RELATIVE SEA LEVEL RISE AND HABITAT ASSESSMENT IN THE NUECES DELTA

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Prepared by:

Berit E. Batterton, B.A.
Katie Swanson, M.S.
and
Kenneth H. Dunton, Ph.D.
University of Texas at Austin Marine Science Institute
750 Channel View Drive, Port Aransas, TX 78373
Phone: (361) 749-6744
Fax: (361) 749-6777
E-mail: ken.dunton@utexas.edu

Submitted to:
Coastal Bend Bays & Estuaries Program
1305 N. Shoreline Blvd., Suite 205
Corpus Christi, TX 78401

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EXECUTIVE SUMMARY

The purpose of this study is to provide CBBEP and resource agencies with the information needed to determine and plan for the impacts of future sea level rise on marsh habitats in the Nueces Delta Preserve. Historical and projected rates of relative sea-level rise (rSLR) along the Texas coast are among the highest globally. This work is a subset of research by scientists at the University of Texas Marine Science Institute and the Mission-Aransas National Estuarine Research Reserve to implement long-term monitoring to detect environmental changes, focusing on the ecological integrity of marsh vegetation communities and surface elevations. Long-term ecological monitoring is an extremely valuable tool for evaluating ecological baselines, assessing historical ecological change, and making informed and effective decisions for adaptive management of water and habitat resources. The primary questions addressed include: 1) “What are the spatial and temporal patterns in marsh elevation in the Nueces Delta?”, 2) “What are the characteristics of these Nueces Delta marsh vegetation communities?”, and 3) “How are any changes in marsh elevation, plant percent cover, and species composition, related to measured characteristics of the wetland environmental quality and relative sea level rise?”.

Marsh vegetation covered a sizable portion of all six monitoring sites (71.7%). Dominant plant species included *Salicornia virginica*, *Batis maritima*, and *Borrichia frutescens*. However, significant losses in vegetated marsh area due to erosion or increases in water level have occurred over time at sites 270, 450, and 463. Tidal creek salinities averaged 18.3 while mean porewater salinity values frequently met or exceeded thresholds for hypersalinity (>35). SET-MH sites had a mean surface elevation rate of change of 8.5 mm yr^{-1} and a vertical accretion rate of ~5 mm yr^{-1}. Surface elevation change rates are similar to current estimates of rSLR (7-8 mm yr^{-1}), but lower than projected future rates of rSLR (>10 mm yr^{-1}). Site 270 had greater rates of overall surface elevation change than site 450, while accretion rates were similar at both sites. Based on monitoring data gathered in this study, both hypersalinity caused by drought conditions and rSLR have the potential to be the most critical stressors and drivers of vegetation change and overall marsh resilience in the Nueces Delta. Vegetation plays a foundational role in the creation and maintenance of stable marsh ecosystems, and management efforts should focus not only on sediment delivery and water levels, but also on preserving vegetation abundance and productivity.

INTRODUCTION

Since 1999, members of the University of Texas Marine Science Institute (UTMSI), with support from CBBEP and other agencies, have been monitoring the quality and condition of six sites within the Nueces Delta marsh ecosystem. In 2017 and 2018, UTMSI and Mission-Aransas National Estuarine Research Reserve (MA-NERR) scientists installed six Surface Elevation Tables (SETs) and 24 Marker Horizons (MHs) at two of the six monitoring sites in the Nueces Delta marsh. Long-term ecological monitoring offers data and tools to evaluate ecological baselines and make informed and effective decisions for adaptive management of water and habitat resources (Montagna et al., 2009). The magnitude and longevity of long-term datasets, such as in the Nueces Delta, makes them extremely valuable for assessing historical change in ecological condition and predicting future responses to climate change stressors. Nueces Delta data have been used to assess short-term ecosystem responses to drivers such as riverine discharge (Stachelek & Dunton, 2013) or erosion disturbance (Dunton et al., 2019), but impacts of long-term stresses (e.g., drought, sea level rise) have not yet been quantified.

Research and conservation efforts should seek to develop a knowledge base that outlines the linkages amongst marsh ecosystem components and indicators of climate or anthropogenic stressors to assess marsh condition, stability, and resilience at various temporal and spatial scales. Marsh stability is a key factor in ecological resilience to climate change. South Texas marshes are highly variable and stressful environments with regards to salinity and water availability, due to low precipitation and high evaporation. The Texas coast represents a “zone of ecological instability” in which small disturbances can cause drastic shifts in vegetation cover and community composition (Osland et al., 2019). Changes in freshwater availability and salinity may lead to cascading effects on plant community composition and therefore overall marsh productivity, stability, and critical ecosystem functions and/or services (Osland et al., 2018; Spivak et al., 2019). Human activity, such as upstream watershed modifications, agriculture, industry, and coastal development, intensify these threats to marshes. Accelerated sea-level rise will also likely have a large impact on coastal marshes (Fagherazzi et al., 2020; Saintilan et al., 2022). Historical and projected rates of relative sea-level rise (rSLR) along the Texas coast are among the highest globally due to land subsidence (0.47-0.79 m projected rSLR by 2050; Sweet et al., 2022). Increases in sea levels are expected to push salinity gradients upslope and upstream, exacerbating hypersalinity and causing a potential loss of marsh vegetation (Osland et al., 2022). In addition, rSLR may lead to higher rates of shoreline erosion and eventual marsh collapse (Dunton et al., 2019), if marsh ecosystems are not able to build surface elevation fast enough to keep up with water levels.

The objectives of this study were to (1) continue a long-term marsh vegetation monitoring program at the Nueces Delta, (2) supplement the existing marsh monitoring program with elevation data by monitoring Surface Elevation Tables (SETs) and marker horizons (MHs), and (3) provide CBBEP and resource agencies with the information needed to determine and plan for the impacts of future sea level rise on marsh habitats in the Nueces Delta Preserve. It is vitally important that we understand and quantify how vegetation and ecological functioning in the Nueces Delta marsh has changed over time, so that we may make informed management decisions in the face of rapid climate change

The primary questions addressed by SET-MH and vegetation monitoring include:

1) What are the spatial and temporal patterns in marsh elevation in the Nueces Delta?
2) What are the characteristics of these Nueces Delta marsh vegetation communities, including their species composition and percent cover?
3) How are any changes in marsh elevation, plant percent cover, and species composition, related to measured characteristics of wetland environmental quality and rSLR?

METHODS

SET-MH Installation and Sampling Summary

Installation of three SETs at each of sites 270 and 450 began on 8 May 2017 with the construction of scaffolding, and steel rod installation was completed on 9 June 2017. All rods were pounded 60-80 feet into the ground until refusal (17-20 steel rods per site). Four MHs at each of the three SETs at both sites were installed on 28 June 2018. For each MH, rectangular plots, marked with four pieces of PVC, were established using a thick layer of feldspar clay at each corner of the SET (Fig. 1). Baseline SET readings were collected during MH installation and again on 18 Dec 2018. Additional SET-MH readings were not collected again until 23 Mar 2022, 09 Dec 2022, and 25 May 2023.

SET-MH sampling protocols are adapted from the National Estuarine Research Reserve (NERR) System Sentinel Site Program protocol. At each SET, the SET attachment is inserted into the SET receiver (permanently connected to steel rods located in the ground). The SET arm is then lowered onto the receiver and leveled. Once leveled, fiberglass rods are gently lowered to the surface of the soil and secured with a clothespin. The lengths from the SET arm extender to the tip of the rods are then measured for all 9 rods in each of four directions (NE, NW, SE, SW). At each MH plot, three soil cores are taken throughout the plot and replicate measurements of the distance from the sediment surface to the visible feldspar clay layer are recorded using calipers. Surface elevation and vertical accretion rates of change were estimated using a simple linear regression of years since baseline and averaged cumulative pin heights or depth to marker horizon data, respectively.

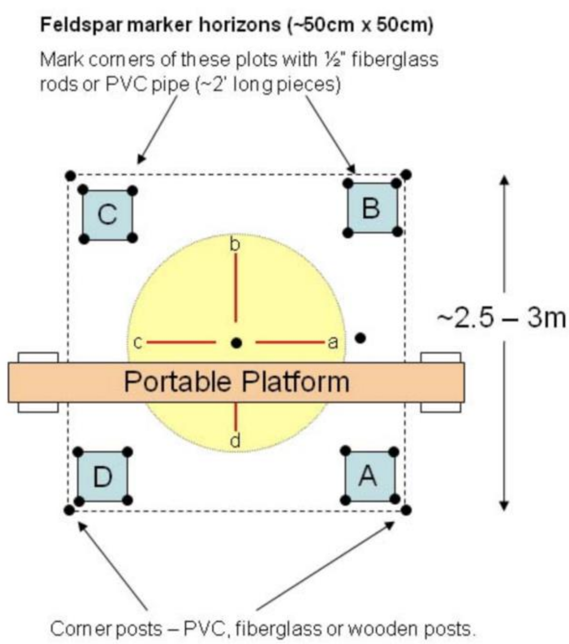

Figure 1. Conceptual diagram of an example SET-MH station.

Vegetation Monitoring Sampling Summary

Sites 254, 270, 271, 450, 451, and 463 have been monitored consistently from 1999 until 12 June 2019. Vegetation transects were re-established, and measurements were collected at all sites on 20 and 22 Feb 2023. Monitoring protocols are consistent with methods historically conducted by UTMSI. Quarterly sampling was additionally conducted on 15 and 25 May 2023 and 1 August 2023. For statistical rigor, a repeated measures design with fixed sampling stations was implemented to maximize our ability to detect future change.

Hydrographic measurements of temperature, salinity, conductivity, dissolved oxygen, chlorophyll-*a* fluorescence, and pH were collected with a YSI 6920 data sonde in tidal creeks/open water adjacent to each site. Water samples were obtained at each station for determination of Total Suspended Solids (TSS) and water column nutrient concentrations. All sonde measurements and water samples were obtained after sediment resuspension due to boat disturbance ceased. Soil cores were taken every 10 m along four transects, starting at 0 m (or the shoreline, if the 0 m point was underwater) for analysis of (1) soil nutrients, (2) soil moisture, and (3) porewater chemistry.

At each site, species composition and percent cover were obtained from a quadrat sample collected every 2 m along the 20 m transects (every 4 m from 24-50 m at site 463). Percent cover of species area was estimated via visual observation using a 0.25 m^2 quadrat frame subdivided into 100 cells. Components assessed with percent cover included vegetation, bare substrate (i.e., cyanobacterial mat, mud flat, etc.), and water.

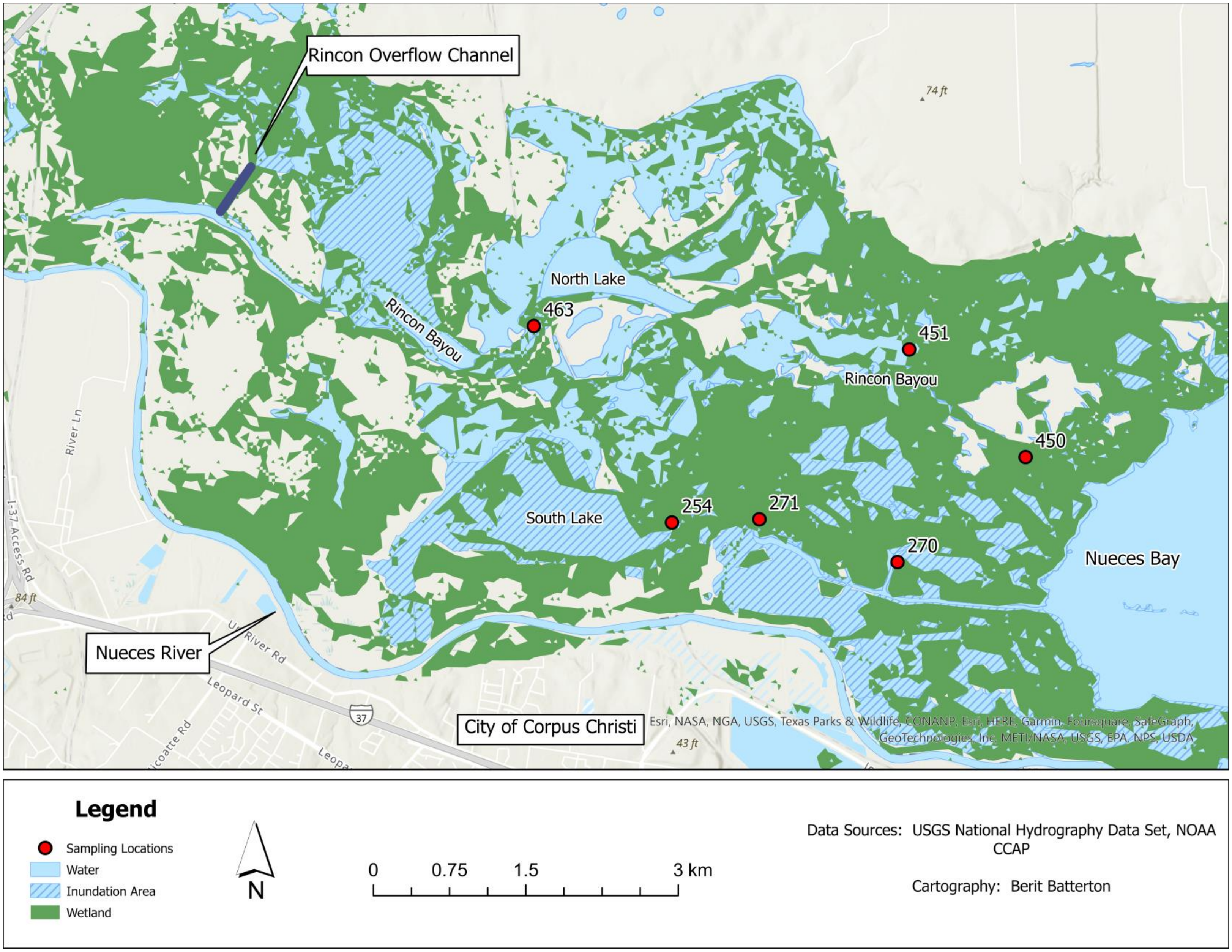

Figure 2. Map of vegetation and SET-MH monitoring sites in the Nueces Delta.

RESULTS

Water and Soil Quality

Tidal creeks adjacent to monitoring sites had a mean water temperature of 25.36 ± 0.51 °C (mean ± standard deviation) and salinity of 18.31 ± 2.03 (Table 1). Dissolved oxygen concentrations were 10.64 ± 5.33 mg L^{-1} with an oxygen saturation of 107.16 ± 8.78% (Table 1). No hypoxic (≤ 2 mg L^{-1}) or low oxygen (≤ 3 mg L^{-1}) conditions were documented. Mean pH values were 7.86 ± 0.07 (Table 2). All stations had a pH of ~ 8. Chlorophyll-*a* concentrations varied widely from 10.04 ± 6.74 to 27.46 ± 35.74 mg L^{-1} (Table 1). Water column nutrient concentrations were 1.37 ± 0.24 and 0.17 ± 0.20, for ammonium and nitrite and nitrates, respectively (Table 1). Mean TSS values were 99.17 ± 62.47 mg L^{-1} (only collected in 2023; Table 1). Stations along the Rincon Bayou (450, 451, 463) typically had more variable salinity, dissolved oxygen concentrations, pH, and chlorophyll-*a* concentrations. Overall, the stations were quite similar in general characteristics.

Soil at vegetation monitoring sites had a mean water content (moisture) of 49.93 ± 6.01% and salinity of 44.26 ± 6.50 (Table 2). Porewater salinity values frequently met or exceeded thresholds for hypersalinity (>35), and many values >100 were recorded. Mean porewater ammonium concentrations were 65.73 ± 13.20 µM (Table 2). Overall, stations exhibited greater spatial and temporal variability in soil parameters versus corresponding tidal creek parameters, indicating the influence of both above and belowground factors (vegetation, microbial processes, elevation, etc.).

Table 1. Summary of tidal creek hydrographic parameters from 2017-2023 by site. Note: water column nutrient values only represent 2017-2018.

	Temperature (°C)	Salinity	Dissolved Oxygen (mg L^{-1})	Dissolved Oxygen (%)	pH	Chlorophyll *a* (μg L^{-1})	Ammonium (μM)	Nitrite + Nitrate (μM)	TSS (mg L^{-1})
254									
Mean	24.90	20.88	8.27	111.64	7.85	17.60	1.55	0.20	183.82
Std. Dev.	6.37	10.38	2.45	28.58	0.49	10.65	1.06	0.30	115.75
270									
Mean	25.12	17.71	8.87	103.91	7.89	10.04	1.43	0.57	53.92
Std. Dev.	5.83	7.42	1.43	43.36	0.41	6.74	1.21	1.09	5.31
271									
Mean	25.46	20.72	8.07	110.03	7.81	17.04	1.68	0.01	109.95
Std. Dev.	6.60	10.72	1.68	26.06	0.37	11.80	1.55	0.02	43.25
450									
Mean	25.13	16.47	8.00	104.81	7.85	17.60	1.24	0.03	99.73
Std. Dev.	4.54	11.47	1.65	16.53	0.49	10.65	0.99	0.05	32.54
451									
Mean	25.19	17.78	21.48	93.26	7.97	19.62	0.94	0.01	75.20
Std. Dev.	4.64	12.71	37.85	38.67	0.45	16.41	0.67	0.03	4.12
463									
Mean	26.34	16.27	9.15	119.33	7.77	27.46	1.39	0.17	72.40
Std. Dev.	4.57	12.50	2.37	17.06	1.30	35.74	0.98	0.38	26.15
Overall									
Mean	25.36	18.31	10.64	107.16	7.86	18.23	1.37	0.17	99.17
Std. Dev.	0.51	2.03	5.33	8.78	0.07	5.59	0.24	0.20	62.47

Table 2. Summary of soil parameters from 2017-2023 by site. Note: porewater nutrient values only measured from 2018-2019.

		Soil Moisture (%)	Porewater Salinity	Porewater Ammonium (µM)
254				
	Mean	50.16	41.07	60.49
	Std. Dev.	4.56	16.91	30.74
270				
	Mean	53.66	37.63	46.73
	Std. Dev.	4.10	16.65	34.17
271				
	Mean	57.79	43.69	85.80
	Std. Dev.	4.83	20.43	48.53
450				
	Mean	53.35	45.26	60.36
	Std. Dev.	5.09	83.74	39.37
451				
	Mean	39.74	57.74	79.98
	Std. Dev.	6.73	32.49	53.24
463				
	Mean	44.89	40.19	61.03
	Std. Dev.	6.28	19.89	46.80
Overall				
	Mean	49.93	44.26	65.73
	Std. Dev.	6.01	6.50	13.20

Marsh Vegetation Cover and Species Distributions

The mean vegetation cover for all sites in the Nueces Delta was 71.6% (Table 3). The dominant plant species, *Salicornia virginica*, *Batis maritima*, and *Borrichia frutescens*, covered 27.1, 17.7, and 12.1% on average, respectively (Table 3). However, the relative dominance of each species varied widely between sites (e.g., from 4.8 to 36.4% for *Batis maritima*; Table 3), due to environmental conditions such as distance upstream, elevation, and salinity. Little to no *Limonium nashii*, *Salicornia bigelovii*, *Suaeda linearis*, *Scirpus maritimus*, *Spartina spartinae*, *Iva frutescens*, *Cuscuta* spp., or *Aster* spp. were found during sampling from 2017-2023 (Table 3). Additionally, *Monanthochloe littoralis* and *Spartina alterniflora* were mostly only found at sites 463 and 270, respectively (Table 3; see appendix for table metadata). Rapid changes in vegetation cover and composition have been observed after weather events (i.e., floods, Hurricane Harvey, etc.).

Sites 270, 271, 451, and 463 had large bare portions, both flooded and non-flooded. These bare patches are often in the middle of transects and oscillate between periods of colonization by vegetation or cyanobacteria (Figure 3a). Abundant cyanobacterial mats were observed covering sizable portions of bare ground. After precipitation events, cyanobacterial mats often lifted from the sediments and subsequently settled on top of marsh vegetation (Figure 3b). Significant losses due to erosion or increases in water level have occurred at sites 270, 450, and 463. At site 270, the water line moved from the 0 m transect line in the 2000s to the 8 m transect line presently. The presence of *Spartina* alterniflora has been reduced to an approximately 2 m band between the 6 and 8 m lines. Similar shifts from low marsh vegetation to mid/high marsh species have occurred at other sites. At site 450, the 0 m transect line has been underwater since approximately 2015, and the 2 m line is now showing signs of erosional collapse (Figure 3c). At site 463, the 0 m line is underwater along four of the five transects.

Figure 3. a) Large bare patch with vegetation island and floating cyanobacteria at site 271, b) Floating cyanobacterial mat at site 451 after a rain event, c) Underwater PVC poles along the 0 m transect line at site 450.

Table 3. Summary of plant areal cover from 2017-2023 by site.

		BM	*BF*	*DS*	*LN*	*LC*	*ML*	*SB*	*SV*	*SA*	*SL*	*SM*	*SS*	*IF*	*AT*	*Other*	*Wrack*	*Bare*
254																		
	Mean	24.64	18.63	12.15	0	0.96	0.04	0	40.42	0.18	0	0	0	0	0	0	0.45	2.52
	Std. Dev.	28.86	28.65	17.23	0	3.38	0.56	0	34.11	4.05	0	0	0	0	0	0	3.98	8.27
270																		
	Mean	11.62	10.6	3.21	0.01	2.90	0	0.08	38.64	5.41	0.02	0	0	0	0	3.03	1.58	21.52
	Std. Dev.	17.92	22.61	8.66	0.13	7.32	0	1.8	35.54	16.5	0.46	0	0	0	0	17.16	9.16	37.68
271																		
	Mean	36.35	1.89	3.93	0.03	0.22	0	0	26.20	0.01	0	0	0	0	0	0	8.49	22.87
	Std. Dev.	37.06	9.02	13.85	0.67	1.38	0	0	34.04	0.27	0	0	0	0	0	0	23.73	33.46
450																		
	Mean	23.14	12.75	12.24	0.03	1.28	0	0	32.17	0.95	0.03	0	0	0	0	0.91	3.69	10.87
	Std. Dev.	27.62	27.71	19.08	0.47	4.28	0	0	32.36	7.28	0.67	0	0	0	0	9.23	14.37	25.28
451																		
	Mean	4.84	9.77	0.28	0	0.74	1.91	0.26	14.27	0	0.12	0	0	0	0	0	0.51	66.35
	Std. Dev.	13.16	26.07	1.43	0	4.68	11	1.93	27.24	0	2.39	0	0	0	0	0	3.97	44.12
463																		
	Mean	5.59	18.68	6.44	0.02	2.57	22.0	0.29	10.88	0	0.88	0	0	0	0	0.44	1.38	30.44
	Std. Dev.	11.39	31.65	16.34	0.25	7.44	32.5	1.69	24.0	0	5.91	0	0	0	0	6.66	7.36	40.07
Overall																		
	Mean	17.70	12.05	6.38	0.02	1.45	3.99	0.11	27.10	1.09	0.18	0	0	0	0	0.73	2.68	25.76
	Std. Dev.	12.45	6.30	4.92	0.01	1.06	8.85	0.14	12.37	2.15	0.35	0	0	0	0	1.18	3.08	22.17

Surface Elevation Dynamics

SET-MH sites had a mean surface elevation rate of change of 8.54 ± 0.40 mm yr^{-1} (mean ± standard error; Table 4). This rate of change appears consistent over time (R^2 = 0.99, $p < 0.001$; Table 4; Figure 4a). Mean rates of vertical sediment accretion were 5.04 ± 2.57 mm yr^{-1} (Table 4). Accretion rates are more uncertain than overall surface elevation change (R^2 = 0.56, p = 0.15; Table 4; Figure 4b), due to both sedimentation and erosion processes that may lead to instability in surficial sediments. Site 270 had greater rates of overall surface elevation change than site 450, while accretion rates were similar at both sites (Table 4).

Table 4. Summary of SET-MH rates of change from 2018-2023 by site.

		Surface Elevation Change (mm yr^{-1})	Vertical Sediment Accretion (mm yr^{-1})
270			
	Slope	9.20	4.82
	Std. Error	0.54	3.46
	R^2	0.99	0.39
	p-value	< 0.001	0.26
450			
	Slope	7.87	5.27
	Std. Error	0.26	2.03
	R^2	0.99	0.69
	p-value	< 0.001	0.08
Overall			
	Slope	8.54	5.04
	Std. Error	0.40	2.57
	R^2	0.99	0.56
	p-value	< 0.001	0.15

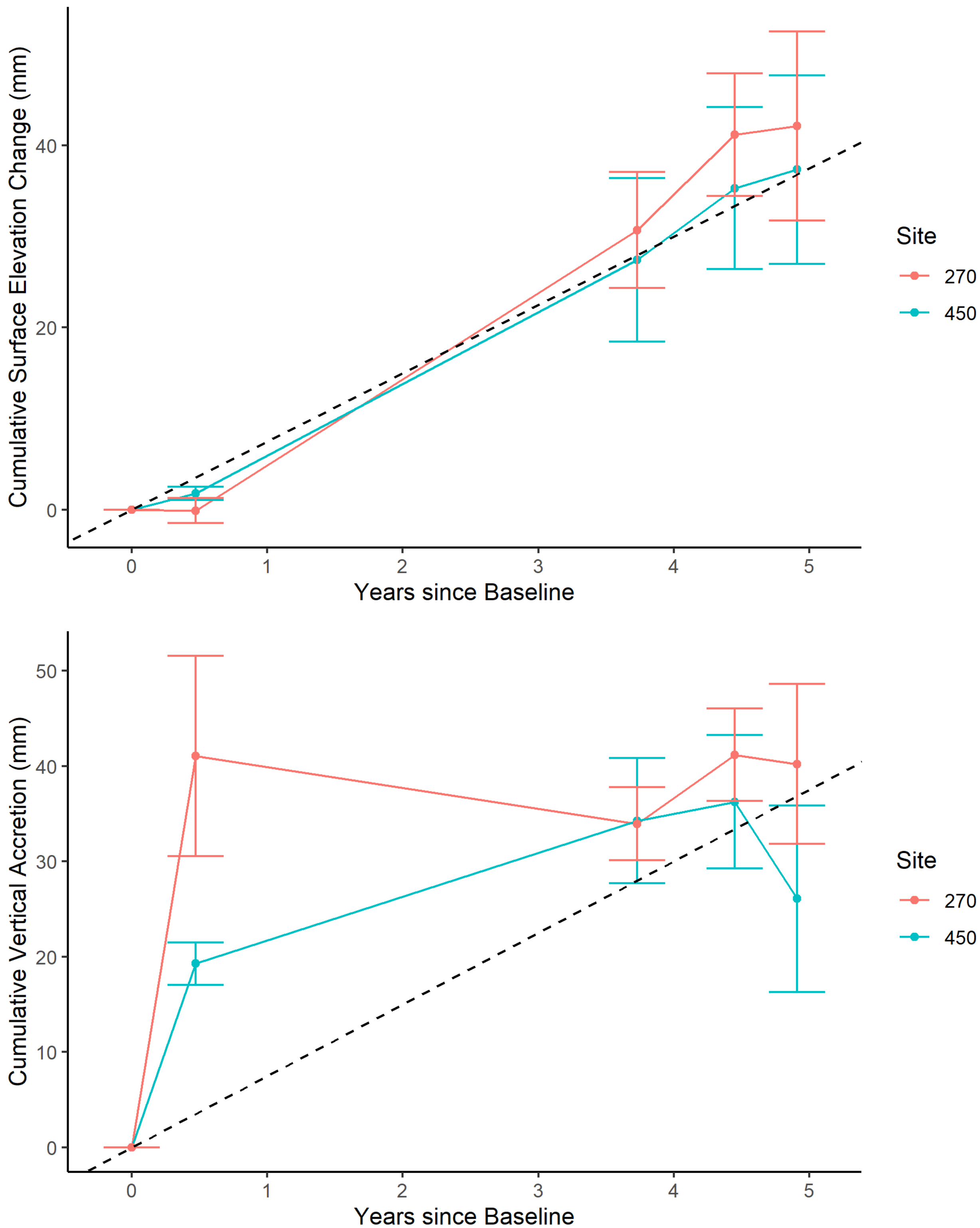

Figure 4. Cumulative surface elevation change (a) and vertical accretion (b) at Nueces Delta sites 270 and 450. Error bars represent the standard error. Mean rSLR rate (~7.5 mm yr^{-1}) is represented by the dashed line.

CONCLUSIONS

Marsh Abiotic and Biotic Conditions

Overall, water and soil quality at the vegetation monitoring sites appear to be within an acceptable range for a productive marsh. There does not seem to be evidence of either excessive nutrient loading (low tidal creek nutrient levels and high dissolved oxygen concentrations) or nutrient limitation (sufficient porewater ammonium concentrations). Water column temperature, salinity, and pH are all within normal ranges for the Texas coastal bend. TSS represents potential sediment delivery to marsh sites. Values of TSS were highly variable across sites and over time, justifying the need for continued sampling. Soil moisture and porewater salinity are inversely related. Drier sites tend to have higher salinities due to reduced tidal flushing and high evaporation. Porewater salinity reached extreme values (>100) for extended periods at many sites. Spatial parameters, such as distance upstream and elevation, are likely the key factors in explaining these differences in water and soil quality between sites. Regarding water and soil quality, hypersalinity caused by drought conditions has the potential to be the most critical stressor and driver of vegetation change in the Nueces Delta.

Each monitoring site displayed unique communities of marsh vegetation. This variation is reflective of differences in abiotic factors, such as salinity, moisture, and nutrient concentrations. Ultimately, these differences are a result of fine-scale spatial heterogeneity in elevation or topography, freshwater inflow, and tidal influence. We observed an increase in high marsh species (i.e., *Monanthochloe littoralis*, *Suaeda linearis*) with distance upstream. Intertidal species, such as *Spartina alterniflora*, were only observed at low elevations at sites nearest to Nueces Bay. While these species can colonize new ground as water levels increase, many shorelines within the Nueces Delta may be too steep due to erosion. It appears that *S. alterniflora* and other low marsh species may all but disappear from the monitoring sites in the future. The brackish species *Scirpus maritimus* has already been lost and has not been recorded at any sites since 2008.

At all sites, significant changes in both vegetation cover and community composition have been observed over time. The most worrying trend is the loss of shoreline vegetation due to erosion and/or increases in water level. Nearly all sites had some level of erosion along the shoreline, with the most severe example being site 270 (~8-10 m retreat). Site 270 is among the closest sites to the wave action of Nueces Bay and has the lowest concentration of TSS in the water column, indicating potential sediment starvation. In addition, hypersalinity was recorded at all sites, due to periods of drought-like conditions. Persistent high salinities can lead to vegetation dieback and expansion of interior bare patches. Recolonization of saline bare patches will only occur in the most disturbance- or salinitytolerant species (i.e., *Salicornia bigelovii*, *Distichlis spicata*) or when salinities are ameliorated by freshwater events.

Surface Elevation Dynamics

Overall, SET-MH measurements indicate an increase in overall marsh surface elevation in the Nueces Delta. Both SET-MH sites exhibited similar rates of surface elevation change as historical rates of rSLR along the Texas coast (7-8 mm yr^{-1}). Only in recent years (2022-2023) have surface elevation gain rates exceeded that of mean rSLR. Surface elevation change rates were higher than vertical accretion rates at all sites, indicating subsurface expansion via belowground vegetation biomass or other biophysical processes. While SET measurements are accurate and high resolution, the quantification of sedimentation via MH-derived vertical accretion rates carries some uncertainty. MH measurements generally skew positive since data are not recorded if a MH is not found, even though an erosion event (negative accretion) may have occurred (Lynch et al., 2015; Moon et al., 2022). This uncertainty is reflected in the low R^2 and p-values present in the accretion rate data. Additionally, drawing conclusions about marsh resilience is typically not recommended until five years of continuous SET-MH measurements have occurred (Moon et al., 2022). While the SETs in the Nueces Delta have been established for five years, measurements have not been taken continuously. Additional measurements and monitoring are necessary to properly model the rates of elevation change and draw conclusions regarding marsh resilience. Despite uncertainties, rSLR is likely another critical stressor and driver of change in the Nueces Delta.

The MA-NERR has several SET-MH sites within the NERR boundary, just north of Nueces Bay. Many of these sites have been monitored since 2013 and 2014. Surface elevation change rates in the MA-NERR range from -23.96 to 47.01 mm yr^{-1} (Vaccaro & Cressman, 2020). SET sites are highly variable in their ecosystem setting, ranging from small island marshes to mangrove-dominated wetlands to wildlife refuges. All sites in the MA-NERR are less protected from wave action than the Nueces Delta sites, but they receive a greater sediment supply from tidal inputs. As monitoring continues for both MA-NERR and Nueces Delta sites, an in-depth comparison of the drivers of differences in elevation changes between the two systems should provide valuable insight into regional marsh resilience to rSLR.

Summary

The Nueces Delta is a highly dynamic estuarine marsh ecosystem. Vegetation plays a foundational role in the creation and maintenance of stable marsh ecosystems. In the Nueces Delta, substantial changes in vegetation cover and community composition have been observed throughout decades of monitoring. As such, marsh management efforts should focus not only on sediment delivery and water levels, but also on preserving vegetation abundance and productivity. Strategies for conserving vegetation productivity may include freshwater inflows management (i.e., water diversion, etc.), thin layer placement, and living shorelines.

While sites in the Nueces Delta show evidence of potential marsh resilience, future rates of rSLR are projected to continue to increase to > 10 mm yr^{-1} (Sweet et al., 2022). Marsh elevation gain typically accelerates as rSLR rates increase, but rapid elevation gain can only occur with sufficient sediment supply, deposition, and stabilization promoted by vegetation. These interactions between marsh biota and abiotic ecosystem properties are known as biophysical feedbacks (Cahoon et al., 2021). Marsh sediment supply is of particular concern in the Nueces Delta due to the history of erosion and alteration of water flow (i.e., mitigation channels, upstream damming; Dunton et al., 2019; Hill et al., 2011). If rSLR rates continue to increase while marsh surface elevation change remains consistent, erosion and drowning may occur. Based on the short timeline within which we have elevation information for the Nueces Delta, several more years of continuous monitoring of surface elevation change and associated biophysical feedbacks is necessary.

APPENDIX

Appendix A. Description of species abbreviations in Table 4.

Abbreviation	Species Name
BM	*Batis maritima*
BF	*Borrichia frutescens*
DS	*Distichlis spicata*
LN	*Limonium nashii*
LC	*Lycium carolinianum*
ML	*Monanthochloe littoralis*
SB	*Salicornia bigelovii*
SV	*Salicornia virginica*
SA	*Spartina alterniflora*
SS	*Spartina spartinae*
SL	*Suaeda linearis*
SM	*Scirpus maritimus*
IF	*Iva frutescens*
AT	*Asteridae*
Bare	No vegetation
Wrack	Dead vegetation
Other	Transient species

REFERENCES

Cahoon, D. R., McKee, K. L., & Morris, J. T. (2021). How Plants Influence Resilience of Salt Marsh and Mangrove Wetlands to Sea-Level Rise. *Estuaries and Coasts*, *44*(4), 883–898. https://doi.org/10.1007/s12237-020-00834-w

Dunton, K. H., Whiteaker, T., & Rasser, M. K. (2019). *Patterns in the Emergent Vegetation of the Rincon Bayou Delta, 2005-2016*. Texas Water Development Board.

Fagherazzi, S., Mariotti, G., Leonardi, N., Canestrelli, A., Nardin, W., & Kearney, W. S. (2020). Salt Marsh Dynamics in a Period of Accelerated Sea Level Rise. *Journal of Geophysical Research: Earth Surface*, *125*(8), e2019JF005200. https://doi.org/10.1029/2019JF005200

Hill, E. M., Nicolau, B. A., & Zimba, P. V. (2011). History of Water and Habitat Improvement in the Nueces Estuary, Texas, USA. *Texas Water Journal*, *2*(1), Article 1. https://doi.org/10.21423/twj.v2i1.2104

Lynch, J. C., Hensel, P., & Cahoon, D. R. (2015). The surface elevation table and marker horizon technique: A protocol for monitoring wetland elevation dynamics. In *The surface elevation table and marker horizon technique: A protocol for monitoring wetland elevation dynamics: Vol. NPS/NCBN/NRR—2015/1078* (Federal Government Series NPS/NCBN/NRR—2015/1078; Natural Resource Report). National Park Service. http://pubs.er.usgs.gov/publication/70160049

Moon, J. A., Feher, L. C., Lane, T. C., Vervaeke, W. C., Osland, M. J., Head, D. M., Chivoiu, B. C., Stewart, D. R., Johnson, D. J., Grace, J. B., Metzger, K. L., & Rankin, N. M. (2022). Surface Elevation Change Dynamics in Coastal Marshes Along the Northwestern Gulf of Mexico: Anticipating Effects of Rising Sea-Level and Intensifying Hurricanes. *Wetlands*, *42*(5). https://doi.org/10.1007/s13157-022-01565-3

Montagna, P. A., Palmer, T., Gil, M., Hill, E., Nicolau, B., & Dunton, K. (2009). *Response of the Nueces Estuarine Marsh System to Freshwater Inflow: An Integrative Data Synthesis of Baseline Conditions for Faunal Communities*.

Osland, M. J., Chivoiu, B., Enwright, N. M., Thorne, K. M., Guntenspergen, G. R., Grace, J. B., Dale, L. L., Brooks, W., Herold, N., Day, J. W., Sklar, F. H., & Swarzenzki, C. M. (2022). Migration and transformation of coastal wetlands in response to rising seas. *Science Advances*, *8*(26), eabo5174. https://doi.org/10.1126/sciadv.abo5174

Osland, M. J., Gabler, C. A., Grace, J. B., Day, R. H., McCoy, M. L., McLeod, J. L., From, A. S., Enwright, N. M., Feher, L. C., Stagg, C. L., & Hartley, S. B. (2018). Climate and plant controls on soil organic matter in coastal wetlands. *Global Change Biology*, *24*(11), 5361–5379. https://doi.org/10.1111/gcb.14376

Osland, M. J., Grace, J. B., Guntenspergen, G. R., Thorne, K. M., Carr, J. A., & Feher, L. C. (2019). Climatic Controls on the Distribution of Foundation Plant Species in Coastal Wetlands of the Conterminous United States: Knowledge Gaps and Emerging Research Needs. *Estuaries and Coasts*, *42*(8), 1991–2003. https://doi.org/10.1007/s12237-019-00640-z

Saintilan, N., Kovalenko, K. E., Guntenspergen, G., Rogers, K., Lynch, J. C., Cahoon, D. R., Lovelock, C. E., Friess, D. A., Ashe, E., Krauss, K. W., Cormier, N., Spencer, T., Adams, J., Raw, J., Ibanez, C., Scarton, F., Temmerman, S., Meire, P., Maris, T., … Khan, N. (2022). Constraints on the adjustment of tidal marshes to accelerating sea level rise. *Science*, *377*(6605), 523–527. https://doi.org/10.1126/science.abo7872

Spivak, A. C., Sanderman, J., Bowen, J. L., Canuel, E. A., & Hopkinson, C. S. (2019). Global-change controls on soil-carbon accumulation and loss in coastal vegetated ecosystems. *Nature Geoscience*, *12*(9), 685–692. https://doi.org/10.1038/s41561-019-0435-2

Stachelek, J., & Dunton, K. H. (2013). Freshwater inflow requirements for the Nueces Delta, Texas: Spartina alterniflora as an indicator of ecosystem condition | Texas Water Journal. *Texas Water Journal*, *4*(2), 62–73.

Sweet, W. V., Hamlington, B. D., Kopp, R. E., Weaver, C. P., Barnard, P. L., Bekaert, D., Brooks, W., Craghan, M., Dusek, G., Frederikse, T., Garner, G., Genz, A. S., Krasting, J. P., Larour, E., Marcy, D., Marra, J. J., Obeysekera, J., Osler, M., Pendleton, M., … Zuzak, C. (2022). *Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines* (Technical Report NOS 01; p. 111). National Oceanographic and Atmospheric Administration, National Ocean Service. https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nostechrpt01-global-regional-SLR-scenarios-US.pdf

Vaccaro, L., & Cressman, K. (2020). *Wetland Surface Elevation Table (SET) Data for Mission-Aransas National Estuarine Research Reserve (MAR) Texas, 2013-2019* [Technical Report]. National Estuarine Research Reserve System Science Collaborative. https://nerrssciencecollaborative.org/media/files/MAR_SET_Analyses_2020-02-26.pdf