IMPACTS OF TIDAL CHANNEL MIGRATION ON SALT MARSH ECOLOGY AND CARBON STORAGE

by

TIANDRA L. MANNS

(Under the Direction of Amanda Spivak)

ABSTRACT

Salt marshes and the role these ecosystems play in local-to-global carbon budgets are an important factor in how these ecosystems play a part in the overall carbon budget. The generation and integration of how tidal channel migration processes affect marsh ecology and carbon storage is important in understanding how marshes change over time. This research evaluated ecosystem function by characterizing plant and animal communities, sediment pore water chemistry, sediment carbon storage, and vertical accretion rates in three marshes impacted by channel migration. Samples were collected from regions within three marshes that were present in the 18000's, 1930's, and 2000's in Doboy Sound, GA. The prograding side consists of these three regions and samples were taken from each. The retreating side consisted of regions that were from the 1800's and beyond. Results concluded that marshes are impacted by tidal channel migration over time, but marsh retreat is compensated by marsh progradation.

INDEX WORDS: Saltmarsh, Tidal channel migration, Carbon, Sediment, Radioisotope

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DEDICATION

Dedicated to my mother, Charmane Manns, who has sacrificed everything to get me to this point and to my husband Craig Williams, without whom this journey would not have been possible.

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TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

1. INTRODUCTION

Salt marshes are geomorphically dynamic environments, reacting to changes in sea level, ocean and estuarine currents, sediment supply, and vegetation growth. Water flowing through salt marshes can cause erosion of creekbanks and the resuspension and redistribution of sediment particles (McCraith et al., 2003). The accretion of salt marshes is the process of growth by deposition of suspended particles that occur during high tide (flooding) resulting in allochthonous growth and then the accumulation of plant and animal detritus from the marsh results in autochthonous growth (Weis, 2016). Eroded and resuspended particles can then be exported out of the estuary or redistributed elsewhere across the marsh (Rahman et al., 2013). High rates of erosion and deposition along focused segments of tidal channel and creek bank edges can result in marsh retreat and progradation, respectively. Patterns of retreat and progradation often occur at opposite creekbanks, with the net effect being lateral migration of the tidal channel (Goodwin & Mudd, 2020). The purpose of this work is to quantify how tidal migration has affected carbon storage in Georgia's saltmarshes.

Interactions between tidal flow through channels and marsh emergent vegetation can result in erosion or deposition of sediment along the exposed marsh edge. This is due to marsh grasses slowing down the water and trapping particles during high tides (flooding) events (Fagherazzi et al., 2013). This sediment erosion results in the lateral retreat of the landward boundary along one side of the marsh, and the redistribution and redeposition of sediment particles elsewhere in the marsh resulting in progradation. This deposition of sediment particles on the marsh interior platform contributes to vertical accretion, or vertical elevation gain (D'Alpaos et al., 2007;

Hopkinson et al., 2019; Luk et al., 2021). This results in higher elevation gain closer to the particle source(creekbank) and slower elevation gain the further into the marsh interior as the grasses filter out the particles. In marsh platforms with slower water velocities, high rates of deposition can result in a prograding marsh edge (Fagherazzi et al., 2013)(Fig 1).

These sediment dynamics can alter the carbon stored in the marsh. During lateral edge erosion, sediment from the creekbank edge of the marsh gets removed (Fig 1). The resuspended sediment is exposed to oxic tidal waters and organic matter associated with the mineral particles becomes more vulnerable to decomposition (Guimond & Tamborski, 2021). Microbial decomposition results in the conversion of organic carbon to inorganic carbon as carbon dioxide or dissolved inorganic carbon (Naorem et al., 2022). It is theorized that these microbes decompose 'new' organic matter from the marsh grasses rather than 'old' organic matter that was delivered by Altamaha River (Wang et al., 2014). Fractions of resuspended particles will be exported out of the system, representing net loss of minerals and organic matter, or re-deposited elsewhere in the marsh-estuary system (i.e. on the marsh, in tidal channels, etc.), but with potentially lower amounts of associated organic carbon.

Particles suspended in tidal waters can come from rivers (i.e., terrestrial), coastal waters, or marsh erosion. Deposition of these particles on the marsh platform contributes to vertical elevation gain, which has historically allowed marshes to keep pace with slow-to-moderate rates of sea-level rise. High rates of deposition at creekbank edges has the potential to lead to lateral marsh progradation (Fig. 1). At the same time the marsh is builind gland laterally and into the tidal channel, it is gaining elevation vertically. Rates of vertical elevation gain are likely extremely rapid initially and slow over time, as the new prograding marsh becomes higher in the tidal frame (Fagherazzi et al., 2020). As a result, rates of elevation gain are likely slower towards the interior of the marsh, which is older and sits at a higher elevation, and faster in creekbank areas that are actively prograding laterally (Goodwin & Mudd, 2020). The composition of particles contributing to elevation gain in the marsh interior and at prograding edges likely also differs. In the older, interior areas sediment likely have higher contributions from autochthonous organic matter (i.e., from marsh grass detritus) (Morris et al., 2016). Newer, prograding areas likely have higher contributions from recently deposited particles that may hold older marsh carbon or organic matter from nearby environments (Van De Broek et al., 2018).As a result, it is important to assess how tidal channel migration impacts marsh carbon storage rates and ultimately their functioning as long term carbon sinks (Kearney & Fagherazzi, 2016).

The overall goal of this research is to quantify the impacts of tidal channel migration on marsh ecology and carbon storage. I focused on three areas where lateral tidal channel migration is evident from historical maps and aerial photographs. In each of these areas, I conducted elevation surveys and characterized aboveground animals and plant communities and sediment pore water chemistry. I wanted to determine if plant and animal communities as well as sediment pore water chemistry were similar across prograding and retreating wetland bands. The reason being is that plant, animal, and pore water collection are from areas that have already been established and are far enough from the creekbank edge that it’s not being immediately or rapidly impacted by marsh progradation and retreat. Sediment organic carbon stocks and accretion rates were assessed through radioisotope age models. I wanted to determine there would be an increase in carbon content along the prograding wetland age bands as the older marsh is well established and it’s expected that the marsh closest to the creekbank edge would have more minerals resulting in a lower carbon content. In addition, the source of sediment organic carbon was determined to understand contributions to carbon burial. It was hypothesized that carbon in the creekbank edge of the prograding marsh would have a more terrestrial source. This is because the river is a primary influencer and there is a great deal of resuspension and respiration occurring here resulting in more terrestrial material staying longer. Ultimately this study will quantify the impacts of tidal channel migration and marsh change on the ability of the marsh to store carbon by examining age bands along Georgia's coastline

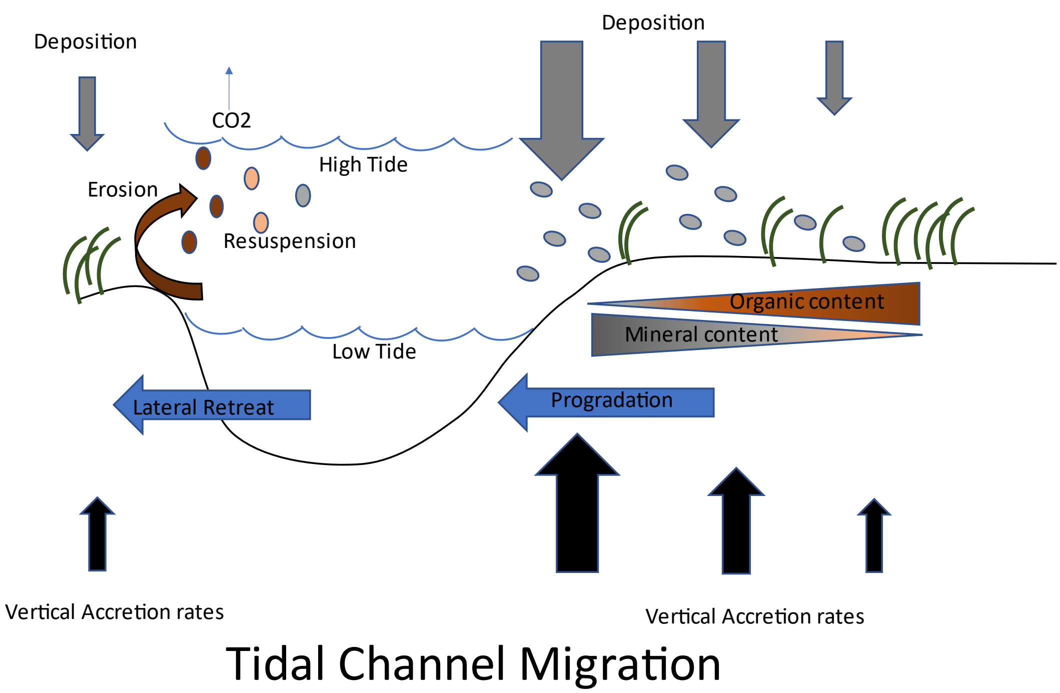

Figure 1: Conceptual model of how tidal channel migration and erosion of the marsh (indicated by the brown arrow) results in the resuspension of soil particles that are broken down (indicated by the color change of particles) and once resuspended it is more likely to be acted upon by bacteria. These broken down particles are then redistributed and deposited into the marsh or completely exported out of the system.

2. METHODS

2.1 Study site and design

Three study sites were identified using a combination of aerial images and the historical maps from the Georgia Wetland Restoration Access Portal(G-WRAP) database (Resources, 2021). These sites were areas that contained a clearly defined retreating marsh as well as clearly defined prograding marshes G-WRAP database defines marsh shorelines that were mapped in the 1800's, 1930's, 2000's (Fig 2). Marsh areas behind these historic shorelines was assumed to have formed earlier and allowed us to identify narrow stretches(to be referred as 'bands') for a space-for-time substitution design (i.e., chronosequence). These study sites were sampled during Fall 2020 and Summer of 2021. Three areas of study were chosen to be sampled that had a clear and present retreating and prograding region with three wetland age bands(Fig 2a). Within each sampling site a total of 4 age bands were sampled from each consisting of one retreating band and three prograding age bands (Fig 2b-d). At each site, the following was collected: sediment cores, plants, pore-water, as well as animal communities enumerated. Each sampling location used a $1m^2$ quadrat that was randomly placed in an undisturbed area. Before sites were sampled elevation points were taken. Within the quadrat, plant and animal communities were identified and abundances, recorded, and plant canopy height was measured. After biotic observations were completed, pore water samples were taken for later analysis, and then sediment cores were removed from each marsh wetland age band.

Figure 2: Sampling sites with historical age bands (a.) with Site 1(b.), Site 2(c.), and Site 3(d.). Each site contains a wetland region with the Retreating (red), Prograding 2000(blue), Prograding 1930 (green), and Prograding 1800 (black)

2.2 Elevation

Elevation points were taken at all sampling sites in the retreating and prograding marshes using a real time kinematic (RTK) GPS. Five elevation measurements were taken around the location of the quadrat at each site location. Measurements used the North American Vertical Datum of 1988 (NAVD88). This is the vertical datum for orthometric heights created for vertical control surveying in the United States of America. Elevation points were then averaged at each site for each sampling location to achieve overall elevation of each age band.

2.3 Plants and animals

Live plants were visually estimated using a percent cover sheet in order to determine plant abundance. Animal communities were identified and counted within four (0.25 m^2) sections of the quadrat. Plant species composition was determined within a 1 m^2 square quadrat placed in an undisturbed area along the retreating and prograding age bands. The height of the five tallest plants of each observed species was measured in order to determine plant canopy height.

2.4 Pore Water

Pore water was collected by inserting a push point sampler 80 cm into the sediment and pulling ~60 ml of water into an acid washed syringe. The sampling system was rinsed with milliQ water between each collection. Collected water samples were stored in a cooler. At the lab, porewaters were analyzed for redox levels, pH levels, and salinity measurements using a pH/ORP probe, and a refractometer. Remaining pore water was then filtered using 25 mm GF/F filters for nutrient and sulfide analyses with sulfide being analyzed within a two week time frame and nutrients frozen and then thawed out later for analysis. Sulfide concentrations were assessed using the Cline method. This was done by adding 4 ml of filtrate to bottles containing 0.1 M zinc acetate (Cline, 1969). These bottles were then filled with ~4 ml of filtered pore water. The clines reagent was added to the solution, agitated and then allowed to incubate for approximately 30 minutes. A standard curve was made by making dilutions of the standard in order to compare the sampled solutions to the standard curve in order to determine if any dilutions needed to occur.

Once samples were done incubating they were measured on the spectrophotometer. Ammonia was measured using between 10-15 ml of filtered pore water. A stock standard of NH_4Cl was made and then pipetted into several working standards. Five ml samples and standards were pipetted and phenol was added to be vortex, then nitroprusside was added and vortex, and lastly an oxidizer was added and vortexed. The samples were then incubated in the dark for two hours and vortexed before reading at a 640nm wavelength. They were analyzed along with sulfide concentrations using spectrophotometry. Ammonia samples were thawed at room temperature in a water bath. Add 5 ml of each concentration standard to tet tubes with 0.5-5ml in order form 0-0.2mM. Then pipette a 1:1 dilution of samples into test tubes with 2.5 ml of sample to 2.5 ml of Milli-Q water. Then the oxidizing reagent a 4:1 sodium citrate to bleach solution. Read absorbance at 640 nm wavelength

2.5 Sediment Cores

Sediment cores measuring 10 cm in diameter by ~100 cm long were collected from each study site for a total of 12 cores. These were split laterally; one half was used for radioisotope analysis(^{137}Cs, ^{210}Pb, and ^{7}Be) while the other half was used for particle size fraction and organic matter analyses. The radioisotope part of the core was sectioned in 1 cm increments and all material was completely removed to pre-weighed bags. The sectionized sediment had wet weights taken, frozen at -80 °C, freeze-dried to remove all moisture, and dry weights taken for analysis of bulk density, and radioisotopic composition. Bulk density was obtained from the dry weights of section intervals by grinding samples into a powder in order to homogenize them. This was done as bulk density can be an early indicator of sediment composition. Sediment bulk density (g /cm ^{3}) was determined from dry weights of each interval based on the volume sample. These sediment samples were analyzed on a planar-type gamma counter for 24 to 48 hours to measure ^{7}Be, ^{137}Cs, ^{210}Pb, and ^{226}Ra at 477, 661.6, 46.6, and 352 KeV energies respectively (Canberra Inc., USA) at the Woods Hole Oceanic Institute (WHOI). Detector efficiency was determined from EPA standard pitchblende ore in the same geometry as the samples. The activities of ^{7}Be, ^{137}Cs, ^{210}Pb were corrected for decay to time of their collection and their suppression of low energy peaks from self-adsorption was corrected following the Cutshall method (Cutshall et al., 1983). The 0-10 cm depth intervals were processed within a 3 weeks of collection to capture bioturbation effects using ^{7}Be, which has a short half-life(53.28 days) as an indicator of exposure to surface deposition. For excess ^{210}Pb present it was subtracted from supported ^{226}Ra from the total ^{210}Pb with a detection limit of 0.1 dpm/g for calculations. Data obtained from this formed a constant initial concentration model (Appleby & Oldfield, 1978), a cesium accretion rate (Lynch et al., 1989), and lead inventory (McCall et al., 1984).

The second sediment core half was used for sediment organic matter(SOM) analyses and was sectioned at different intervals and horizons. The 0-10 cm of the core were sampled at 1 cm intervals (i.e., 0-1, 1-2, 2-3, etc.), then sectioned from 10-30cm at 2 cm intervals (ie., 10-12, 12-14, etc.), 35-50 cm at 2 cm intervals taken every 5th depth horizon (35-37, 40-42, etc.), and lastly at 50-80cm at 2 cm intervals taken every 10th depth horizon(50-52, 60-62, etc.). SOM samples were analyzed for percent organic carbon content and isotopic composition ($\delta^{13}C$). SOM samples were freeze-dried to remove all moisture and homogenized by mixing the entirety of the collected section of sediment. A subsample (2-10 g) of each horizon was split into three size dractions. Briefly soil particles were agitated for ~18 hours with a chemical dispersant (sodium hexametaphosphate: NaHMP) (Craig et al., 2019). Samples were subsequently frozen at -80°C, freeze-dried to remove all moisture, re-homogenized by mixing the sample, and then wet sieved to separate the different size fractions (> 1mm, >53 μm – 1 mm, <53 μm (Bradford et al., 2008).

Samples that were >1mm were identified as coarse particulate organic matter (cPOM) and consisted of roots and rhizomes with a marsh grass source. Samples that had sizes of >53 μm - 1mm were identified as fine particulate organic matter (fPOM) and consisted of detrital and fine roots with a marsh grass source as well. Lastly samples <53 μm consisted of mineral associated POM and were derived from minerals, resuspended particles, or eroded marsh with a more mixed source of marsh grass and terrestrial material. After size fractionating samples were again frozen at -80 °C, freeze-dried, and then had their contents ball milled in order to be weighed out for elemental analysis and isotopic composition. This process used ~5mg for the coarser fraction, ~7mg for the fine fraction, ~20mg for the mineral associated fraction, and ~15mg for the bulk fraction. These samples were weighed into silver capsules used for isotopic analysis and loaded into a 96 well-plate. The well-plate was placed into an acid desiccator for 48 hours and fumed with hydrochloric acid in preparation for bulk elemental (total organic carbon) and isotopic composition ($\delta^{13}C$) (Hedges & Stern, 1984). Once the 48 hours concluded samples were dried in a 60 °C oven for 24 hours and then the silver capsules containing the sample were rolled into a ball and placed back into the 96 well-plate for analysis at the Marine Biological Laboratory by using dual inlet and continuous-flow isotope ratio mass spectrometer systems for measuring $\delta^{13}C$.

2.6 Data Analysis

In order to determine whether or not data varied with sampling site, geomorphic setting (age bands), distance from the creekbank, elevation of the marsh statistical analysis was conducted. A test of variance and normality was conducted first in order to determine if a parametric (ANOVA) or non-parametric (Kruskal-Wallis) test was needed. Based on the results obtained it was evaluated how the response variable differentiated across the geomorphic setting, study site, and if there was significance based on the test ran then test were followed with a post-hoc contrast. In order to evaluate directional correlation between response variables a linear model was conducted and then paired with a regression to be more mechanistic to determine which study sites, or age bands had any significance.

3. RESULTS

3.1 Elevation

Elevation was thought to match previous studies that indicate elevation increases from creekbank edge to the marsh interior. To determine this elevation was evaluated at each wetland age band, study site, and distance from the creekbank(taken from the multiple elevation points and measured using Google Earth) to determine if there was any relationship between these variables and elevation statistically. Areas with similar elevations were targeted based on lidar data and elevation ranged from 0.65-1 (m, NAVD88) across the entirety of the sampling sites (Fig. 3). Elevation was lowest in the wetland band closest to the creek (P2000) and elevation increased as the wetland bands increased in age along the prograding wetland. There was similar elevations with study site 1 and 2, but site 3 had lower elevation (Table 1). From there it was determined that elevation increased with marsh wetland age so elevation and distance from the creekbank edge was analyzed. Statistical analysis demonstrated that there was no relationship between elevation and distance. Elevation did increase with marsh wetland age along the prograding side with the retreating side having a greater range of elevation (Fig 3b.). There was significant differences in elevation with the Prograding 1800 and 2000 geomorphic environments which are the furthest from the creekbank (~230m) and closest to the creekbank (~100m) respectively. These age bands represent the oldest and youngest prograding bands with a main affect that is not yet clearly defined from the post-hoc contrast.

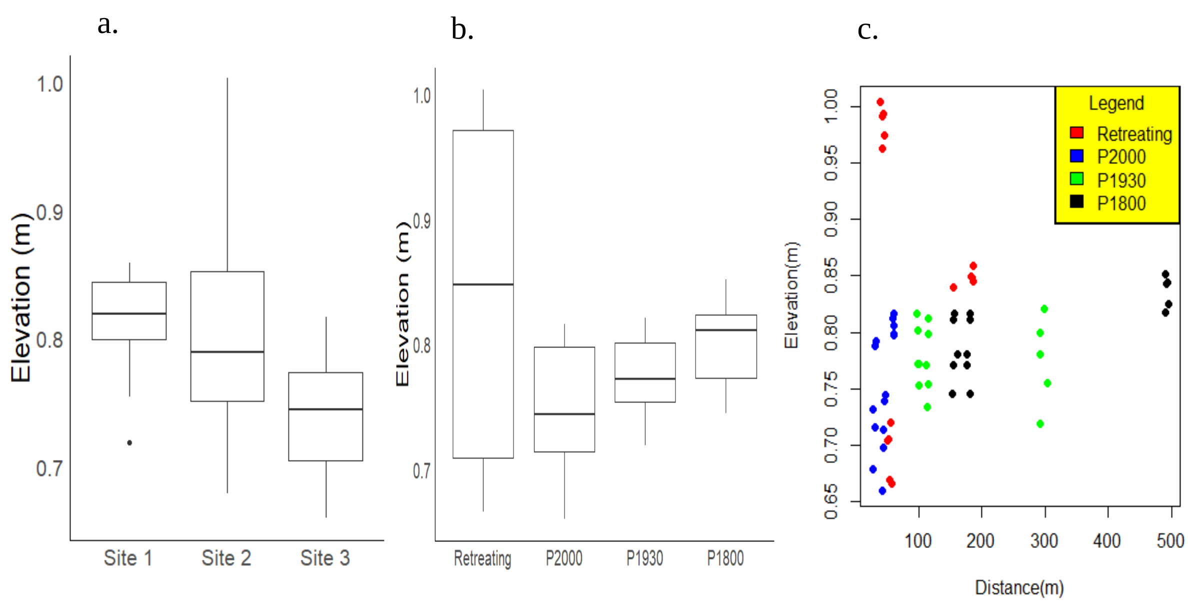

Figure 3: Elevation evaluated across each Study Site (a.) and elevation evaluated at each wetland age band (b.) and elevation evaluated by distance from the creekbank identified by wetland age band (c.)

Table 1: Statistical analysis looking at elevation in response to Wetland age band and Study Site after elevation was proven significant (P<0.05) Significant differences are marked with an * and used a adjusted p-value in order to compensate for doing multiple comparisons to control for the false discovery rate		
Elevation	Kruskal p-value	0.02
Response	**Age Band**	**Site**
	Wilcox Contrast	P-ADJUSTED
	Retreat v P2000	0.11
	Retreat v P1800	0.20
	Retreat v 1930	0.17
	P1930 v P2000	0.20
	P1800 v P2000	0.04*
	1800 v P1930	0.15
	Kruskal p-value	0.00
Response	**Site**	
	Wilcox Contrast	P-ADJUSTED
	Site 1 vs Site 2	0.14
	Site 1 v Site 3	0.00*
	Site 2 v Site 3	0.02*

3.2 Animals

It was theorized that animal community abundance would be similar across prograding and retreating marshes. To answer this animal abundancies were evaluated to determine if there was a relationship with the study site, the wetland age band, distance from the creekbank, elevation of the marsh, as well as the plant height. I found two epifaunal species: *Littorina littorea* snails and *Uca pugnax* crabs. Average snail abundance was 71.67 ± 32.16 (ind/^{2}) across the entirety of the marsh. Snail abundance was significantly different with the wetland age bands and a low snail community abundance at the creekbank edge of the prograding marsh (Table 2). The highest snail abundance was evaluated at the older prograding marsh with the retreating band snails having a high snail abundance as well (Fig 4a). There was a negative relationship between plant height and snails only at Site 2. When evaluating crab abundancies it was analyzed that crabs did not have any relationship with the wetland age band. Crab abundancies had an average of 3.92 ± 1.32(ind/^{2})

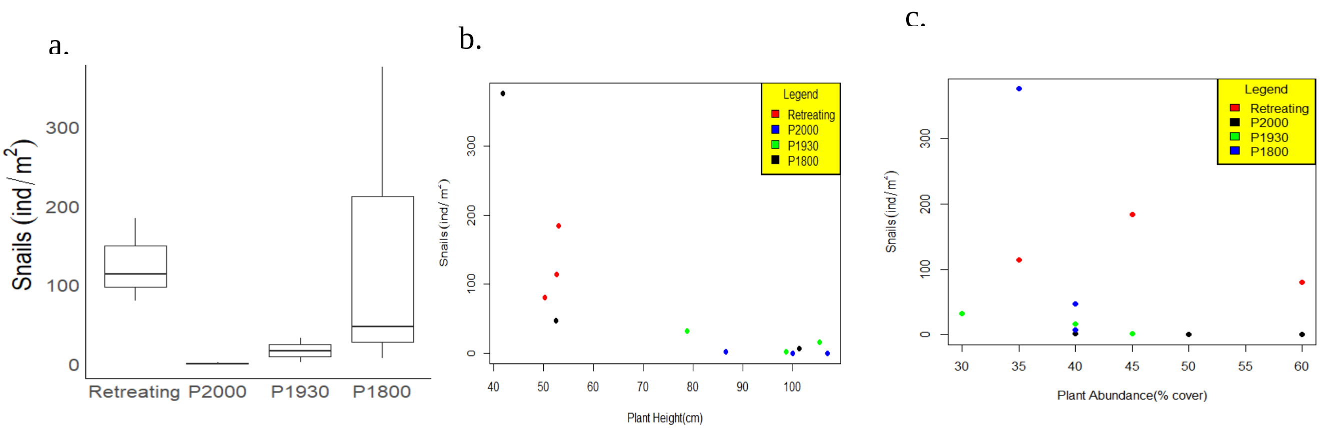

Figure 4: Snail abundance at the different wetland regions (a.) and snail abundance with plant height with wetland region identified (b.) and snail abundance with plant abundance with the wetland age band identified (c)

Table 2: Snail abundance relationship in response to wetland age band and plant height as snail abundance proved to be significant (P< 0.05) with these relationships					
Snail	Kruskal p-value	0.04			
Response	**Location**				
	Wilcox Post	P-ADJUSTED			
	Retreat v P2000	0.17			
	Retreat v P1800	0.70			
	Retreat v 1930	0.17			
	P1930 v P2000	0.17			
	P1800 v P2000	0.17			
	1800 v P1930	0.48			
Response	**Plant Height**	P-VALUE	STD. ERROR	ESTIMATE	R-SQUARED
	Overall	0.01	0.92	-3.27	0.51
	Site 1	0.19	3.26	-6.45	0.49
	Site 2	0.01*	0.20	-2.03	0.97
	Site 3	0.24	1.49	-2.44	0.36
	Retreating	0.37	19.55	9.37	0.39
	P2000	0.22	0.04	-0.10	0.77
	P1930	0.47	0.73	-0.81	0.10
	P1800	0.50	4.49	-4.53	0.01

3.3 Plants

It was theorized that plant canopy height and plant abundance would be similar across the prograding and retreating marshes. To test this theory plant canopy height and abundance was evaluated at the different wetland age bands, different study sites, as well as distance from the creekbank. The only plant species at my sites were *Spartina alterniflora*. Canopy height and abundance was looked at to determine if either had a relationship with the wetland region, the marsh sampling site, elevation of the marsh, distance from the creekbank, or if animal presence mattered. Plant height was determined to have a relationship with the wetland age band. There were similarities in plant height shown in the geomorphic wetland age bands of the retreating and P1800 wetland age bands as well as similarities of plant height in the prograding 2000 and 1930 age bands (Table 3). Plant canopy heights varied across the different study sites with no similar canopy heights detected. For the relationship between canopy height and distance from the creekbank there were only similarities in canopy height detected at study sites 2 and 3, but no similarities were detected geomorphically. Further evaluations were used to determine if plant canopy height would vary if both elevation and distance from the creekbank would matter. When evaluated only the retreating and prograding 1930 age bands had similarities with one another.

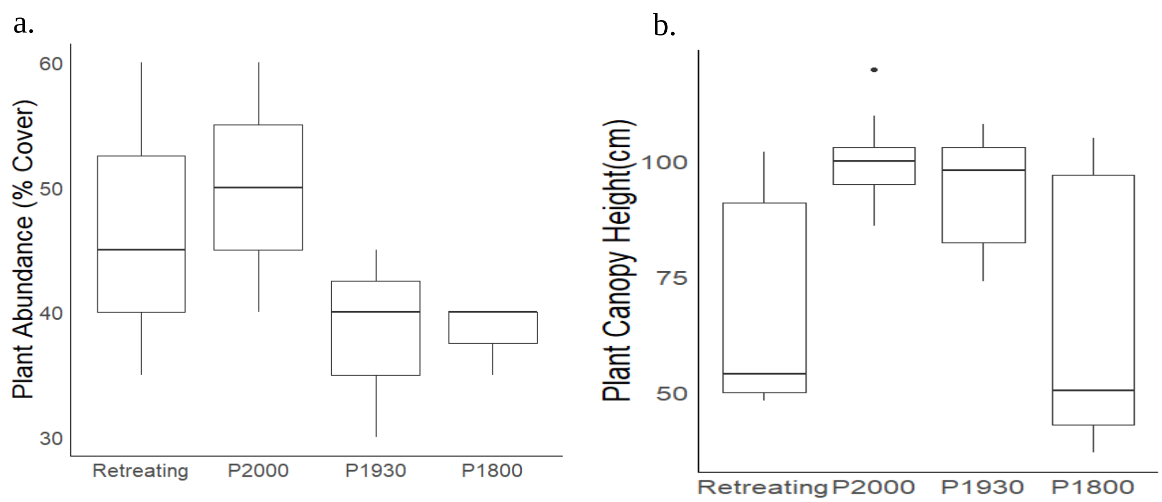

Figure 5: Plant percent abundance relationship evaluated with wetland age band (a.), and plant canopy height at the wetland age bands (b)with strong correlations between Site 1, the retreating band, and Prograding 2000 and 1930

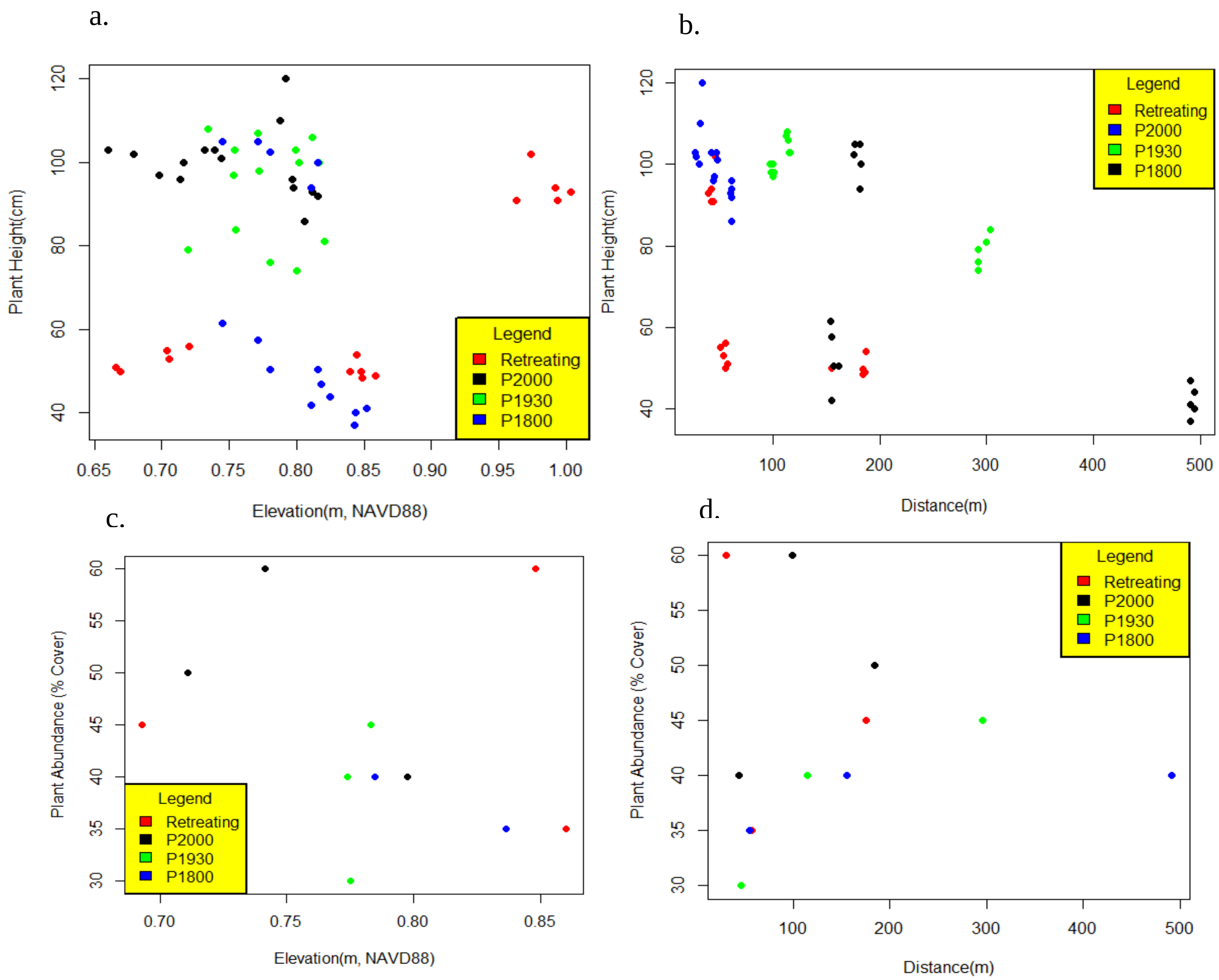

Figure 6: Plant height in relation to elevation highlighted by the different wetland age bands (a), plant height in relation to distance (b), plant abundance in relation to elevation at the different wetland age bands (c) and plant abundance in relation to distance(d)

Table 3: Plant height analysis with location, site, and distance which is then followed with contrast analysis with distance by elevation with a focus on the area that was sampled or the marsh wetland region					
Height	0.00008871				
responses	**Location**				
	Wilcox Post	Adjusted p-value			
	Retreat v P2000	0.00*			
	Retreat v P1800	0.69			
	Retreat v 1930	0.00*			
	P1930 v P2000	0.66			
	P1800 v P2000	0.01*			
	1800 v P1930	0.01*			
Height	4.173E-07				
Response	**Site**				
	Wilcox Post	Adjusted p-value			
	Site 1 vs Site 2	0.00*			
	Site 1 v Site 3	0.02*			
	Site 2 v Site 3	0.00*			
Height					
Response	**Distance**	p-value	std error	estimate	r-squared
	Overall	0.00	0.02	-0.11	0.30
	Site 1	0.00*	0.02	-0.09	0.44
	Site 2	0.80	0.03	0.01	-0.05
	Site 3	0.09	0.12	-0.21	0.11
	Retreating	0.02*	0.07	-0.20	0.31
	P2000	0.00*	0.12	-0.45	0.48
	P1930	0.00*	0.01	-0.12	0.84
	P1800	0.02*	0.04	-0.10	0.28
	post Site 1				
		p-value	std error	estimate	r-squared
	Distance	0.00*	187.0736	-836.855	0.8376
	Elevation	0.01*	0.5241	-1.5182	0.8376
	Distance*Elevation	0.01*	0.6359	1.7456	0.8376
	Retreating				
		p-value	std error	estimate	r-squared
	Distance	0.65	1.71	-0.81	0.96
	Elevation	0.36	100.42	95.56	0.96
	Distance*Elevation	0.73	2.00	0.72	0.96
	P2000				
		p-value	std error	estimate	r-squared
	Distance	0.04*	1.98	4.65	0.69
	Elevation	0.01*	114.66	348.04	0.69
	Distance*Elevation	0.02*	2.56	-6.75	0.69

	P1930				
		p-value	std error	estimate	r-squared
	Distance	0.73	0.37	-0.13	0.82
	Elevation	0.82	103.08	-24.72	0.82
	Distance*Elevation	0.98	0.47	0.01	0.82

3.4 Pore Water

Pore water chemistry was assumed to be similar across the retreating and prograding wetland age bands. In order to evaluate whether this was supported or not several aspects of pore water chemistry were examined: redox, salinity, pH, ammonia, and sulfide. Pore water chemistry did not have any relationship with geomorphic locations or distance from the creekbank, but redox had a relationship with the study site. Site 1 and Site 3 had a difference in redox levels (Fig7f.).

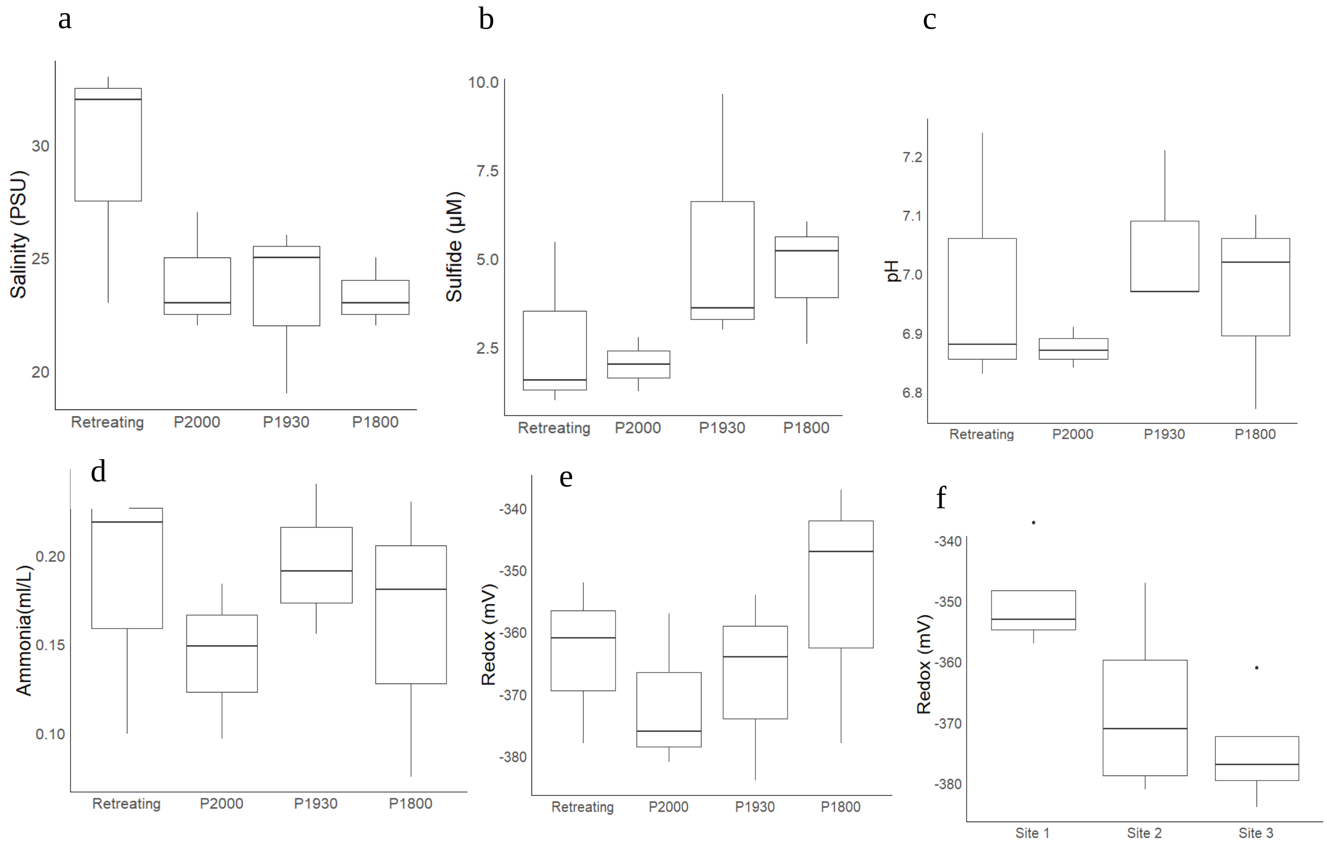

Figure 7: Pore water chemistry looking at salinity (a.), sulfide (b.), pH(c.), ammonia (d.), redox at the different wetland age bands (e.) and redox across study sites (f.)

Table 4: Analysis of pore water with a focus on Redox as all pore water data had no statistical significance. This followed a post-hoc contrast			
Response	Site		
		P-VALUE	
	Overall	0.04*	
	Site 1 vs Site 2	0.14	
	Site 1 vs Site 3	0.04*	
	Site 2 vs Site 3	0.67	

3.5 Radioisotope

Sediment data analysis was used in order to identify whether there would be an increased carbon content along the prograding wetland as well as if the carbon in the creekbank edge of the prograding marsh would have a more terrestrial source. Radioisotope data was used to calculate bulk density(Fig 8.) and accretion rates of ^{137}Cs and ^{210}Pb (Fig 9). Regarding the bulk density (Fig 8) there was a consistent bulk density weight up until about 40 cms and below and then there was some variability. From these data lead inventory was also able to be calculated. The rate of lead deposition was higher in the prograding marsh compared to the retreating, and this rate decreased form the creekbank edge to the marsh interior(Fig 9). This data shows that the prograding bands have a high deposition rate and contain a lot of ^{210}Pb that slows from the prograding creekbank edge to the marsh interior. The retreating marsh is indicating a slower depositional and accretion rate as compared to the prograding marsh which shows a high rate of deposition and accretion from the youngest prograding marsh to the oldest. The lead inventory indicates that more lead is being deposited in the youngest prograding bands and as the marsh increases with age that lead deposit decreases (Fig 9b.).

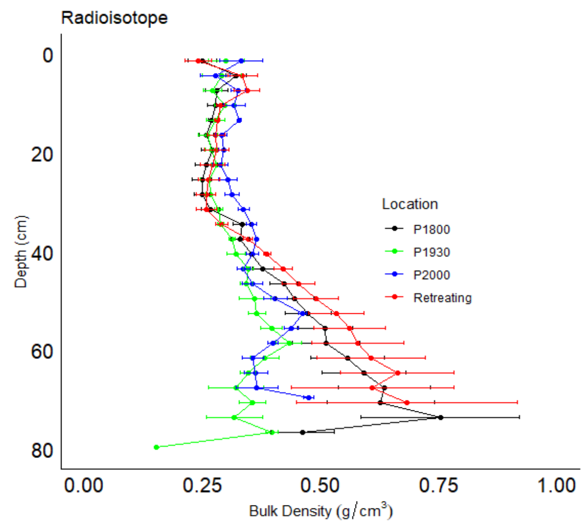

Figure 8: Bulk Density calculated for the different sectioned intervals from radioisotope core

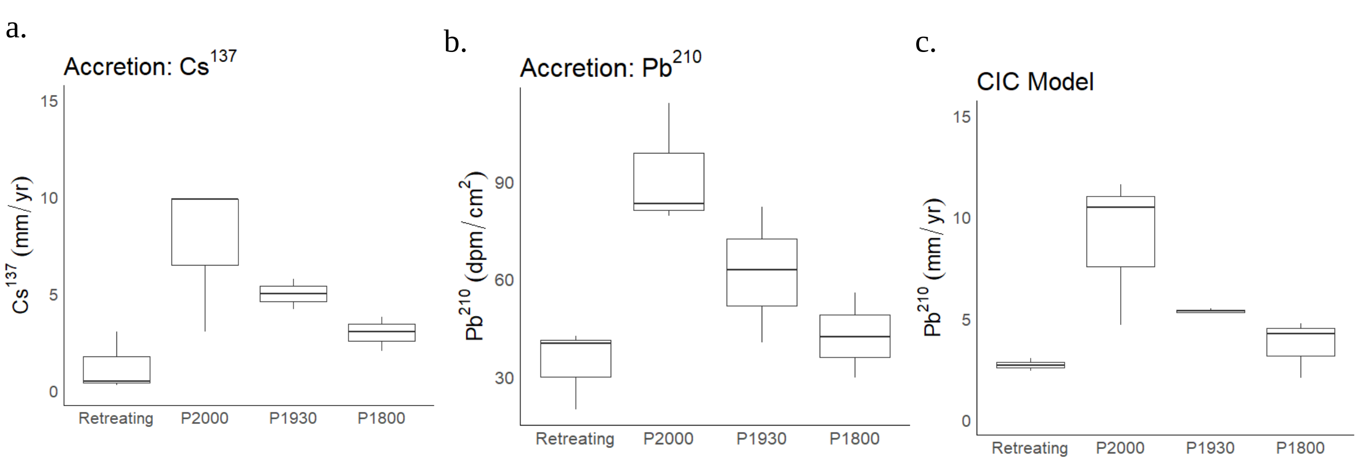

Figure 9: Vertical accretion calculated from ^{137}Cs profiles (a.), ^{210}Pb inventory, and a constant initial concentration (CIC) model vertical accretion rate (c.) based on ^{210}Pb

Table 5: Analysis to determine relationships found from Cesium accretion, CIC model, and lead inventory. Wetland age bands were found to be significant and a post-hoc contrast was conducted		
Cesium		
Responses	**Region**	
	p value	0.04
		P-VALUE
	Retreat v P2000	0.03*
	Retreat v P1800	0.79
	Retreat v 1930	0.24
	P1930 v P2000	0.50
	P1800 v P2000	0.12
	1800 v P1930	0.68
CIC		
Responses	**Region**	
	p-value	0.05
	Wilcox Post	Adjusted p-value
	Retreat v P2000	0.2*
	Retreat v P1800	0.7
	Retreat v 1930	0.2*
	P1930 v P2000	0.7
	P1800 v P2000	0.3*
	1800 v P1930	0.2*
Inventory		
Responses	**Region**	
	p value	0.01
		P-VALUE
	Retreat v P2000	0.01*
	Retreat v P1800	0.92
	Retreat v 1930	0.25
	P1930 v P2000	0.19
	P1800 v P2000	0.02*
	1800 v P1930	0.53

3.6 Carbon

Data obtained for carbon content only evaluated the retreating weltand age band as well as the prograding 2000 and 1800 band down core. Sediment organic matter samples were evaluated in order to determine what source of carbon is comprising marsh sediment. Percent mass of each sample and was examined at each of the following size fractions: cPOM, fPOM, and MAOM (Fig 10a-c.). The cPOM (coarse sediment) was expected to be comprised of primarily roots which is shown in the 10-15 cms indicating the active rooting zone. The fPOM (fine sediment) was expected to be similar to the coarse sediment just at lower levels. Lastly the MAOM (mineral associated sediment) was expected to be comprised of primarily minerals which has the highest percent mass (Fig 10c.). Percent organic carbon at the different size fractions was also evaluated (Fi 10d-f.). It was expected that the coarse fraction would have the highest carbon content and that the fine would follow next to it, with the MAOM fraction having the lowest carbon (Fig 10d.). Carbon density was evaluated from the % organic carbon, bulk density of the soil, and the percent mass of each fractionated sample. The coarse fraction had the highest carbon density near the surface where the rooting zone is, but below that carbon density decreases. The fine and mineral fractions had similar carbon densities with vary little variations in depth. Data suggest that all three fractions have similar carbon densities below the rooting zone. Lastly $\delta^{13}C$ was evaluated at the different size fractions.

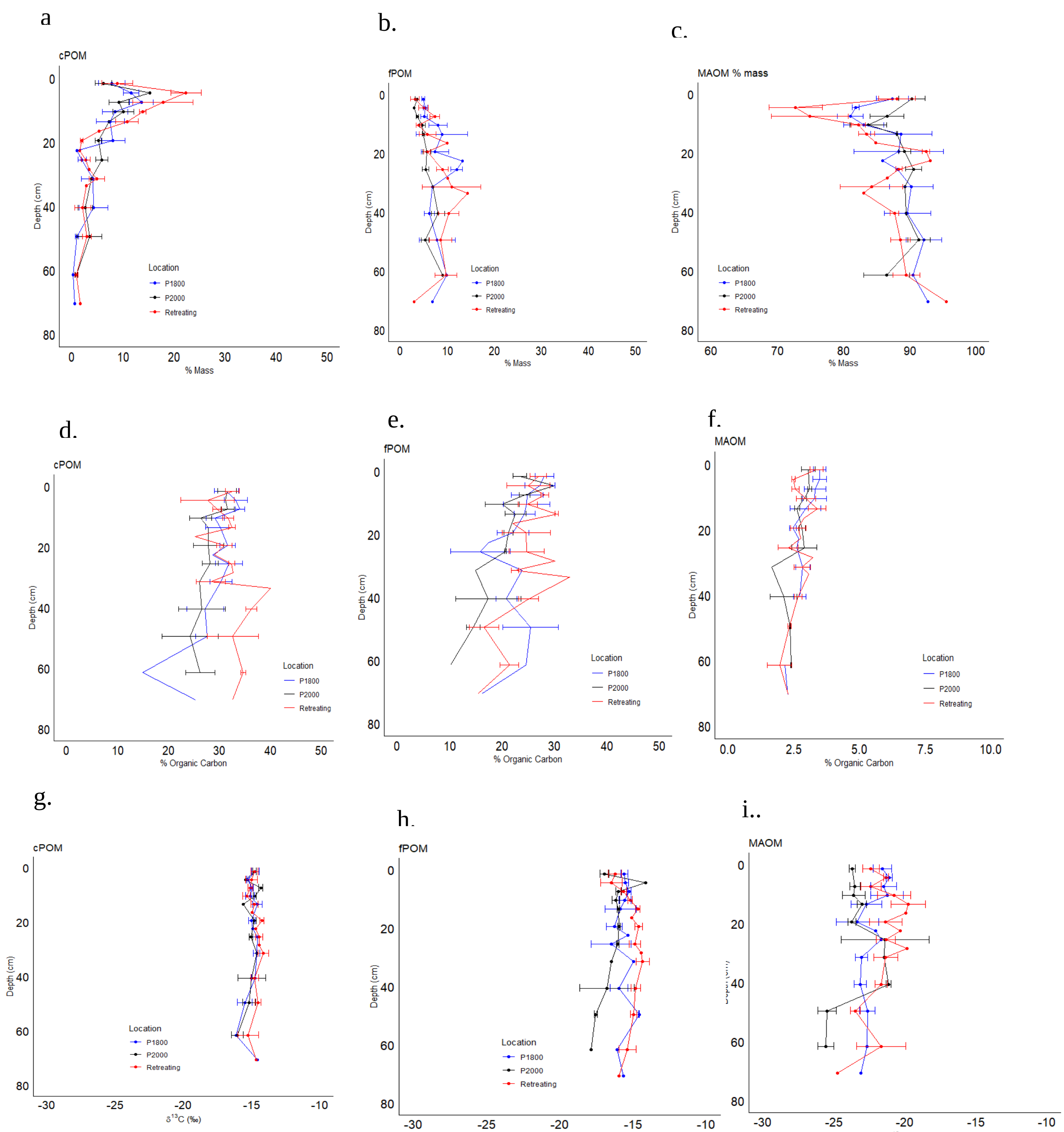

Fig 10: Percent mass of fractionated coarse particulate organic matter (cPOM)(a.), fine particulate organic matter (fPOM)(b.), and mineral associated organic matter (MAOM)(c.) Percent organic carbon for cPOM(d.), fPOM (e.), and MAOM(f.) and δ^{13}C values for cPOM(g.), fPOM (h.), and MAOM(j.)

4. Discussion

4.1 Plant and animal communities, and pore water chemistry

All sampled study sites contained 4 age bands: one retreating and three prograding age bands that had sampled data from the 2000’s, 1930’s, and the 1800’s. There was a slight different in elevation when it came to the study sites even though efforts were made to sample from areas that had similar elevation. When it came to the geomorphic settings the retreating side had a greater range of elevation and the prograding marsh had elevation that increased with marsh age. The reason elevation was examined is that it can be an early indicator of marsh age. Studies show that marsh interiors typically have lower elevation (Allen et al., 2018).

For the plant canopy height and abundance I hypothesized that plant canopy height and abundance would be similar across the wetland age bands. Previous studies indicate that canopy height of marsh vegetation will vary across different areas of the marsh (Bos et al., 2005). Overall plant canopy height did in fact differ with the wetland age bands. This matches studies conducted on *Spartina alterniflora* which have evaluated that these plants grow at different elevation levels and as a result experience different flooding cycles which impacts there growth (Liu & Pennings, 2019). When evaluating plant canopy height with distance and identifying the different wetland age bands it was determined that canopy heights does vary with distance from the creekbank. This further matches other studies as depending on the creek distance these sites would experience different levels of flooding. Elevation was different at the different wetland age bands, and then canopy height follows this elevation difference as plants grow differently at different elevations as a result of flooding. There should not be a relationship with plant abundance and elevation because abundance is dependent on pore water chemistry which was similar across the wetland age bands (Mendelssohn & Seneca, 1980).

Animal abundance was theorized to be similar across the different wetland age bands. This was measured because marsh animals impact soil carbon content through the process of bioturbation of the soil or the grazing of the plants (Gittman & Keller, 2013). Only periwinkle snails and fiddler crabs were identified which are known to shred dead plant material as they feed which also aids in the decomposition process of the plants. When evaluating the fiddler crabs they did support my hypothesis that crab abundance was similar across the wetland age bands. This could possibly be because crabs either borrowed themselves in the soil or ran away when sampling was conducted. As canopy height was shorter there was a higher abundance of snails. Studies have shown that plant canopy height is impacted by snail abundance with snail abundance, particularly periwinkle snails, as studies show they exert a strong top-down control on *Spartina* productivity (Silliman & Zieman, 2001). Taller *Spartina* at low elevations don't have as many snails and are subject to flooding, whereas shorter *S*partina which are at higher elevations have more snails and are not subject to flooding.

Pore water chemistry was hypothesized to be similar across the wetland age bands. This is an important factor as pore water chemistry is an indicator of what the plant roots are experiencing (Moffett et al., 2012). When evaluating sulfide, salinity, redox, pH, and ammonia levels all were similar across the different wetland age bands. When it came to the pore water chemistry at the three different study sites only redox had differences detected between Site 1 and 3. This could be in part due to another dilution needing to be conducted for redox levels as only a limited amount of sample was able to be used without retrieving more and therefore altering the results further. Overall though porewater chemistry did in fact support my theory that pore water chemistry is similar across the geomorphic settings

My hypothesis was that plant abundance, plant canopy height, animal abundance, and pore water chemistry would be similar across the different wetland age bands. From the data presented only plant abundance and pore water chemistry were able to fully support this hypothesis. Only crab abundance was able to support my hypothesis, but only visible crabs were assessed as crab burrows or disturbing the burrows to determine if crabs were present did not occur. Plant canopy height did vary with the different wetland age bands which has been supported in other research as these plants could be responding to flooding events that are being experienced with different elevations (Liu & Pennings, 2019). It was expected that these factors would not vary across the different geomorphic settings as sampling took place far enough from the creekbank edge that there would be no immediate or rapid impacted of marsh progradation and retreat. Pore water chemistry reflects what the plant roots are experiencing and the fact that all pore water was similar across the different wetlands is why plant abundance did not vary with wetland age bands. Plant canopy height on the other hand did vary which studies have stated that these plants are being impacted by their elevation level because of flooding events (Liu & Pennings, 2019). Snail abundance varying with wetland age bands (particularly periwinkle snails) could be in response to flooding events impacting the plants that they are consuming. The older age bands would experience the least amount of flooding and has the shortest plant heights, but the most snails. Whether or not the geomorphic environments that have developed overtime result in conditions that support similar biological communities still needs to be further explored.

4.2 Vertical accretion

Vertical accretion rates were hypothesized to be faster along the prograding wetland. The reason vertical accretion is important is because they allow for determining how the marsh is growing over time. The accretion rates evaluated were for ^{137}Cs and ^{210}Pb and by evaluating the CIC mode model and the accretion of cesium the rate of accretion was able to be determined. The vertical accretion of salt marshes is dependent on the rate of deposition. A high deposition rate should indicate a high vertical accretion rate, and a low deposition rate should indicate a low deposition rate. The CIC model is the vertical accretion based on the depth distributions of the lead and cesium models. It uses the event horizon to create an age model. With the data currently obtained the ^{137}Cs and CIC model that's been based off of ^{210}Pb are indicating accretion rates. There is ~10mm/yr at the youngest prograding wetland age band. Based on the rate of vertical accretion the sampled prograding marshes are able to survive sea level rise (6.1 mm/yr) (Crotty et al., 2020). Overall vertical accretion rates do support my hypothesis that vertical accretion would be faster along the prograding wetland age bands. There were differences seen but these differences only reflect the last 100 years or so its possible that the rates I'm seeing have changed as the marsh has gained elevation over time. It may be fast at the beginning when data sampling first took place in the 1800's but slowed over time. The likelihood of the rates of deposition changing over time will depend on other factors (Schumer & Jerolmack, 2009). If storms or extreme flooding events occur the deposition rate would in fact change and be altered which is why the lead inventory is taken into account. The lead inventory allows for determining how much lead is being deposited into the marsh. When comparing it with the cesium rate it can be seen that there are higher rates of these two elements being deposited along the youngest prograding age band and they decrease with marsh age.

4.3 Carbon

I hypothesized that there would be an increase in carbon content along the prograding wetland age band. I also theorized that more carbon in the creekbank edge of the prograding marshes would be terrestrially sourced. To evaluate whether these hypothesizes could be supported or not several factors were evaluated. First bulk density was examined as it can be an early indicator of sediment composition. The bulk density remained fairly consistent until 40cms and below when it came to sediment weight. A lower bulk density near the surface is do to more roots present at this level whereas a higher bulk density at deeper depths are indicating the decomposition of roots and more minerals being left behind. Based on the bulk density results it can be indicated that when size fractionating samples it should be expected that their will be some plant detritus as well as minerals present. To evaluate that sediment organic matter percent mass was examined. This was done in order to compare which size fractions are being composed of at the different wetland age bands. A majority of the weight from the three size fractions formed the mineral associated organic matter fraction.

Sediment organic matter fractions were also evaluated for % organic carbon content and expected to have more carbon content in the coarse fraction (cPOM) due to the roots and rhizomes present at this size. The mineral fraction had the lowest % organic carbon content as things like minerals and rocks would barely have any organic carbon associated with them.

Carbon density was also evaluated and used % organic carbon, bulk density of the soil, and the percent of each fractionated section mass to indicate how each size fraction is contributing to carbon burial. The coarse had the highest carbon density near the surface where the active rooting zone is and the mineral associated fraction had lower carbon densities associated with it. The fact that the coarse fraction had the lowest % mass and higher % carbon whereas the mineral had the highest % mass and the lowest % carbon suggest that all three fractions have similar carbon densities below the rooting zone.

Lastly $\delta^{13}C$ values were evaluated in order to determine carbon sources. The average $\delta^{13}C$ values for cPOM was -15.50, fPOM was -16.38, and the MAOM was -22.14 these values match previous literature for terrestrial C3 plants, and salt marsh grass C4 plants (Rosenbauer et al., 2009). It was expected that the cPOM would have a salt marsh grass source, the fine with a slightly more negative salt marsh grass source, and the MAOM fraction to have a mixture between a salt marsh grass source and a terrestrial source. Based off of literature values and the research done on benthic algae organic matter not surviving far down core expected sourcing was supported.

Overall a comparison model could not fully determine if formulated hypothesis could be supported or not as statistical analysis has not been conducted yet. Currently the % organic carbon does not seem to have any difference in carbon content across the prograding and retreating marshes. Carbon densities seem to vary between the retracting and prograding 1800 band as we travel downcore.

4.5 Conclusion

I was only able to partially support my hypothesis that plant and animal abundance would be similar across the wetland age bands, but plant canopy height did differ from prograding and retreating marshes. Vertical accretion is faster along the prograding wetland and that accretion slows as you move further inland. I cannot fully determine if my hypothesis for carbon content can be supported or not as there is still more analysis needed as carbon stocks need to be calculated. I was able to support that the carbon in the edge of the prograding marsh has a higher terrestrial source which is present in the MAOM fraction, but statistical analysis needs to be conducted.

Overall there is still work to be done to determine if I can fully support whether or not there is an increased carbon content along the prograding wetland band or not by calculating carbon stocks. I will also generate a mixing model that will estimate the relative sources of my marsh and indicate how much terrestrial carbon and how much marsh carbon are comprising my fractions.

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