FINAL REPORT

Project Name: CMP 24 – Understanding ecosystem responses to the closure of Rollover Pass on Bolivar Peninsula

Principal Investigator: Dr. Anna Armitage, TAMUG

GLO Contract No.: 20-041-000-B749

Reporting Period: 1 October 2019 through 31 December 2021

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Table of Contents

Task 1: Project Planning and Data Collection

Status and Deliverables

☐in progress ☒completed

Deliverable Name	Date Due	Date submitted/completed
1. Literature review	6/30/20	9/30/20
2. Map of project sites	12/31/19	12/31/19
3. Resume of graduate and undergraduate students recruited	3/31/20	10/11/21
4. TAMU Animal Use Protocol Permit	12/1/19	11/21/19
5. Notification of datasondes deployed	12/31/20	10/1/19, 10/12/20
6. Initial plant and nekton sampling	12/31/20	10/12/20
7. 6-month sampling update and summary	7/31/21	3/31/21
8. 1-year Sampling update and summary	12/31/21	9/18/21

Major accomplishments and findings

1. A literature review summarized relevant findings from 18 papers and reports that described plant, animal, or hydrogeographic features of tidal ecosystems in the Anahuac National Wildlife Refuge and eastern Galveston Bay near Rollover Pass. This literature review is appended in Appendix A.
2. A map of the four project survey sites is included in Appendix B.
3. This project supported two graduate students, including one (A. McDonald) who focused on this project for her thesis research (graduation planned spring 2022). In addition, one undergraduate student assisted in the field with sample collection. (See also Task 3.) Additional undergraduate assistance was limited due to COVID-related safety considerations (see "Problems or obstacles" section below).
4. The PI's existing TAMU Animal Use Permit IACUC 2018-0236 was amended to include this project in November 2019. In 2021, a renewed permit (IACUC 2021-0119) was issued to continue this project.
5. Datasondes to collect water data were deployed at two of the sites (sites 1 and 2 on the map in Appendix B) in September 2019. Deployment at sites 3 and 4 were delayed until September 2020 due to equipment shortages and COVID-related restrictions on field work. Some supplemental data from Site 4 from September 2019-March 2020 were provided by TPWD project partners. Findings are summarized in the Data Analysis Report (Appendix B).
6. Sites 1, 2, and 3 were sampled in October 2019. Site 4 was added to the study after Pass closure in December 2019, and was not sampled until June 2020. Major findings are included in the Data Analysis Report (Appendix B).

7. All four sites were sampled in October 2020. Findings are summarized in the Data Analysis Report (Appendix B).
8. All four sites were sampled in March and September 2021. Findings are summarized in the Data Analysis Report (Appendix B).

Problems or obstacles

☒Yes ☐No If yes, please explain:

Fieldwork plans were disrupted in early 2020. Plant and nekton sampling was planned in February 2020, but was rescheduled to mid-March due to mechanical issues with the airboat provided by our project partners at the Anahuac National Wildlife Refuge. Unfortunately, the March 2020 sampling date was then postponed in response to sudden and unexpected restrictions on field work and travel due to the COVID-19 pandemic. TAMU, as well as our project partners (Texas Parks & Wildlife Department and Anahuac NWR) were under strict work-from-home and social distancing orders, and for several months, it was neither safe nor feasible to conduct field work.

We were able to collect data at one of the four sites in June 2020, and rescheduled remaining field work for August and September 2020. Unfortunately, those attempts at field work were disrupted by tropical storm events (Hurricane Laura, Tropical Storm Beta) that caused localized flooding and prevented safe field operations. We were able to safely conduct field operations in October 2020, March 2021, and September 2021.

As a consequence of these delays, a 9-month no-cost extension was granted to extend the project end date to 12/31/21. All tasks were completed by that end date.

Task 2: Data Analysis

Status and Deliverables

☐in progress ☒completed

Deliverable Name	Date Due	Date submitted/completed
1. Collate pre-closure data	12/31/21	12/31/21
2. Post-closure analysis report	12/31/21	12/31/21
3. Comparison of pre- and post-closure datasets	12/31/21	12/31/21

Major accomplishments and findings

1. Based on our literature review, few previous studies had published or publicly-available datasets, so data collation products were descriptive and integrated into the literature review (Appendix A).
2. The narrative in Appendix B describes the key findings and data analyses.

3. A discussion comparing the collected data to pre-closure descriptions of the region is included in Appendix B.

Problems or obstacles

☒Yes ☐No If yes, please explain:

Few previous studies have published publicly-available datasets, and we were not able to obtain unpublished data from project partners due to agency restrictions. Therefore, data collation products were descriptive and integrated into the literature review (Appendix A) and data analysis report (Appendix B).

Task 3: Data Dissemination, Education and Outreach

Status and Deliverables

☐in progress ☒completed

Deliverable Name	Date Due	Date submitted
1. TAMU-G website launch	12/31/19	3/31/20
2. Notification(s) of TAMU-G website update	12/31/21	12/31/21
3. Notification of data upload to TWDB database	12/31/21	12/31/21
4. Copies of presentations	12/31/21	4/9/21, 12/31/21
5. Notification of recruitment and training of two graduate students	8/31/21	10/11/21
6. Notification of recruitment and training of one or more undergraduate research interns	12/31/21	10/11/21
7. Stakeholder meeting notes	12/31/21	4/9/21

Major accomplishments and findings

1. The PI's lab website was updated in early 2020 with a summary of the project goals and an acknowledgement of the funding source.
2. In December 2021, the project website was updated with a summary of key findings: https://www.tamug.edu/armitage/Current_Projects.html. The final report will be publicly available on a GLO server.
3. The water data were provided to the project manager for review and approval prior to uploading to the Texas Water Development Board (TWDB) database. That approval was received on 12/15/21. Data were curated and uploaded to https://www.waterdatafortexas.org/coastal.

4. Two conference presentations on this project were given in 2021; both poster presentations were led by one of the graduate students (A. McDonald) on the project. Copies of the presentations are appended in Appendix D.
   McDonald, A.E. and A.R. Armitage. November 2021. A decadal-scale case study of coastal primary producer responses to tidal restoration. Coastal and Estuarine Research Federation 26th Biennial Conference (virtual).
   McDonald. A.E., A.R. Armitage. December 2021. Past, present, and future: A decadal-scale case study of coastal primary producer responses to tidal alterations. American Geophysical Union Fall Meeting, New Orleans, LA.

5. Two graduate students (M.S. student Ashley McDonald, Ph.D. candidate Jamie Thompson) worked on this project. Ms. McDonald's thesis focused on this project, and her expected graduation is spring 2022.
6. One undergraduate student (Erica Werner) assisted Ms. McDonald with field work and sample collection. Additional undergraduate assistance was limited due to COVID-related safety considerations.
7. Presentations to stakeholders were given at Galveston Bay Estuary Program subcommittee meetings held virtually on January 8, 2021 and December 8, 2021. Copies of the presentations and notes from the meetings are appended in Appendix D.
   Armitage, A.R. January 2021. Understanding ecosystem responses to the closure of Rollover Pass on Bolivar Peninsula. Galveston Bay Estuary Program Natural Resources Subcommittee meeting (virtual).
   Armitage, A.R. and A.E. McDonald. December 2021. Ecosystem responses to Rollover Pass closure. Galveston Bay Estuary Program Monitoring & Research Subcommittee meeting (virtual).

Problems or obstacles

☒Yes ☐No If yes, please explain:

Recruitment of undergraduate assistants was limited due to COVID-related safety restrictions on lab and field work. In addition, most conferences and stakeholder meetings were held virtually.

Task 4: Project Monitoring and Reporting

Status and Deliverables

☐in progress ☒completed

Deliverable Name	Date Due	Date submitted
1. Quarterly progress reports and reimbursement requests	Quarterly	Quarterly
2. Draft final report	12/15/21	12/15/21
3. Final report	12/31/21	12/31/21

Major accomplishments and findings

1. All quarterly progress reports have been submitted on schedule.
2. The draft final report was submitted to the project manager on 12/15/21.
3. The revised final report was submitted to the project manager on 12/31/21.

Problems or obstacles

☒Yes ☐No If yes, please explain:

A 9-month no-cost extension was granted to extend the project end date to 12/31/21 (See Task 1). All tasks were completed by that end date.

Appendix A

Literature review and Collation of pre-closure data

Rollover Pass was a constructed channel on the Bolivar Peninsula that linked the Gulf of Mexico to Rollover Bay and East Bay in eastern Galveston County. Rollover Pass was originally opened by Texas Game and Fish Commission (now the Texas Parks and Wildlife Department (TPWD)) in 1954 to increase bay water salinity and provide access for marine fish to and from spawning and feeding areas in East Bay (Prather and Sorensen 1972). Some local accounts suggest that there may have historically been a narrow tidal channel in this location (Wallach 2009), though that channel is not consistently documented on historical maps of the region. Nevertheless, by most accounts, prior to the construction of Rollover Pass, East Galveston Bay was predominately characterized by fresh to brackish conditions due to its isolation from tidal influx and freshwater inflow from Oyster Bayou, fringed by grass-dominated marshes (Bhattacharjee et al. 2007). However, there was a perception that low salinities (in addition to poor water quality) limited the distribution of benthic species (Copeland and Bechtel 1971). Therefore, in an effort to improve marine biological conditions and fishing opportunities in East Galveston Bay, the Rollover Pass was constructed in 1954 (Prather and Sorensen 1972). After Pass closure, salinity in the East Bay ranged from 5-15 ppt (Johnson et al. 2013; White et al. 1985), presumably an increase from the previously fresh- to mesohaline conditions typical of other Chenier Plains wetlands in the area (Gosselink et al. 1979).

However, the construction of Rollover Pass was not without problems. Initial severe stability issues were corrected by the Army Corps of Engineers (Bales and Holley 1985; Prather and Sorensen 1972). However, shoreline erosion in East Galveston Bay continued in response to both natural and anthropogenic factors, and it became clear that the construction of Rollover Pass had led to an altered equilibrium between erosion and accretion in the region (Hall et al. 1986). East of Rollover Pass there was net accretion at Sabine Pass, but net erosion from Sabine Pass west to Crystal Beach (Gosselink et al. 1979; Morton 1975). Due to these continuing stability problems, in the 1980s TPWD began developing plans to reconstruct deteriorating retaining walls (Bales and Holley 1985). However, in order to do this, TPWD needed to understand sand transport through Rollover Pass due to concerns about shoaling and beach erosion. These questions were addressed in part by Bales and Holley (1985) by comparing different methods of estimating net sand transport through tidal inlets. They found that Rollover Pass increased sediment transport into the Gulf Intracoastal Waterway (GIWW), which subsequently increased the need for GIWW dredging maintenance activities more than threefold (Bales and Holley 1985).

In addition to structural problems with Rollover Pass, this alteration caused many ecological changes. The initial ecological impacts of constructing Rollover Pass were large, but the impacts became more muted over time (Prather and Sorensen 1972). In the decades following the opening of Rollover Pass, many studies occurred in the surrounding coastal environments with the majority finding transitions consistent with an increase in saline conditions. Seagrasses and other submerged aquatic vegetation declined in the greater Galveston Bay system from 1956-1979, which can be attributed to multiple additional causes including coastal development, nutrient pollution, and changes to freshwater inputs (Pulich and White 1991). The marshes of Anahuac National Wildlife Refuge (Anahuac NWR) are currently characterized as intermediate marshes, meaning that these ecosystems contain plant communities tolerant of a wide range of salinities (Bhattacharjee et al. 2007). This contrasts with the fresh- to mesohaline plant assemblages that are typical of the Chenier Plains ecosystem (Visser et al. 2000), and were likely dominant prior to the opening of the Pass in 1954. Further, after the disturbance caused by the construction of Rollover Pass, the ecosystem transitioned from a grass-dominated system to a sedge-dominated system, with only 54% similarity in species composition compared to pre-disturbance (Bhattacharjee et al. 2007). Following pass construction, plant species diversity and evenness initially increased, but within one decade returned to pre-disturbance levels (Bhattacharjee et al. 2007).

Many fishery species could also be impacted by changes in the salinity regime. However, relatively few data are available on benthic and nektonic fauna from prior to the Pass opening. One exception is oyster reefs, as the oyster industry is extremely economically important in Galveston Bay. In the two decades following the opening of the pass, oysters appeared to flourish (Gosselink et al. 1979). However, by the early 2000s, decreased freshwater dominance led to a long-term reduction in the abundance of market size oysters (Buzan et al. 2009). The response of nekton (fish and motile invertebrates) to the opening of the Pass is less well documented, though southern flounder (*Paralichthys lethostigma*) juveniles tend to be more common in the East Bay compared to other areas of the Galveston Bay Estuary (Glass et al. 2008). This may be attributable to lower salinities and the proximity of Rollover Pass to nursery grounds for this species (Glass et al. 2008).

Since the 1960s, the Galveston Bay ecosystem has experienced widespread salt marsh loss, largely attributed to rapid subsidence and other anthropogenic drivers in the late 20th century (White et al. 1993). Tidal wetland restoration is a common management approach to mitigate for this loss, and several studies have compared natural and created marshes in the area surrounding Rollover Pass. Natural and created marshes *Spartina alterniflora* were compared and no difference was found in the relative abundance of microhabitat types, but there were significant differences in elevation profiles and in marsh-water edge ratios and area-perimeter ratios because natural marshes had undulating edges (Delaney et al. 2000). Other restoration studies demonstrate that natural and created marshes were not functionally equivalent, with lower densities of both fish and decapod species in created marshes (Minello and Webb Jr 1997; Rozas et al. 2005). These density differences could be due to differences in hydrology, which limited species access to the marsh platform (Minello and Webb Jr 1997). Although not directly linked to the opening of closing of Rollover Pass, these studies demonstrate the challenges of successful and comprehensive ecosystem restoration across multiple trophic levels. Furthermore, heterogeneity among sites highlights the importance of site-specific data to inform assessments of restoration success.

Due to ongoing erosional issues on Bolivar Peninsular near to Rollover Pass, compounded by substantial structural damage during Hurricane Ike (2008), the Pass was closed in December 2019, despite local objections and unsuccessful legal challenges. This action should restore the historical hydrological conditions of East Galveston Bay. Once again, the nearest tidal influx is adjacent to the pass is between the west end of Bolivar Peninsula and eastern Galveston Island. There is a great need to understand how large-scale hydrological alterations, such as the closure of Rollover Pass, will impact coastal wetland communities in the context of ongoing climate change and hydrological alterations. Current research is focused on obtaining information about the emergent or submerged plant communities and nekton utilizing this area of Bolivar Peninsula or East Bay; this information is critical to understanding whether the hydrologic restoration of the ecosystem will support a diverse array of species and functions.

Appendix B

Data Analysis Report

Post-closure Analysis (Task 2, Deliverable 2), and Comparison of Pre- and Post-closure datasets (Task 2, Deliverable 3)

Approach

Rollover Pass (29.508287, -94.500271) was located on Bolivar Peninsula east of Galveston Island, allowing tidal flow into East Galveston Bay (Figure 1). To assess how the closure of the pass impacted surrounding wetland plant communities, four sites occurring along a natural salinity gradient were selected. Sites 1, 2, and 3 were located northeast of the pass along Oyster Bayou within Anahuac National Wildlife Refuge, while Site 4 was located approximately 1-km from the eastern bay-side of the Pass.

At each site, a permanent 50-m transect was established perpendicular to the shoreline. At three stations along the transect (0, 25, and 50 m from the water's edge), four 0.5 m^2 quadrats were haphazardly placed, with two to the left of the transect and two to the right. Within each quadrat, percent cover for each plant species present was recorded based on a bird's eye visual estimate.

In the tidal channel adjacent to each site, submerged aquatic vegetation (SAV) abundance was assayed. SAV was sampled by dragging the head of a 16-tine metal rake over a one meter area extending perpendicular from the marsh vegetation–water interface; each drag covered an area of ~1 m^2 (modified from (Spears et al. 2009). Three replicate drags were conducted at least five meters apart along the shoreline. Any collected SAV was stored on ice until it could be identified to species in the lab.

At each site, an Onset Hobo conductivity/temperature logger (Model U24-002-C) was placed in the tidal creek (~0.5 m deep) adjacent to each site; loggers collected data every 30-60 minutes. Loggers collected conductivity in µS/cm, and these values were converted to psu following Hill et al. (1986). Loggers were periodically exposed during periods of low water. During these emersion periods, salinity values were typically less than 0.5 psu and temperatures were more variable (reflecting air temperatures) than water temperatures. During periods of immersion, conductivity values were typically above 2 psu. Therefore, most

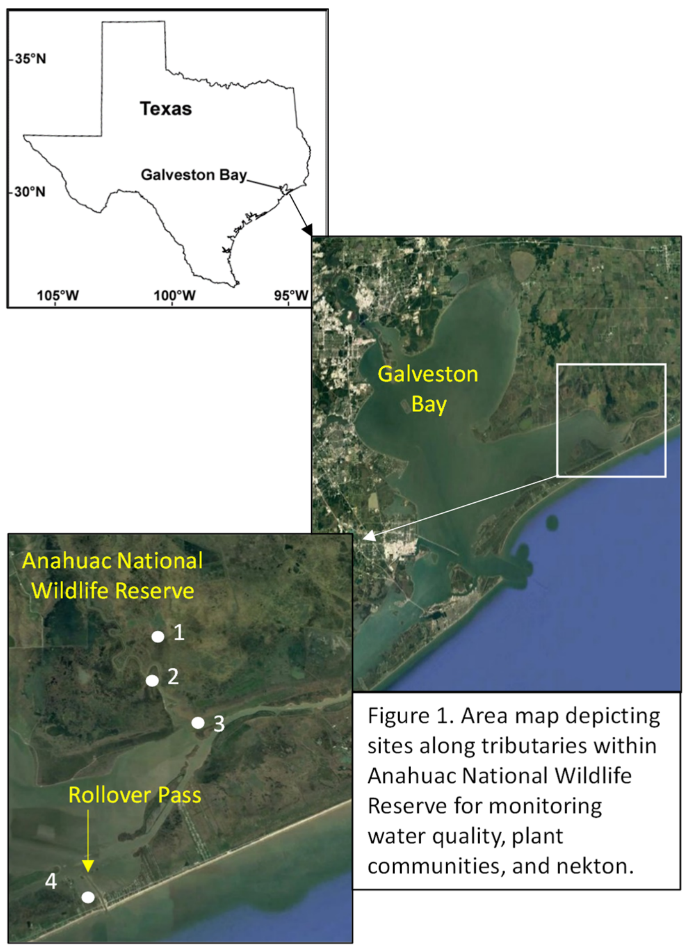


Figure 1. Area map depicting sites along tributaries within Anahuac National Wildlife Reserve for monitoring water quality, plant communities, and nekton.

values less than 0.5 psu were likely to be instrument error. This threshold is noted in the data presented below.

These sites were sampled pre-closure in October 2019 (sites 1, 2, 3), and post-closure in June 2020 (site 4), October 2020 (all sites), March 2021 (all sites), and September 2021 (all sites). The June 2020 sampling at site 4 closely approximated pre-closure conditions and was therefore included in the "2019" statistical category described below. Each of the sites had different starting plant communities due to the natural tidal gradient and had different elevation profiles, so changes over time were analyzed separately at each site. To analyze the changes in plant community composition over time at each site, percent cover of each species was used in permutational multivariate analyses of variance (PERMANOVA) using adonis from the vegan package in RStudio (Version 1.4.1103), where year (2019, 2020, 2021) was the independent variable and a p-value less than 0.05 indicated significant differences among years. Differences among years were visualized with non-metric multi-dimensional scaling plots. Following the PERMANOVA analyses, exploratory similarity percentages (SIMPER) analyses were used to determine which species contributed the most to differences among years. Water salinity was graphed continuously (with gaps due to incidences of logger error) over time beginning in October 2019.

Results

Water

At each site, water column salinity was variable over time (Figure 2). At site 4 (closest to Rollover Pass), variability in salinity appeared to decrease after Pass closure in December 2019. At site 4, monthly average and monthly maximum salinity also appeared to decrease over time from 25 psu in October 2019 to 15 psu in April 2021 (Figure 3). Salinity was overall higher (> 10 psu) at sites closest to Rollover Pass and the Gulf of Mexico (Sites 3 and 4) compared to upstream sites (Sites 1 and 2; < 5 psu) (Figures 2, 3).

Comparison to pre-closure conditions. Prior to the construction of Rollover Pass and the subsequent increase in saltwater and tidal flow, East Bay marshes were described as estuarine and/or brackish (Lay and O'Neil 1942, Reid et al. 1956). Immediately following the construction of Rollover Pass, the ecology and hydrology of East Galveston Bay was substantially altered (Reid Jr 1956). Bay salinity increased two-fold to 22 at Rollover Pass and decreased incrementally with distance from the pass (minimum of 13 in East Galveston Bay) due to the introduction of salty Gulf of Mexico waters (Reid 1957; Reid Jr 1956).

Emergent vegetation

The community composition of the plant community changed significantly over time at Sites 1, 2, and 3 ($p < 0.01$) but not at Site 4 ($p = 0.326$). However, NMDS plots indicated that there was a great deal of variability within sites each year, and that there was substantial overlap in assemblages across years (Figure 4). To better understand the ecological significance of the PERMANOVA and NMDS results, similarity percentages (SIMPER) were established to examine which species contributed the most to the differences between dates (Figure 5). The SIMPER analysis indicated that the shifts within sites 1-3 were not toward freshwater species, but instead were due to fluctuations in the abundance of previously occurring saltwater species (Table 1, Figure 6). Few freshwater species appeared or expanded in any sites over the three-year study, indicating that the colonization of freshwater tolerant species did not contribute to the differences between years in an ecologically meaningful way.

Comparison to pre-closure conditions. Prior to the construction of Rollover Pass, Lay and O'Neil (1942) described area marshes as dominated by *Spartina alterniflora*, along with *Juncus militaris*, *Schoenoplectus robustus*, and *Juncus roemerianus* with *Spartina spartinae* at the upland transition and *Phragmites australis* at the water's edge (scientific names were determined based on common names used in Lay and O'Neil (1942) and may not be fully inaccurate). In the early 1990s (nearly 40 years after the construction of Rollover Pass), wetland habitats in East Bay, nearest to Rollover Pass (Sites 3 and 4) were predominately brackish and salt marshes (White 1992). During the same time, upstream sites (Sites 1 and 2) within Anahuac NWR were primarily brackish and fresh marshes (White 1992). Overall, there were few salt-intolerant species at any of the sites and there was greater diversity upstream (Table 1, Figure 6). These patterns are similar to those documented in the current study.

During the 1940s, more predominantly freshwater or salt-intolerant species were found in the marshes around East Galveston Bay (Table 1) than in the current study. In the 1990s, there were more salt-intolerant species found upstream compared to the downstream sites during the same period (Table 1). These patterns indicate that the plant community in East Galveston Bay was always somewhat brackish but may have been fresher prior to the construction of Rollover Pass.

<u>Submerged aquatic vegetation</u>

Submerged aquatic vegetation (SAV) did occur at the sampling sites but was very rare. The only instance of SAV collected with the rake tosses at any site was in October 2021 at Site 1, where a small amount of *Ruppia maritima* was found in the channel adjacent to the site. Surveys over a larger spatial scale may be needed to fully assess the timeline and extent of SAV recovery as salinities decrease over time.

<u>Fauna</u>

Nekton were variable across sites and over time. Most of the species encountered were salt tolerant, and the most common species (*Brevoortia patronus*, *Palaemonetes pugio*, and *Farfantepenaeus* spp.) occurred at all sites (Table 2). No fauna were found in September 2021. These sparse nekton populations indicate that the sampling approach used did not fully characterize the nekton assemblages, and that a larger temporal and spatial scale is needed to assess the trajectory and dynamics of nekton response to Rollover Pass closure.

Summary and Conclusions

Our evaluation of the near-term ecosystem responses within East Bay to the closure of Rollover Pass indicated that ecosystem responses were gradual and non-directional. Near the Pass, water salinity decreased modestly, and became less variable over time. Upstream changes in salinity were more subtle. In the marshes, the plant communities changed over time, but the species present remained the same. Changes in emergent plant communities were largely attributable to fluctuations in abundance of existing species, and there was no clear shift towards species characteristic of freshwater marshes. Likewise, all of the fish and invertebrate species present were salt tolerant. Submerged aquatic vegetation was sparse at all sites. Overall, these data indicate that ecosystem responses to the closure of Rollover Pass are occurring gradually, and any additional changes may occur slowly over the coming years.

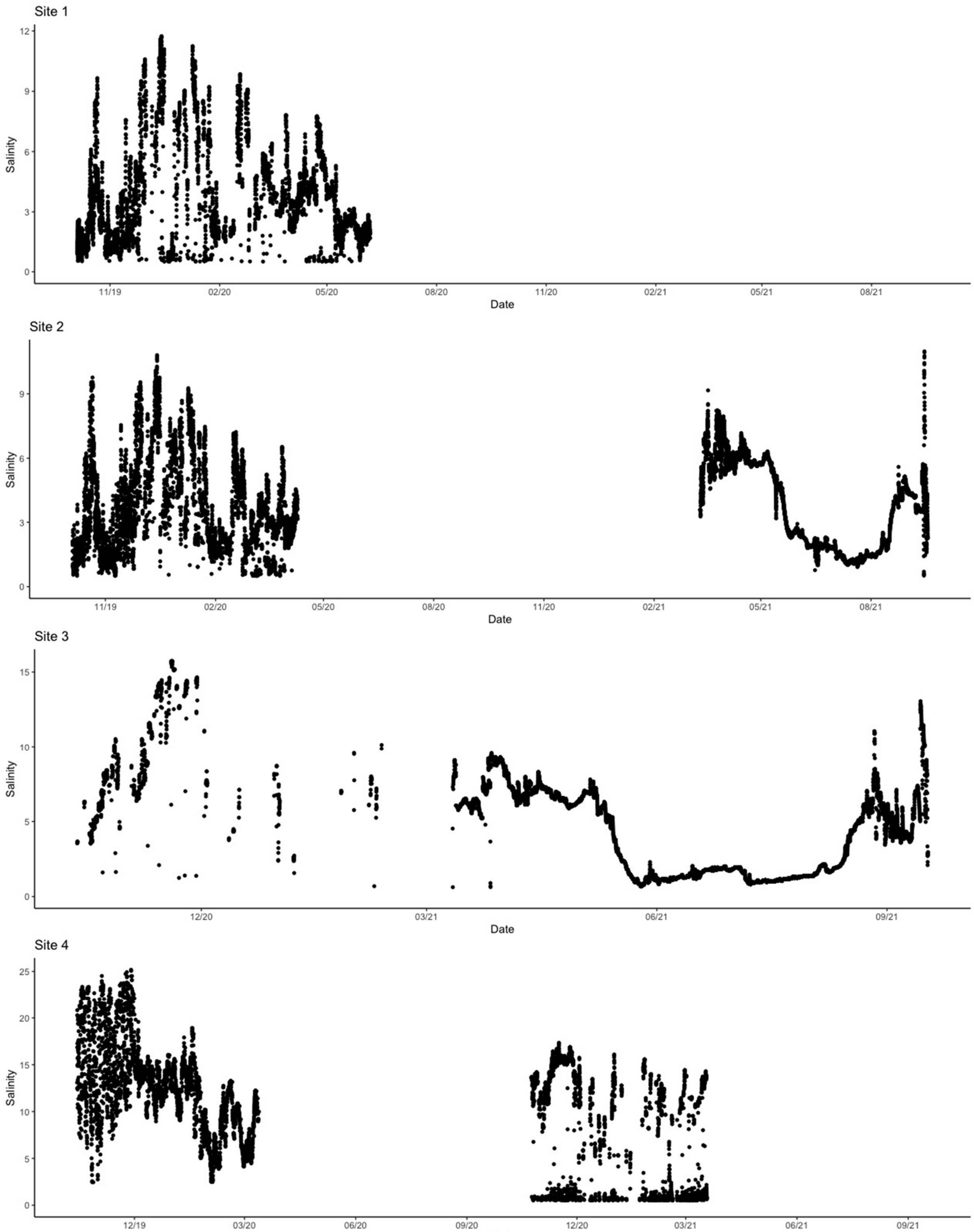


Figure 2. Water column salinity (psu) over time. Missing points represent periods of logger exposure or failure. Note different time scales on the x-axes, and different salinity scales on the y-axes.

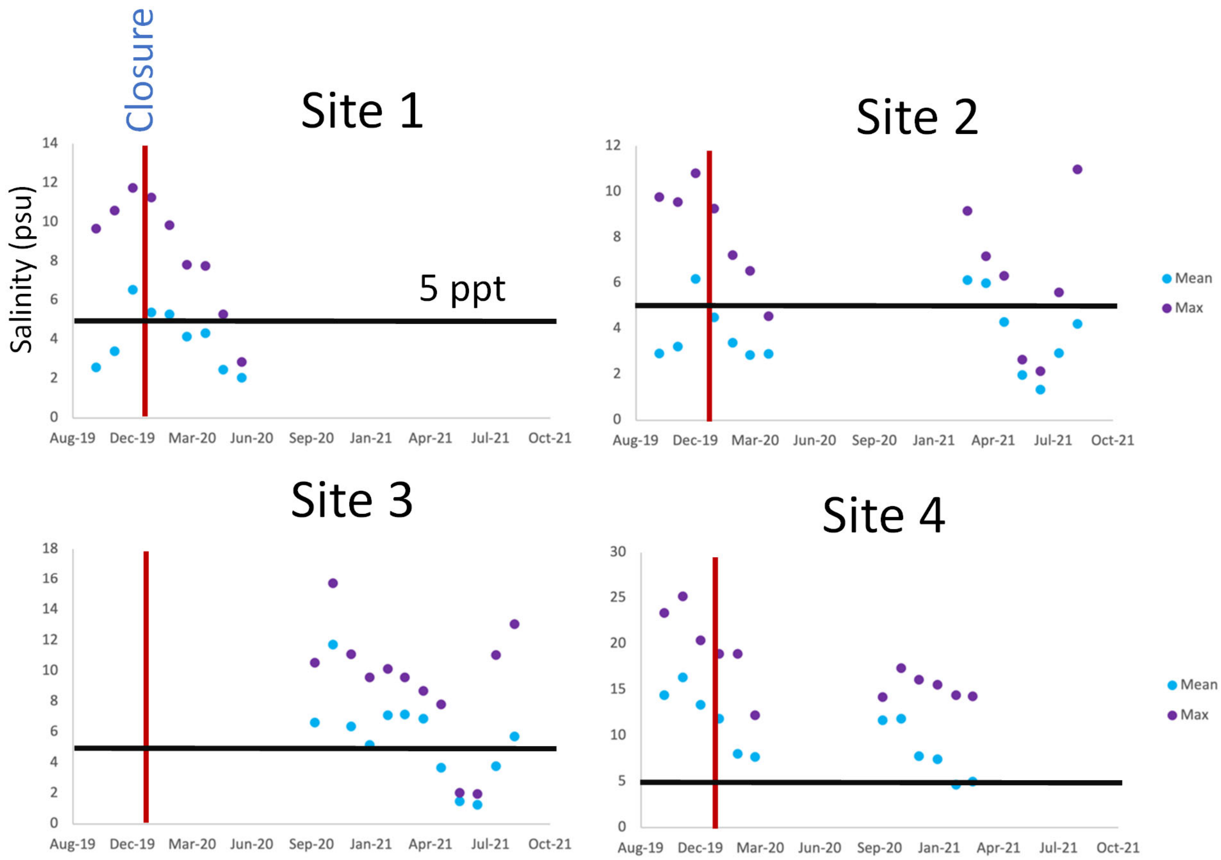


Figure 3. Monthly mean and maximum water column salinity (psu) over time. Note different salinity scales on the y-axes; the black horizontal line depicts 5 psu as a reference. The red vertical line indicates the date of Rollover Pass closure.

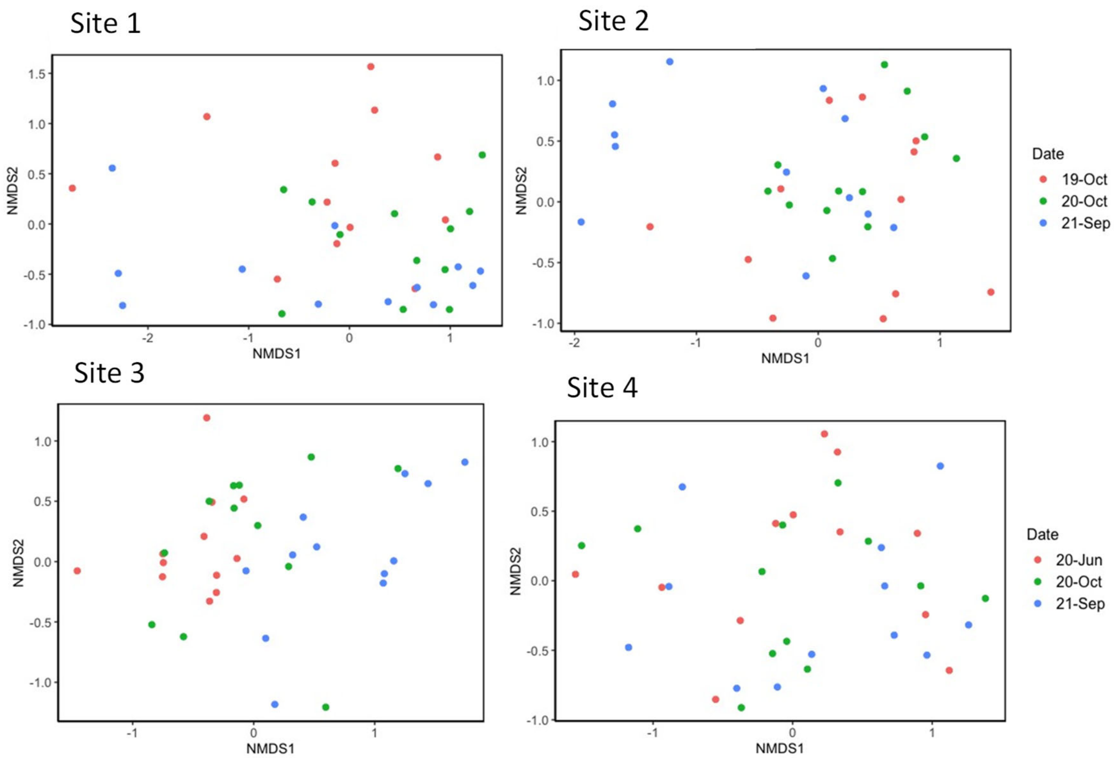


Figure 4. Non-metric multidimensional scaling (NMDS) plots depicting changes in plant community composition over time within each site. Points clustered close together had similar plant assemblages, and points further apart had more dissimilar assemblages.

Site 1			
Species	**10/2019 – 10/2020**	**10/2020 – 9/2021**	**10/2019 – 9/2021**
Cuscuta sp.	12%		
Distichlis spicata	17%		18%
Iva fructescens	16%	24%	23%
Schoenoplectus pungens	14%	17%	
Schoenoplectus robustus		13%	13%
Spartina patens	18%	17%	22%

Site 2			
Species	**10/2019 – 10/2020**	**10/2020 – 9/2021**	**10/2019 – 9/2021**
Schoenoplectus americanus	13%		
Schoenoplectus robustus	25%	21%	26%
Spartina alterniflora	19%	28%	22%
Spartina patens	19%	21%	18%
Symphiotrichum tenuifolius		14%	12%

Site 3			
Species	**10/2019 – 10/2020**	**10/2020 – 9/2021**	**10/2019 – 9/2021**
Schoenoplectus robustus	33%	36%	41%
Spartina alterniflora	30%	32%	34%
Symphiotrichum tenuifolius	31%	32%	

Site 4			
Species	**6/2020 – 10/2020**	**10/2020 – 9/2021**	**6/2020 – 9/2021**
Batis maritima	23%		
Distichlis spicata	36%	43%	41%
Spartina alterniflora	29%	29%	30%

Figure 5. SIMPER results for changes in plant community composition over time at each site. Each chart shows how much of the change between years was attributable to a particular species. Colors represent the direction of the change (green = increased cover and red = decreased cover)

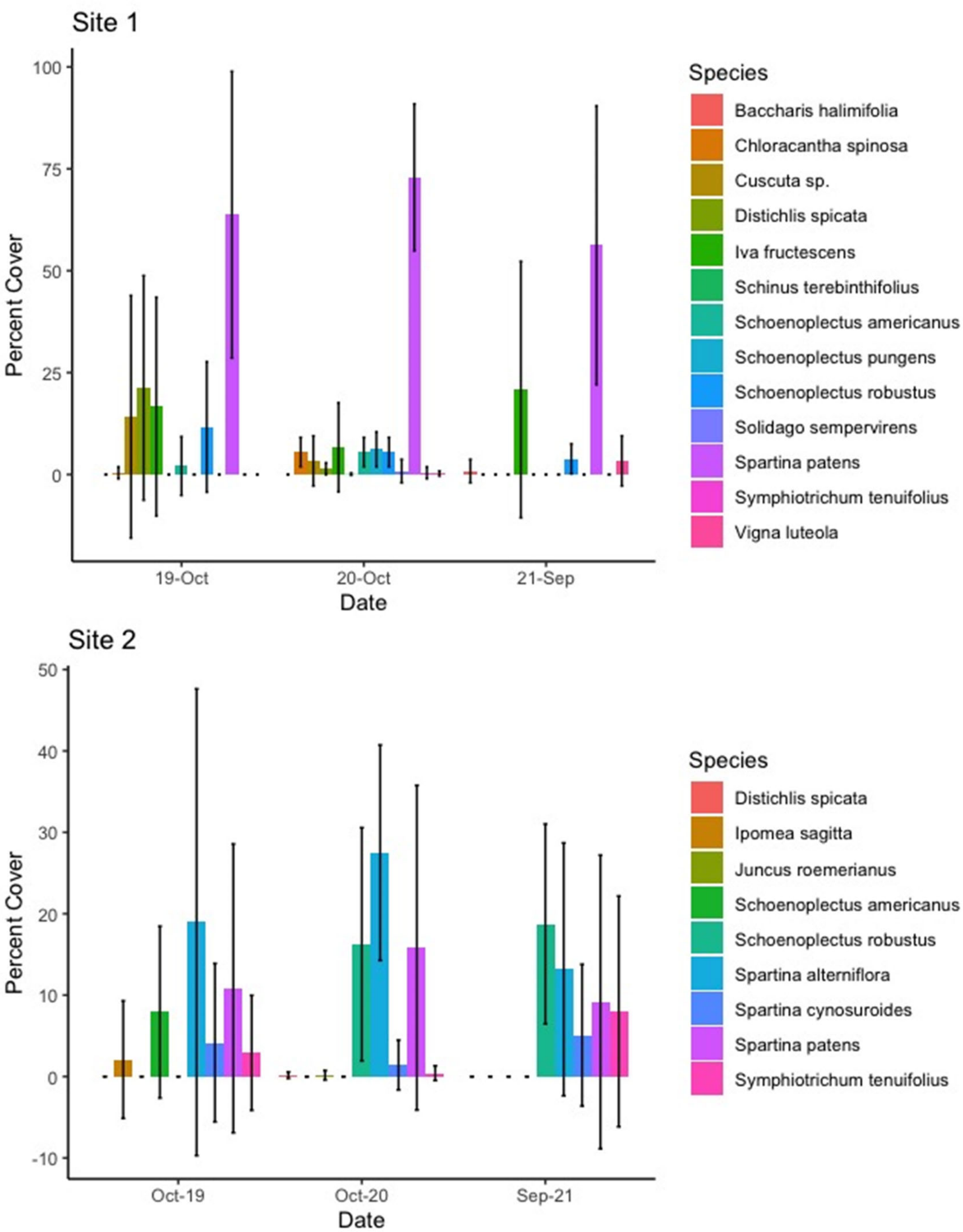
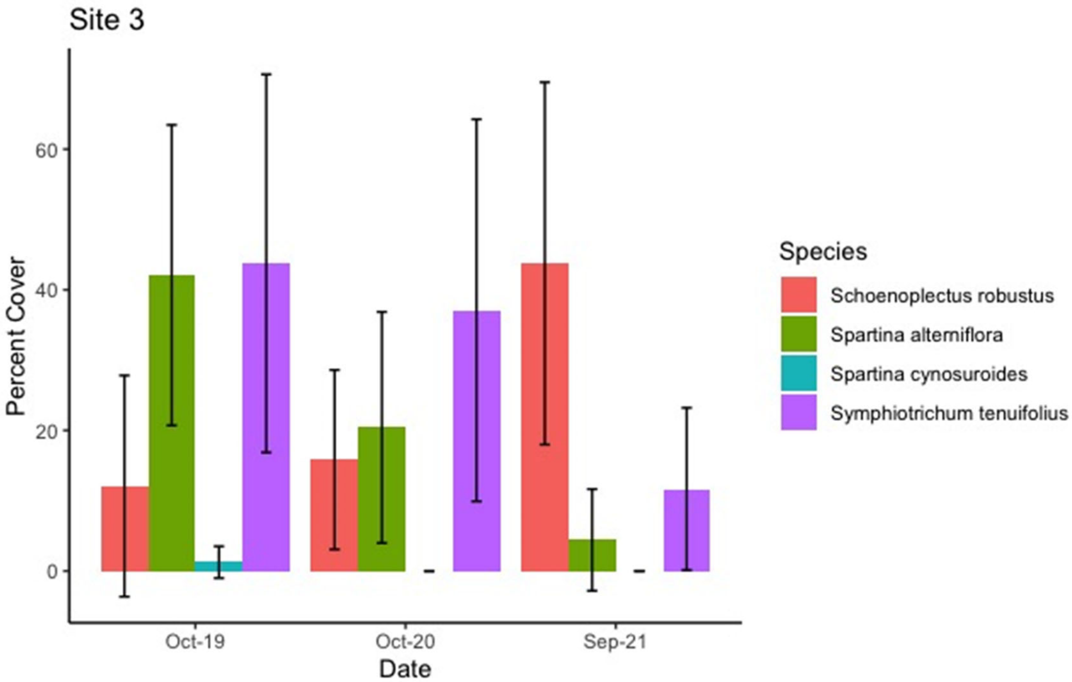


Figure 6. Mean cover (± standard error) of each plant species at each site over time.



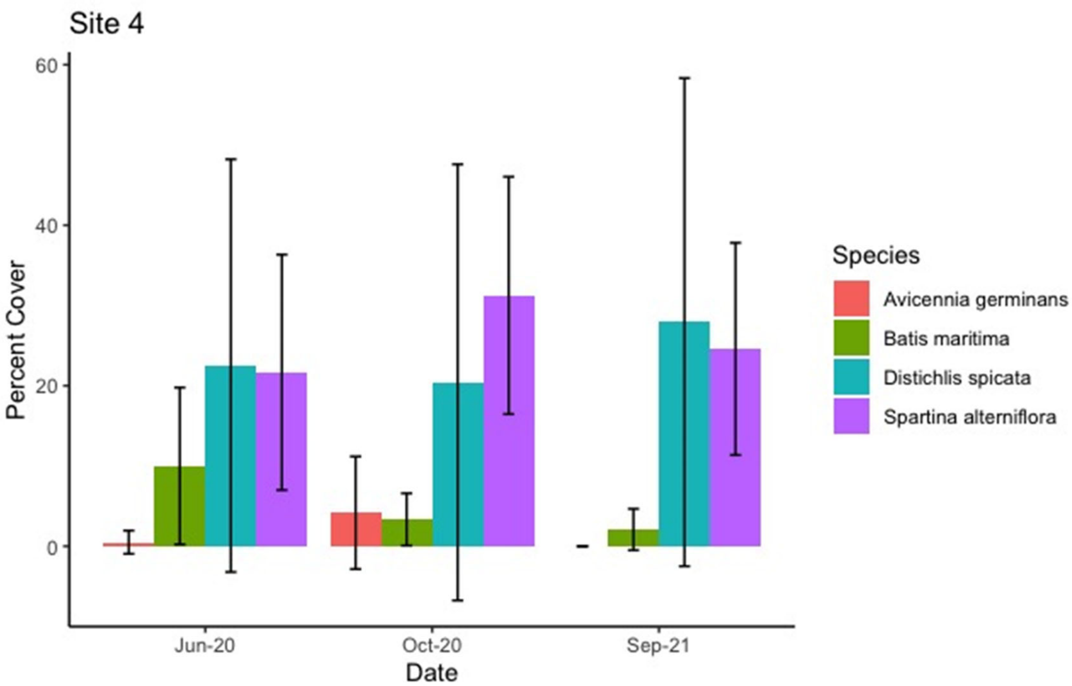


Figure 6 (continued). Mean cover (± s.e.) of each plant species at each site over time.

Table 1. Species reported in marshes surrounding field sites in the 1940s by Lay and O’Neil (1942), the early 1990s by White (1992), and species found at field sites during this study in the 2010s and 2020s. Bolded species indicate those that only occurred in one of the time periods at that site, and asterisks indicate species that are predominately freshwater species.

Species Found in East Galveston Bay (1940s)
• *Spartina alterniflora* • ***Juncus militaris**** • *Schoenoplectus robustus* • *Juncus roemerianus* • *Spartina spartinae* • ***Phragmites australis***

Species Found Nearest to Sites 1 and 2 (1990s)	**Species Found Nearest to Sites 3 and 4 (1990s)**
• ***Borrichia fructescens*** • ***Echinichloa crus-galli**** • *Iva fructescens* • ***Juncus effusus**** • ***Panicum virgatum**** • ***Paspalum vaginatum*** • *Schoenoplectus americanus* • ***Schoenoplectus maritimus*** • ***Setaria geniculata*** • *Spartina patens* • *Spartina spartinae* • *Sporobolus virginicus* • ***Typha sp***.	• ***Aster sp.**** • *Batis sp.* • ***Borrichia sp.*** • *Distichlis spicata* • *Juncus roemerianus* • *Limonium sp.* • *Monanthochloe sp.* • *Salicornia spp.* • ***Schoenoplectus maritimus*** • *Spartina alterniflora* • *Spartina patens* • *Spartina spartinae* • ***Suaeda sp***.
Species Found in Sites 1 and 2 (2010s and 2020s)	**Species Found in Sites 3 and 4 (2010s and 2020s)**
• ***Baccharis halimifolia*** • ***Chlorocantha spinosa*** • ***Cuscuta sp.*** • ***Distichlis spicata*** • ***Ipomea sagitta*** • *Iva fructescens* • *Juncus roemerianus* • ***Schinus terebinthifolius*** • *Schoenoplectus americanus* • ***Schoenoplectus pungens**** • ***Schoenoplectus robustus*** • ***Solidago sempervirens*** • *Spartina alterniflora* • ***Spartina cynosuroides*** • *Spartina patens* • *Sporobolus virginicus* • ***Symphiotrichum tenuifolius*** • ***Vigna luteola***	• ***Avicennia germinans*** • *Batis maritima* • *Distichlis spicata* • *Spartina alterniflora* • ***Spartina cynosuroides*** • *Spartina patens* • ***Schoenoplectus robustus*** • ***Symphiotrichum tenuifolius***

Table 2. Total number of nekton collected, pooled over three cast net tosses at each site.

Site 1		**Date**	
Species		Oct-20	Mar-21
Anchoa mitchilli		0	1
Brevoortia patronus		71	2
Farfantepenaeus duorarum		1	0
Site 2			
Species		Oct-20	Mar-21
Brevoortia patronus		2	0
Cynoscion nebulosus		1	0
Farfantepenaeus aztecus		1	0
Farfantepenaeus duorarum		1	0
Litopenaeus setiferus		1	0
Palaemonetes pugio		0	33
Site 3			
Species		Oct-20	Mar-21
Microponia undulatus		0	3
Farfantepenaeus aztecus		5	0
Farfantepenaeus duorarum		1	0
Palaemonetes pugio		1	17
Site 4			
Species	Jun-20	Oct-20	Mar-21
Anchoa mitchilli	1	0	0
Brevoortia patronus	43	0	0
Microponia undulatus	0	0	1
Farfantepenaeus aztecus	1	0	0
Farfantepenaeus duorarum	2	6	0
Litopenaeus setiferus	1	0	0
Palaemonetes pugio	1	11	0

Appendix C

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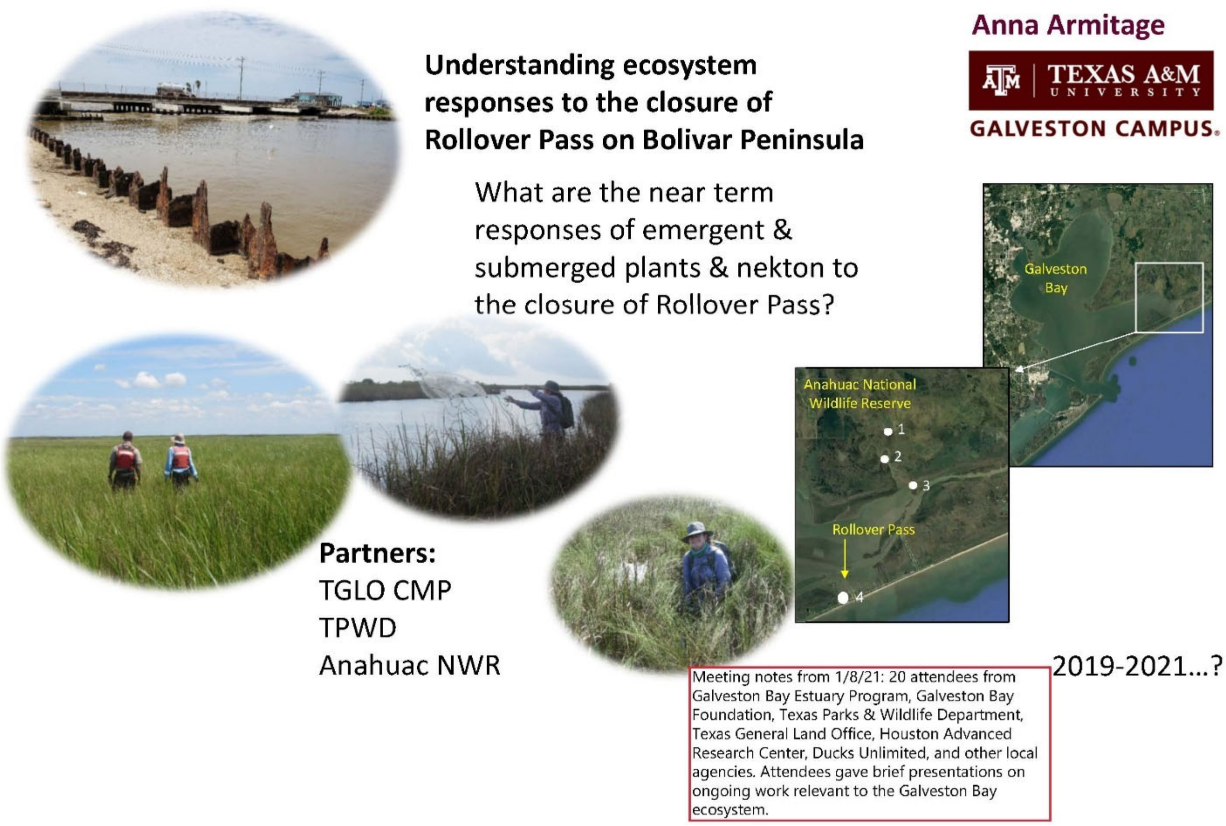
Appendix D

Presentations

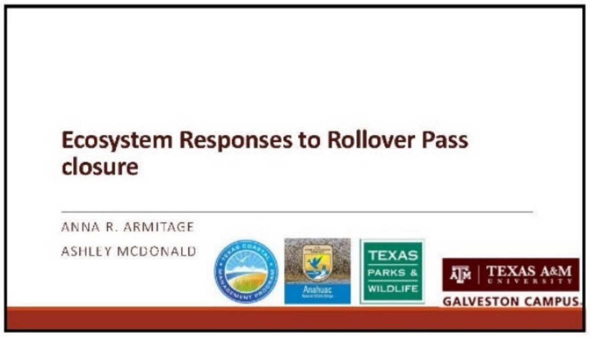
Stakeholder meetings

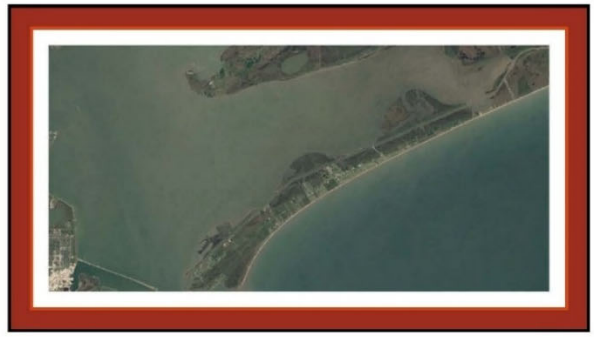
Galveston Bay Estuary Program, Natural Resource Use Subcommittee, January 2021

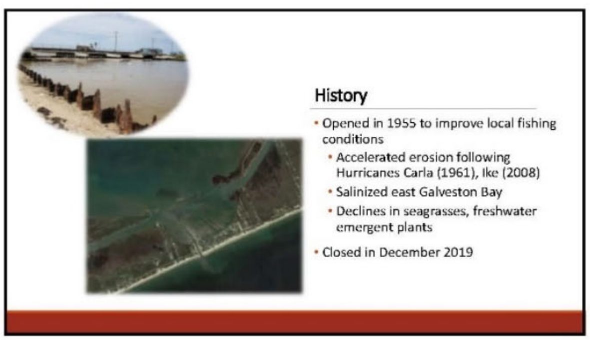
Meeting notes: Armitage gave a brief presentation on ongoing projects, including the Rollover Pass project. Attendees included representatives from the Galveston Bay Estuary Program, Galveston Bay Foundation, Texas Parks & Wildlife Department, Texas General Land Office, Houston Advanced Research Center, local universities, and other local and federal agencies.

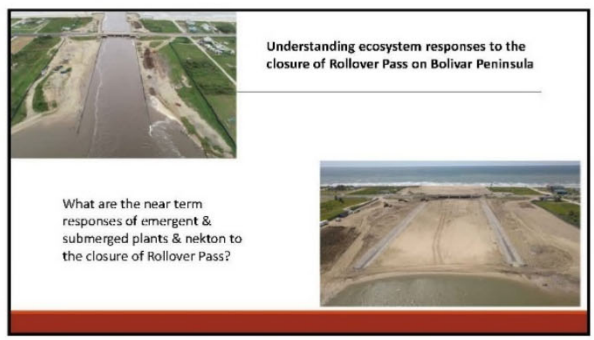


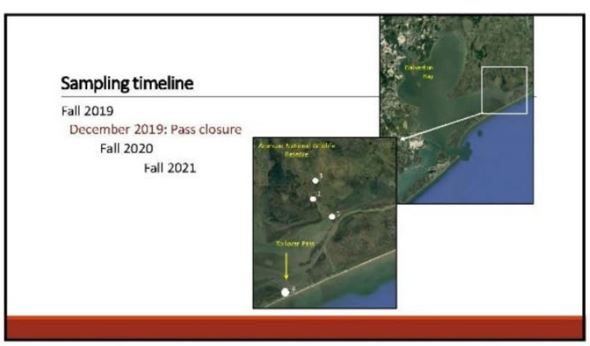
Galveston Bay Estuary Program, Monitoring & Research Subcommittee, December 2021
Meeting notes: Armitage gave a member spotlight presentation to 25+ attendees from the Galveston Bay Estuary Program, Galveston Bay Foundation, Texas Parks & Wildlife Department, Texas General Land Office, Houston Advanced Research Center, local universities, and other local and federal agencies.

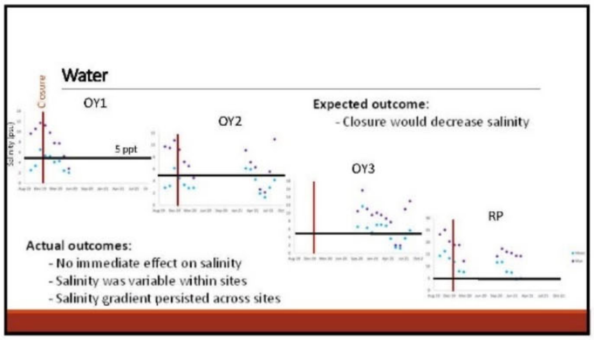


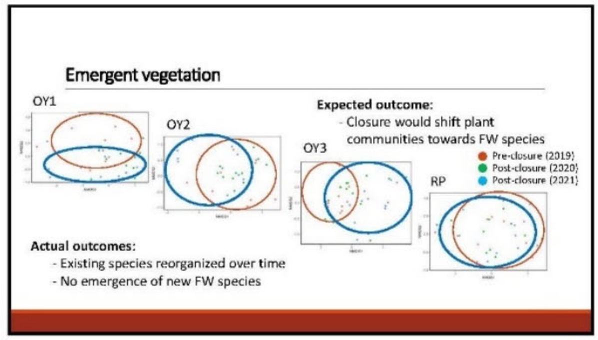


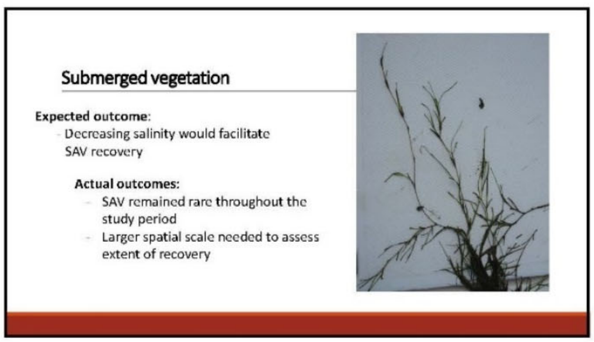


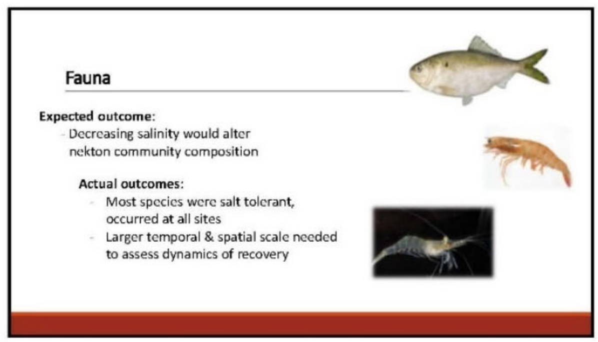




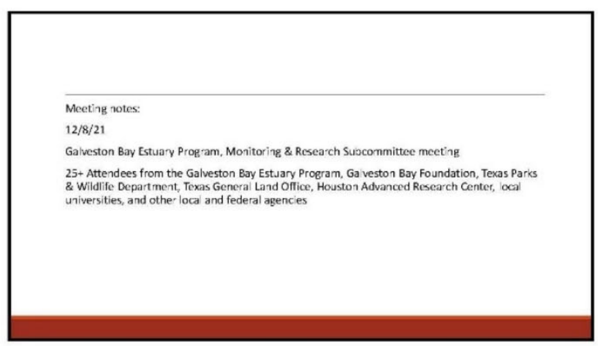

Water
Closure
OY1
OY2
OY3
RP
5 ppt
Salinity (psu)
Expected outcome:
- Closure would decrease salinity
Actual outcomes:
- No immediate effect on salinity
- Salinity was variable within sites
- Salinity gradient persisted across sites


Emergent vegetation
OY1
OY2
OY3
RP
Expected outcome:
- Closure would shift plant communities towards FW species
Pre-closure (2019)
Post-closure (2020)
Post-closure (2021)
Actual outcomes:
- Existing species reorganized over time
- No emergence of new FW species


Submerged vegetation
Expected outcome:
- Decreasing salinity would facilitate SAV recovery
Actual outcomes:
- SAV remained rare throughout the study period
- Larger spatial scale needed to assess extent of recovery

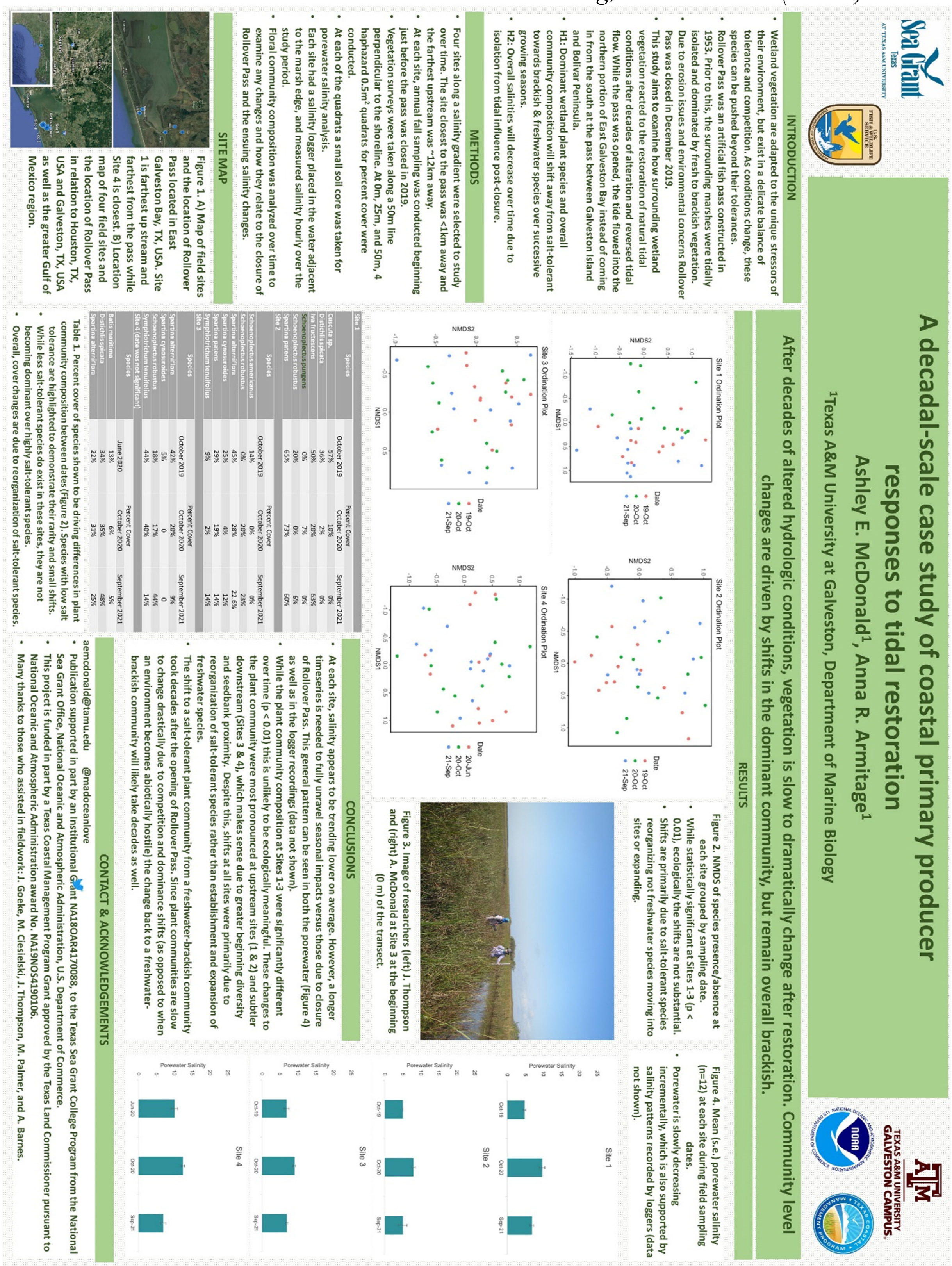

Fauna
Expected outcome:
- Decreasing salinity would alter nekton community composition
Actual outcomes:
- Most species were salt tolerant, occurred at all sites
- Larger temporal & spatial scale needed to assess dynamics of recovery

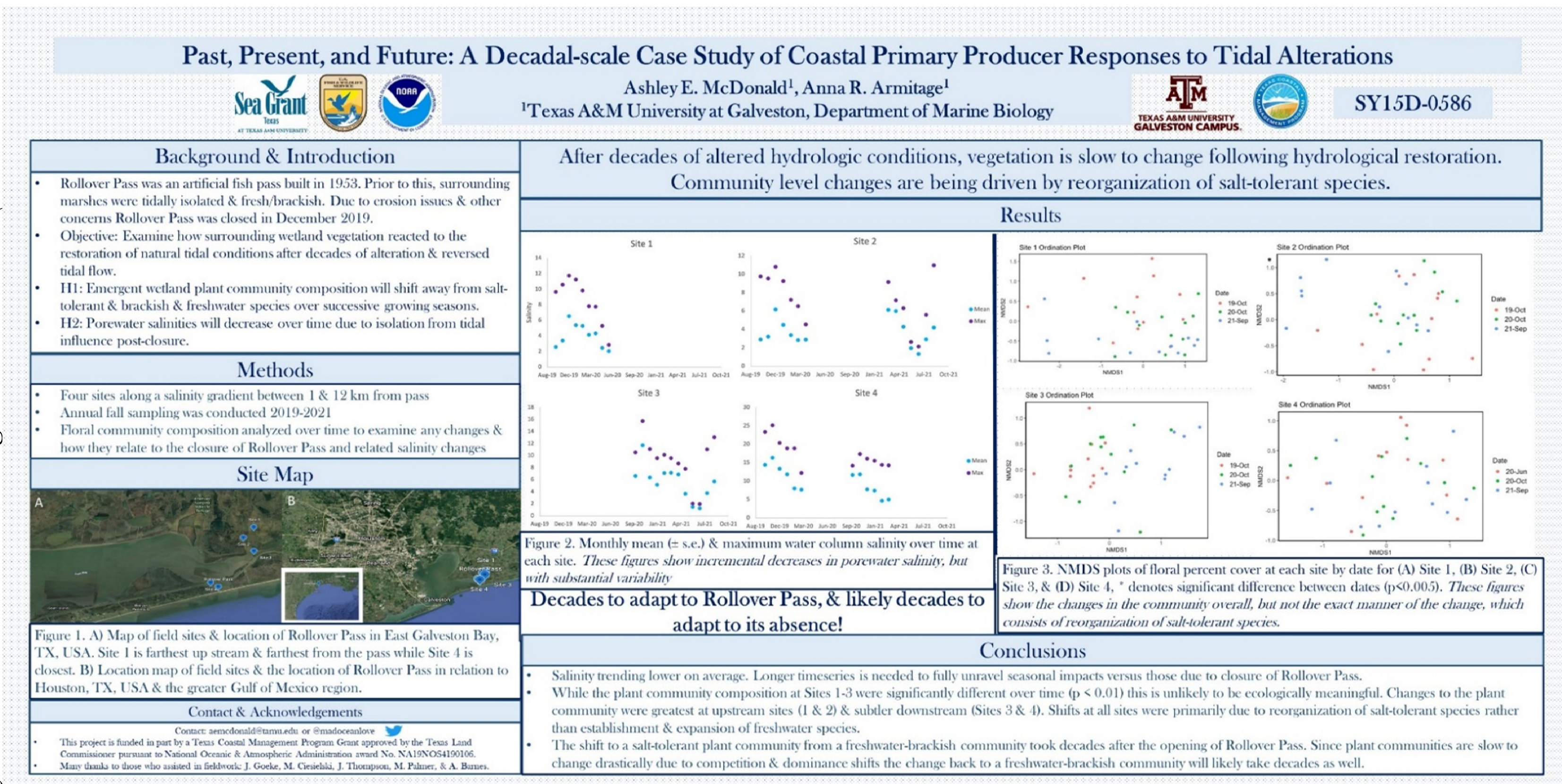

Take-home and next steps
Salinity changes gradual, variable over time
Plant communities are reorganizing, but may not be a direct salinity response
Fauna are salt tolerant
→ Long time scale of change
Stay tuned through 2022!


Meeting notes:
12/8/21
Galveston Bay Estuary Program, Monitoring & Research Subcommittee meeting
25+ Attendees from the Galveston Bay Estuary Program, Galveston Bay Foundation, Texas Parks & Wildlife Department, Texas General Land Office, Houston Advanced Research Center, local universities, and other local and federal agencies

Conference presentations

Coastal and Estuarine Research Federation Biennial Meeting, November 2021(virtual)




Past, Present, and Future: A Decadal-scale Case Study of Coastal Primary Producer Responses to Tidal Alterations
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1Texas A&M University at Galveston, Department of Marine Biology
SY15D-0586
Sea Grant Texas
TEXAS A&M UNIVERSITY GALVESTON CAMPUS.
Background & Introduction
• Rollover Pass was an artificial fish pass built in 1953. Prior to this, surrounding marshes were tidally isolated & fresh/brackish. Due to erosion issues & other concerns Rollover Pass was closed in December 2019.
• Objective: Examine how surrounding wetland vegetation reacted to the restoration of natural tidal conditions after decades of alteration & reversed tidal flow.
• H1: Emergent wetland plant community composition will shift away from salt-tolerant & brackish & freshwater species over successive growing seasons.
• H2: Porewater salinities will decrease over time due to isolation from tidal influence post-closure.
Methods
• Four sites along a salinity gradient between 1 & 12 km from pass
• Annual fall sampling was conducted 2019-2021
• Floral community composition analyzed over time to examine any changes & how they relate to the closure of Rollover Pass and related salinity changes
Site Map
Figure 1. A) Map of field sites & location of Rollover Pass in East Galveston Bay, TX, USA. Site 1 is farthest up stream & farthest from the pass while Site 4 is closest. B) Location map of field sites & the location of Rollover Pass in relation to Houston, TX, USA & the greater Gulf of Mexico region.
Contact & Acknowledgements
Contact: aemcdonald@tamu.edu or @madoceanlove
• This project is funded in part by a Texas Coastal Management Program Grant approved by the Texas Land Commissioner pursuant to National Oceanic & Atmospheric Administration award No. NA19NOS4190106.
• Many thanks to those who assisted in fieldwork: J. Goeke, M. Ciesielski, J. Thompson, M. Palmer, & A. Barnes.
After decades of altered hydrologic conditions, vegetation is slow to change following hydrological restoration. Community level changes are being driven by reorganization of salt-tolerant species.
Results
Site 1
Site 2
Site 3
Site 4
Salinity
Mean
Max
Figure 2. Monthly mean (± s.e.) & maximum water column salinity over time at each site. These figures show incremental decreases in porewater salinity, but with substantial variability
Decades to adapt to Rollover Pass, & likely decades to adapt to its absence!
Site 1 Ordination Plot
Site 2 Ordination Plot
Site 3 Ordination Plot
Site 4 Ordination Plot
NMDS1
NMDS2
Date
19-Oct
20-Oct
21-Sep
20-Jun
Figure 3. NMDS plots of floral percent cover at each site by date for (A) Site 1, (B) Site 2, (C) Site 3, & (D) Site 4. * denotes significant difference between dates (p<0.005). These figures show the changes in the community overall, but not the exact manner of the change, which consists of reorganization of salt-tolerant species.
Conclusions
• Salinity trending lower on average. Longer timeseries is needed to fully unravel seasonal impacts versus those due to closure of Rollover Pass.
• While the plant community composition at Sites 1-3 were significantly different over time (p < 0.01) this is unlikely to be ecologically meaningful. Changes to the plant community were greatest at upstream sites (1 & 2) & subtler downstream (Sites 3 & 4). Shifts at all sites were primarily due to reorganization of salt-tolerant species rather than establishment & expansion of freshwater species.
• The shift to a salt-tolerant plant community from a freshwater-brackish community took decades after the opening of Rollover Pass. Since plant communities are slow to change drastically due to competition & dominance shifts the change back to a freshwater-brackish community will likely take decades as well.