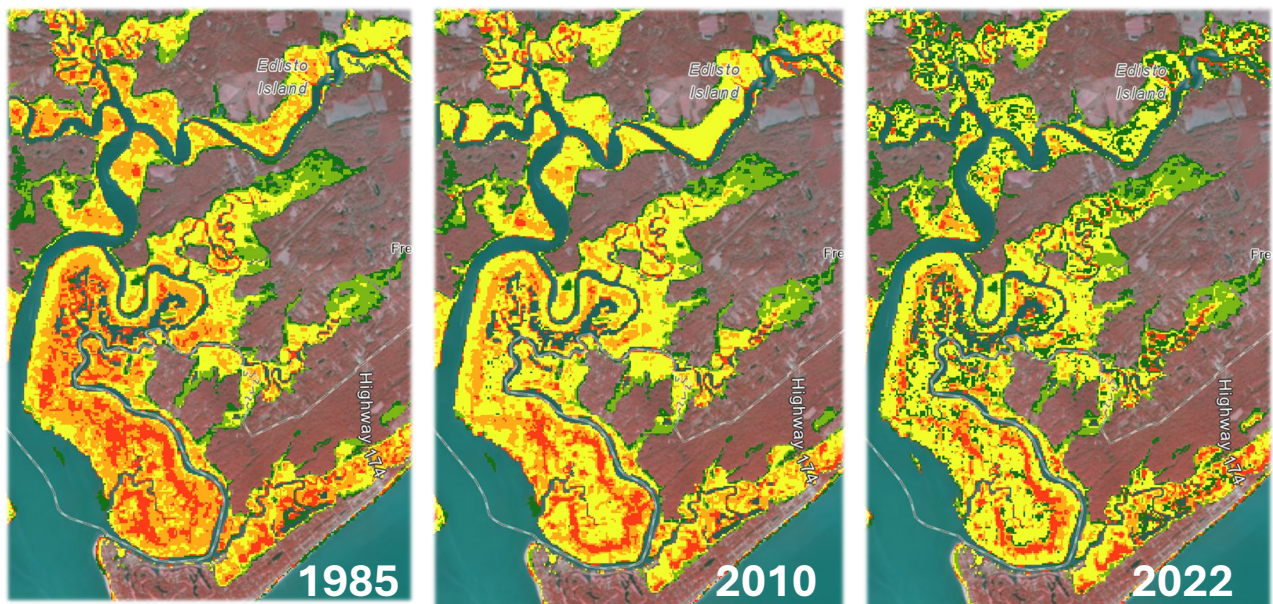
Large Scale Change in UVVR NP

The USGS UVVR National Product can be visually assessed at the two reserves for 1985, 2010, and 2022. Warmer colors have decreased since 1985. UVVR is not increasing over time. SC marshes appear to be improving and becoming more vegetated between 1985 and 2022.

NI-WB



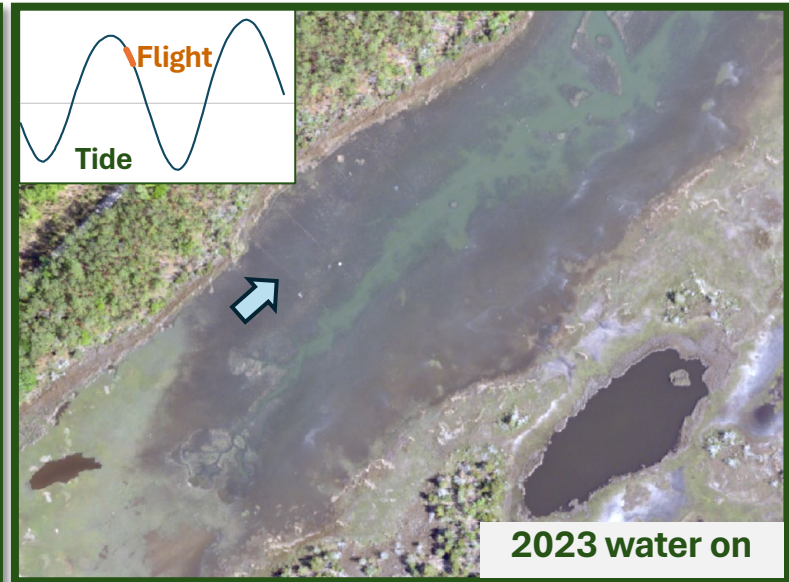
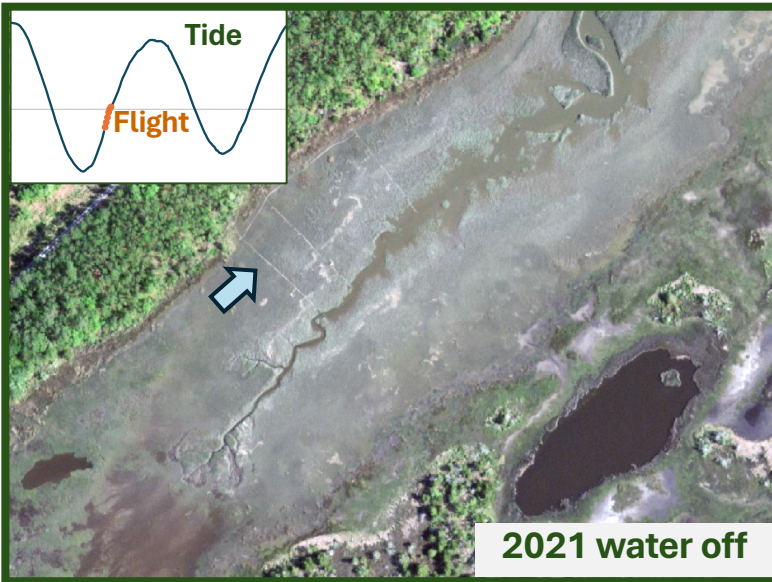
ACE



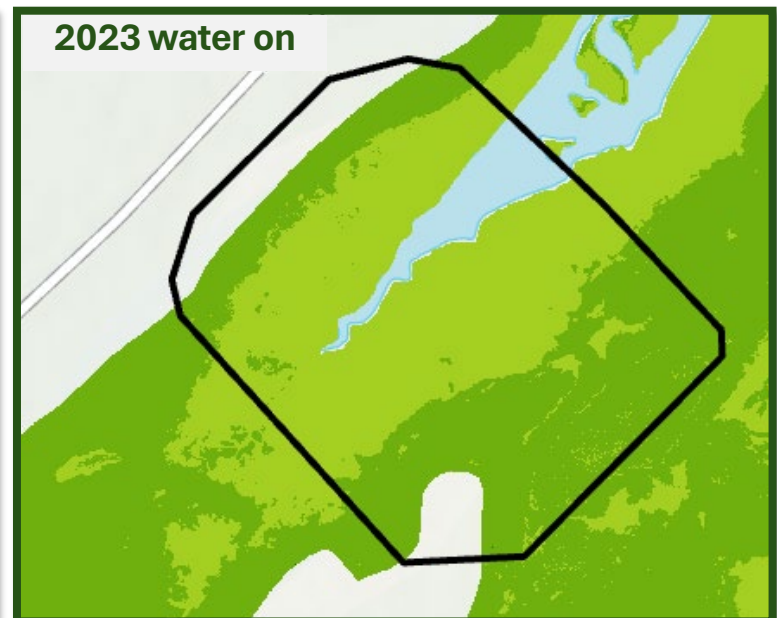
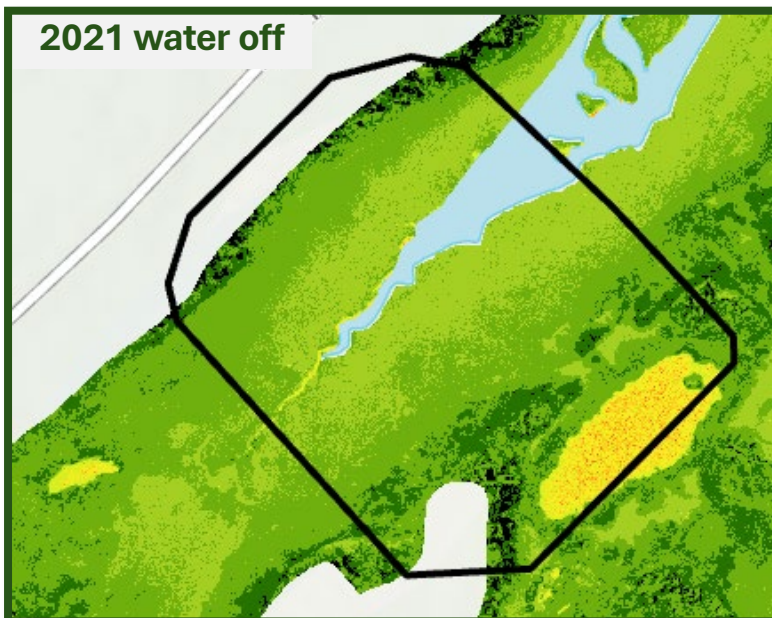
If SC marshes are degrading with increasing SLR then one would expect to see green (resilient) in 1985 changing to warmer (vulnerable) colors in 2010 and 2022, especially since the highest rate of SLR occurred in the last 10 years.

Timing of Imagery Collection

- Publicly available images such as NAIP are high resolution (< 1 m) and flown in the spring every two years. Some NAIP images are captured with water on the marsh (high tides) and others with water off the marsh (low tides). The 2021 image on the left is largely with water off the marsh and the 2023 image on the right is with water on the marsh surface; note how walkways on the marsh can be seen in 2021 but are almost completely covered in 2023 (blue arrow).



- Very different interpretations of marsh resilience emerge depending on tidal level as seen in this example at NI-WB WWL. If % vegetated and UVVR are calculated based on water on the marsh imagery, then NERR-derived UVVR resulted in a muted effect with loss of pixel resolution and no extreme values (no very dark green or yellow/orange).



Take Away Lessons

- 🦅 The ACE and NI-WB long-term marsh monitoring sites are stable or increasing in vegetative cover.
 - 🦅 The plot level vegetated cover averages ~50% with most *Spartina alterniflora* plots below the proposed national threshold of 87% vegetated cover.
 - 🦅 Vegetated cover from 2021 imagery ranged from 35 to 82% across the three scales at the two NERRs, all below the 87% proposed national threshold.
 - 🦅 ACE WWL marsh as indicated by marsh elevation change (surface elevation tables – SETs) is keeping pace with SLR but NI-WB WWL is not.
 - 🦅 Different metrics provided different resilience estimates.
- 🦅 National metrics and thresholds need additional evaluation. For example, the UVVR threshold of < 0.15 or vegetated cover $> 87\%$ appears to be too stringent for the naturally sparse, *Spartina alterniflora* dominated SC marshes.
- 🦅 Timing and resolution of imagery was found to be important.
 - 🦅 Imagery captured around low tide when water was off the marsh was found to provide a better assessment of vegetated cover.
 - 🦅 Imagery color bands varied between the different flight or satellite captures. Further research is needed to understand this variability and how it effects potential differences across years.

SC marshes do not appear to be as vulnerable as national products suggest; however, more marsh monitoring is needed at a larger scale and in areas that are clearly showing degradation to develop a more informative and reliable suite of metrics that can be used to provide an accurate picture of the health and resilience of SC marshes.



National Estuarine
Research Reserve System
Science Collaborative



North Inlet - Winyah Bay
National Estuarine Research Reserve