Evaluating the trophic value of beneficial uses restoration sites for coastal birds
22-045-004-D101

Final Report
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Prepared By:

Anna R. Armitage, Ph.D.; Project Manager
Department of Marine Biology
Texas A&M University at Galveston
PO Box 1675
Galveston, TX 77553
armitage@tamu.edu
409-740-4842

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Project Background

Coastal wetland restoration projects often employ beneficial uses of dredge material techniques to bring large, degraded areas to an elevation appropriate for emergent marsh vegetation. Frequently, plant coverage increases quickly in these areas through seed dispersal and vegetative spread, but this outcome is not always directly related to boosting the ecological and economic functions of the degraded area. Birds select habitat primarily based on food availability, so the value of these restored areas as bird habitat is closely linked to the abundance of nekton, infauna, and benthic fauna (invertebrates living on and in the sediment or shallow waters nearby). Previous work on beneficial-uses restoration sites in the Texas Upper Coast suggest that the recovery of essential ecosystem features may not always be an outcome of beneficial uses restoration projects.

Texas A&M University at Galveston (TAMUG) used CMP Cycle 26 funds to assess the value of the beneficial-uses restoration sites in the Salt Bayou ecosystem for migratory and resident waterfowl and shorebirds, using invertebrate assemblages as a proxy for habitat quality. will revisited restored sites that were previously sampled in 2013, along with more recently restored areas, and sampled the nekton, infauna, and invertebrate abundances. This dataset will help inform future restoration practices by identifying the features of sites that best support waterfowl and shorebirds.

The project will benefit Texas Parks and Wildlife Department (TPWD) and the J.D. Murphree Wildlife Management Area because these organizations lead the development of restoration plans for the Salt Bayou area and have a clear need for data on the ecological functions of restored wetlands. TPWD and partner agencies will benefit from a rigorous understanding of how beneficial uses restoration projects could have long-term benefits for associated wildlife populations and can use this information to inform management decisions regarding habitat restoration and outdoor recreation opportunities.

Task 1 Summary: Data Collection

Deliverables	Due Date	Date submitted/completed
1. TAMU animal use permit	12/1/21	Completed 12/1/21
2. Map of project sites	6/30/22	Completed 6/30/22
3. Notification of first sampling	6/30/22	Completed 6/30/22
4. Notification of second sampling	12/31/22	Completed 10/31/22

Major accomplishments and findings

1. PI Armitage was issued a TAMU Animal Use Permit (IACUC 2021-0119) for work on this project in May 2021.
2. A map of the four project survey sites is included in Appendix A.
3. The first sampling was conducted in May 2022 and notification was submitted with the corresponding quarterly report.
4. The second sampling was completed in October 2022; notification was submitted with the corresponding quarterly report.

Problems or obstacles

None.

Task 2 Summary: Data Analysis

Deliverables	Due Date	Date submitted/completed
1. Historic data from 2013 sampling	6/30/24	Completed 6/30/24 (See Appendix A)
2. Compiled bird use data	6/30/24	Completed 6/30/24 (See Appendix A)
3. Report discussing analyses	6/30/24	Completed 6/30/24 (See Appendix A)

Major accomplishments and findings

1. Appendix A includes a description of the historic infauna data from previous sampling.
2. Appendix A describes available compiled bird use data.
3. The narrative in Appendix A describes the key findings and data analyses.

Problems or obstacles

The previous project was conducted from 2013-2015, but no infauna cores were collected in 2013 due to a lack of qualified personnel for processing. Thus, all available infauna data are from 2014; these data are presented in the Data Analysis Report (Appendix A).

Field sampling was completed on schedule, but sample processing took longer than expected due to turnover in personnel and delays in hiring a technician to assist with the lab work. Infaunal processing is delicate and time-consuming work if done completely and accurately, and generating quality output took more time than anticipated. in addition, due to a large number of unknown organisms in the initial sorting counts, we decided that it was necessary to recount all samples using additional taxonomic guidance to increase the precision of the infaunal data. The recounts were completed in May 2023; this delayed the initiation of data analysis. Tasks 2.1 and 2.2 ultimately took longer than expected due to these obstacles, and so a no-cost extension through June 2024 was requested and approved.

Task 3 Summary: Data dissemination, Education, and Outreach

Deliverables	Due Date	Date submitted/completed
1. Notification of TAMU website launch	12/31/21	Completed 12/31/21
2. Graduate and undergraduate students recruited	8/31/22	Completed 9/30/22
3. Copies of presentations	6/30/24	Completed 2/28/24
4. Notification of website update	6/30/24	Completed 6/30/24
5. Notes from Salt Bayou workgroup meeting	3/31/23	Completed 6/8/22

Major accomplishments and findings

1. In December 2021, the PI Armitage's institutional website was updated with a summary of project goals and an acknowledgement of the funding source: https://www.tamug.edu/armitage/Current_Projects.html. The final report will be publicly available on a GLO server.
2. Three graduate students assisted as volunteers with the May 2022 sampling. A new research technician position was posted in June 2022 to replace a technician who left the university on 5/31/22. A new technician was hired in August 2022. Five undergraduate student volunteers were recruited to assist with lab work. Two student workers were hired to complete sorting and identification of infaunal samples.
3. Findings from this project were presented at a conference at the Estuarine & Coastal Sciences Association meeting in Spain, September 2022 (no foreign travel was charged to the grant). In addition, a presentation (lightning talk) on this project was given at the Coastal and Estuarine Research Federation Biennial meeting in Portland, OR in November 2023. In 2024, two opportunities arose to combine results from this project with another related project in a presentation at regional and national conferences. Copies of all presentations were submitted with the corresponding quarterly reports, and presentation details are below.

    Armitage, A.R. September 2022. Links between restoration design and ecosystem service provision in coastal wetlands. Estuarine and Coastal Sciences Association 59, Kursaal, San Sebastian, Spain.

    Armitage, A.R., *A. Gaona Hernandez, L. Jurgens. November 2023. Evaluating the trophic value of beneficial uses restoration sites for coastal birds. Coastal and Estuarine Research Federation Biennial Meeting, Portland, OR.

Armitage, A.R., *A. Gaona Hernandez, L. Jurgens, J. O'Connell. February 2024. Evaluating the long-term trophic value of tidal wetland restoration sites for coastal birds. Gulf of Mexico Conference (GOMCON). Tampa Bay, FL.

Armitage, A.R., *A. Gaona Hernandez, L. Jurgens, J. O'Connell. April 2024. Evaluating the long-term potential trophic value of tidal wetland restoration sites for coastal birds. 52nd Annual Benthic Ecology Meeting. Charleston, SC.

4. PI Armitage's institutional website was updated with a brief summary of project findings and an acknowledgement of the funding source: https://www.tamug.edu/armitage/Current_Projects.html. The final report will be publicly available on a GLO server.
5. A Salt Bayou/Chenier Plain workgroup meeting was held June 8, 2022. Attendees included 12 online + 15 in person representatives from Texas Parks & Wildlife Department, US Fish & Wildlife Service, Ducks Unlimited, and local universities, among others. A CMP project update was provided as part of a discussion about future restoration research priorities. Presentation slides and notes were submitted with the corresponding quarterly report.

Problems or obstacles

None.

Task 4 Summary: Project monitoring and reporting

Deliverables	Due Date	Date submitted/completed
1. Quarterly progress reports and requests for reimbursement	Quarterly	Quarterly
2. Draft final report	6/15/24	6/15/24
3. Final report	6/30/24	6/30/24
4. Project closeout form	6/30/24	6/30/24

Major accomplishments and findings

1. All quarterly progress reports have been submitted.
2. The draft final report was submitted to the project manager prior to 6/15/24.
3. The revised final report was submitted to the project manager by 6/30/24.
4. The project closeout form was submitted to the project manager by 6/30/24.

Problems or obstacles

A no-cost extension was granted to extend the project end date to 6/30/24 (See Task 2 for explanation). All tasks were completed by that end date. On occasion, turnover in support personnel delayed the submission of accurate reimbursement requests.

Appendix A: Data Analysis Report (Task 2)

Historic infauna data

As part of a previous project from 2013-2015, infauna cores were collected in planted and unplanted areas of beneficial use marshes in April and June 2014. No cores were collected in 2013 due to a lack of qualified personnel for processing, thus all available data are from 2014. Six replicate cores of a 10 cm diameter were taken to a depth of 15 cm. Samples were sieved through a 500 µm mesh, fixed and stained with a formalin-rose bengal solution, and preserved with 70% ethanol. Infauna were identified to the lowest practical taxonomic group.

Infaunal density was 68 times higher in unplanted beneficial uses areas than in planted areas (Figure 1). These unplanted areas corresponded with the areas where game cameras captured birds foraging (see next section). Snails (Class Gastropoda) were the most common type of fauna found, followed by bivalves (Class Pelecypoda) and worms (Class Oligochaeta) (Figure 2).

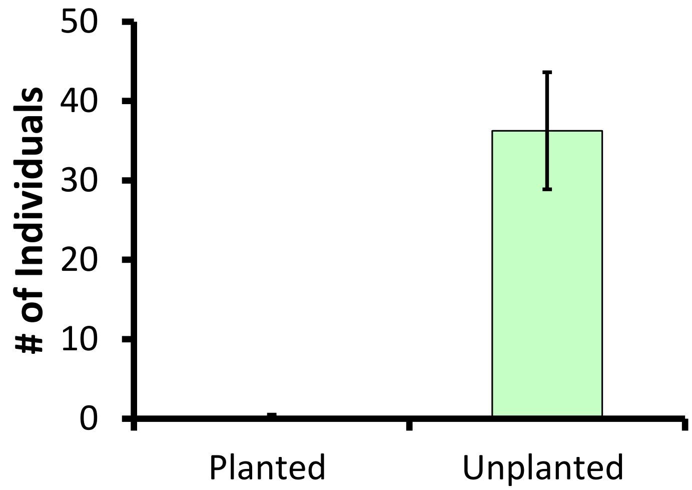


Figure 1. Total number of infauna per core in planted and unplanted beneficial uses restored areas, pooled across sampling dates.

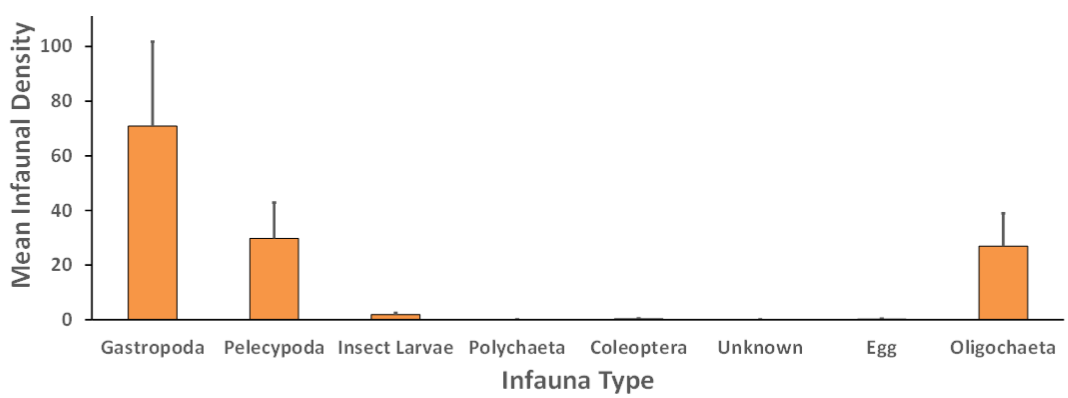


Figure 2. Average densities of infaunal groups across all beneficial uses restored sites in spring 2014. Error bars represent standard error.

Compiled bird use data

Historic bird use data is primarily from an earlier study that deployed time-lapse wildlife cameras were deployed at sites representing four different restoration states during the overwintering and spring and fall migration periods in 2013 and 2014. The restoration states included Beneficial uses – planted (BP; see Figure 5), Beneficial uses – unplanted (BUO), and Reference (REF) sites. In addition, this study included a type of restored site comprised of long narrow terraces; these sites were not resampled in the current study but are included in this compilation of bird use data.

Birds were most frequently observed in unplanted areas (Figure 3). In addition, species richness and frequency of occurrence were substantially higher in unplanted areas (Figure 4). Shorebirds and waterfowl preferred the less vegetated restored marshes, relative to the heavily vegetated reference marsh. There were different species of waterfowl, wading birds, and shorebirds utilizing each restored marsh type. For instance, *Eudocimus albus* (white ibis) and *Limnodromus* sp. (dowitcher) were more commonly seen along the edges of the terraces, whereas *Himantopus mexicanus* (black-necked stilts) were common in unplanted BU sites. *Anas discors* (blue-winged teal) were common in areas with deeper water habitat. Common birds in restored areas included species of ibis, herons, egrets, and ducks.

American Coots (*Fulica americana*) and Snowy Egrets (*Egretta thula*) comprised the majority of the total number of birds observed in the planted marshes. In the unplanted marshes, more Sandpipers (Scolopacidae), Dowitchers (*Limnodromus* spp.), American Avocets (*Recurvirostra americana*), and Black-necked Stilts (*Himantopus mexicanus*) were observed.

Restoration techniques did appear to influence initial bird utilization of recently restored brackish marsh. These data suggest that coastal wetland restoration designs should incorporate mudflat habitats such as those in the unplanted beneficial use marsh in order to revitalize migratory flyways for waterfowl, colonial waterbirds, and shorebirds. Higher species richness and frequency of birds observed occurred in unplanted and wet marshes. Higher abundance of infauna was also found in marshes where large flocks of birds were observed foraging. Our study seeks to further investigate the value of restored marshes as foraging grounds and whether bird presence could serve as a bioindicator for prey abundance.

Additional data sources

Based on stakeholder conversations and a literature search, we found a number of studies that documented bird use within the J.D. Murphee Wildlife Management Area (Table 1). Several studies addressed rail (Family Rallidae) use of the focal area, though only one investigated rail use of restored BU sites. That study (2016-2021) quantified rail abundance in restored and unrestored areas (M. Rezsutek, pers. comm 2021). Rail abundance varied among years but was typically as high or higher in restored areas relative to reference sites. The links to vegetation characteristics and tidal inundation were not assessed in this study but were identified as a future research need.

A M.S. thesis (Boothby 2017) characterized bird assemblages in restored and reference areas within the study area using monthly point-count surveys in 2015-2016. Of the 68 species recorded during the study, 27 were unique to the restored BU sites and six were detected only in the natural sites, suggesting that the BU sites increased bird abundance and diversity within the ecosystem. This analysis also suggested that BU sites with higher habitat heterogeneity (based on vegetation characteristics) tended to have higher bird diversity.

Several studies conducted in the study area examined bird habitat use at sites that were not restored with sediment placement but were hydrologically managed (Rodriguez 2011; Pickens 2012; Pickens and King 2013; Pickens and King 2014b; Pickens and King 2014a). These studies generally indicated that water depth and drawdown patterns strongly influenced bird abundance. However, the nature of that relationship varied among species, with some groups (e.g., gallinules) preferring wetter conditions and others (e.g., rails and bitterns) selecting drier sites with intermediate vegetation cover. Water presence, vegetation cover, and habitat heterogeneity were highlighted as especially relevant predictors of bird use, though the patterns were species-specific and varied seasonally and between intermediate salinity and freshwater sites (Pickens 2012; Pickens and King 2013; Pickens and King 2014a). Notably, these analyses primarily focused on rails and gallinules, and did not directly consider shorebirds (but see Pickens and King (2014b) for some discussion of Yellowlegs [*Tringa* spp.]). The study area has also been identified as important habitat for Mottled Ducks (*Anas fulvigula*) (Stutzenbaker 1988; McClinton et al. 2019), a species of conservation concern.

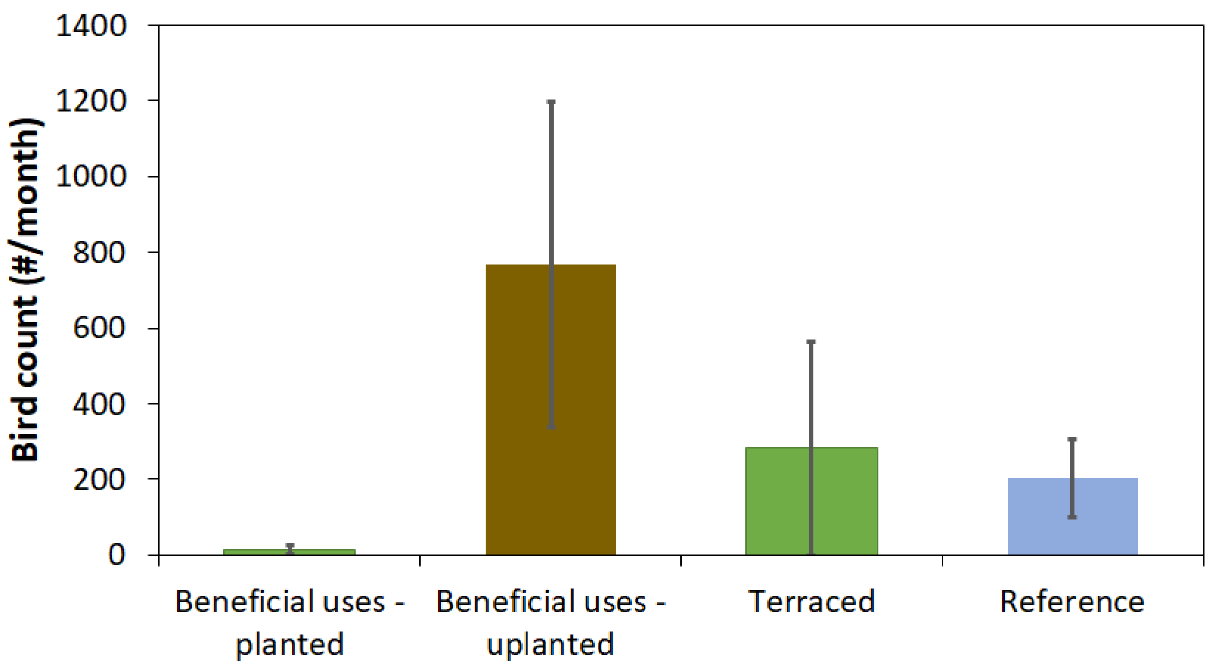


Figure 3. Average bird counts per site type in restored and reference sites in spring 2014. Error bars represent standard error.

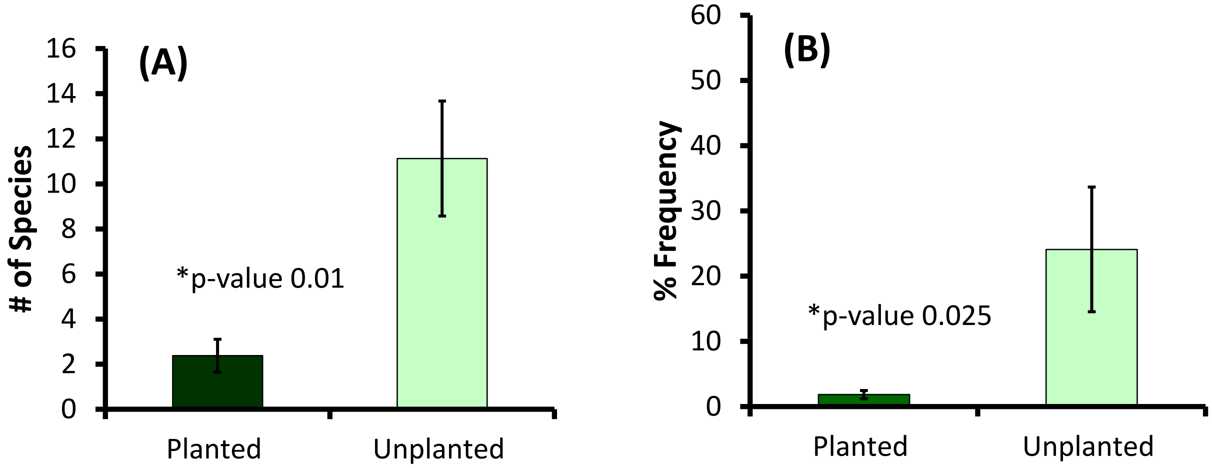


Figure 4. Bird species richness (a) and frequency of occurrence (b) in planted and unplanted beneficial uses sites, pooled across observations in 2013 and 2014.

Table 1. Summary of datasets or publications available for the Salt Bayou Unit study area. *A* indicates abundance data, *H* indicates habitat use data, and *F* indicates data on food availability.

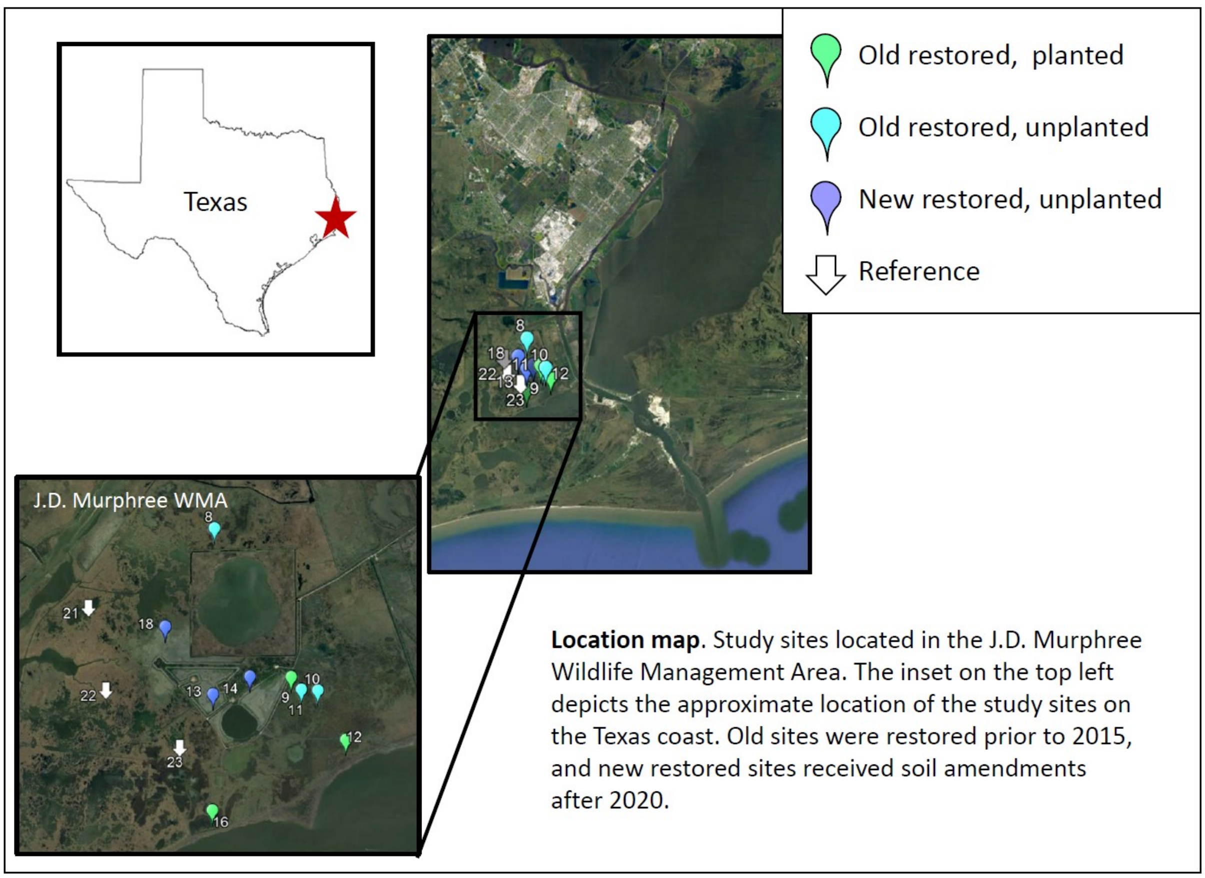
Shorebirds	Waders	Waterfowl	Rails	Other	Reference
AH	AH	AH	AH	AH	Boothby 2017
		A			McClinton et al. 2019
			AH	AH	Pickens 2012
			AH		Pickens and King 2013
			AH		Pickens and King 2014a
AH	AH		AH		Pickens and King 2014b
			A		Rezsutek, TPWD, unpub. data
AH	AH	AH	AH		Rodriguez 2011
		AHF			Stutzenbaker 1988
AHF	AHF	AHF			Armitage in prep; Norris 2014

Sampling approach

<u>Study sites</u>

Twelve study sites were identified, with three sites in each of four different restoration states: BUN: Beneficial uses new (created in 2021); BUO: Beneficial uses old (created in 2013)/unplanted; BP: Beneficial uses old/planted; REF: Reference (Figure 5, Figure 6). Each site was stratified by habitat type as defined by elevation: vegetated, edge, mudflat, water. Not all habitat types were present at all sites. Site characteristics are described in Table *2*. All twelve sites were sampled in May 2022.

In October, the field protocol was modified in order to more precisely assess food availability in places where birds are likely to forage. Specifically, nine sites were selected (three reference, three old restored sites with areas of nonvegetated habitat, three newly restored sites) to sample infauna. Samples were collected from up to three habitat types where birds are typically observed foraging: marsh edge, mudflat, and pond.



Location map. Study sites located in the J.D. Murphree Wildlife Management Area. The inset on the top left depicts the approximate location of the study sites on the Texas coast. Old sites were restored prior to 2015, and new restored sites received soil amendments after 2020.

Figure 5. Location map of study sites located in the J.D. Murphree Wildlife Management Area. The inset on the top left depicts the approximate location of the study sites on the Upper Texas Coast.

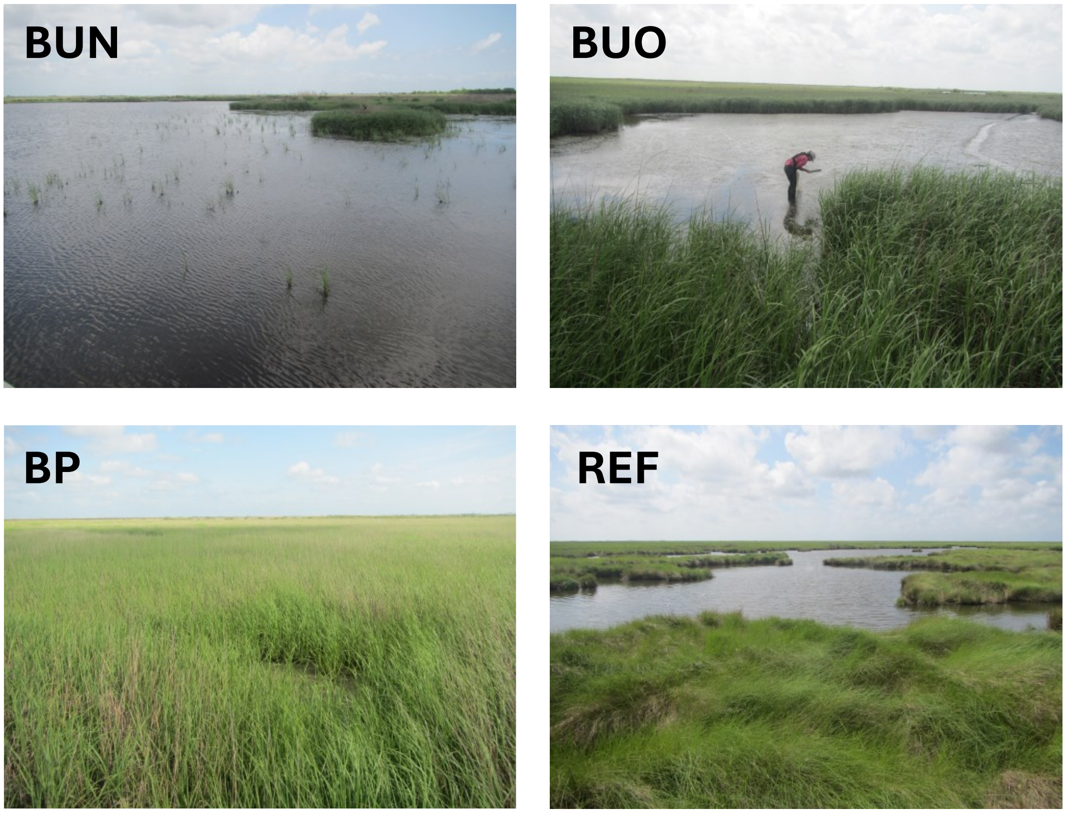


Figure 6. Representative images of sites in each restoration state: BUN: Newly restored beneficial uses site, unplanted; BUO: Older beneficial uses site, unplanted; BP: Older beneficial uses site, planted; REF: reference site

Table 2. Characteristics of each site.

Site ID	Restoration state[1]	Vegetation (% cover)	Mudflat (% cover)	Pond/subtidal (% cover)	Dates sampled
18	BUN	10	0	90	May, Oct
13	BUN	35	40	25	May, Oct
14	BUN	20	60	20	May, Oct
11	BUO	30	30	40	May, Oct
10	BUO	70	0	30	May, Oct
8	BUO	100	0	0	May
9	BP	50	25	25	May, Oct
12	BP	100	0	0	May
16	BP	97	0	3	May
23	REF	65	0	35	May, Oct
22	REF	60	0	40	May, Oct
21	REF	50	0	50	May, Oct

[1]BUN: Newly restored beneficial uses site, unplanted; BUO: Older beneficial uses site, unplanted; BP: Older beneficial uses site, planted; REF: reference site

Nekton

In areas where subtidal habitat was present and accessible, nekton were sampled with three replicate cast net (1-m diameter, 1-cm mesh) tosses from the vegetation edge (Figure 7). Fauna were identified in the field to the lowest practical taxonomic level and released. Nekton were sampled only in May 2022. Due to low abundances, nekton data are reported but were not statistically analyzed.

Figure 7. Cast net toss into a subtidal pond within a reference site.

Infauna

Replicate infauna cores were collected from each site in May and October 2022 (five per site; Figure 8). Cores were 2.5 cm diameter and 5 cm deep and were stored on ice for transport to the lab. Within 72 hours of collection, cores were rinsed through a 500 μm sieve and fixed and stained in a 10% Formalin/Rose Bengal solution. Infauna were identified by trained observers under a dissecting scope and stored in 70% ethanol.

To analyze the differences in infaunal communities among habitat types and restoration states, total infaunal abundance (per core) was analyzed with two-way Analyses of Similarity (ANOSIM) based on Bray-Curtis similarity matrices for each sampling period. The factors were habitat type (vegetated, edge, mud, pond) and restoration state (Beneficial uses old/planted; Beneficial uses old/unplanted; Beneficial uses new/unplanted, Reference). ANOSIM generates an R-statistic that is essentially an indicator of effect size; where values < 0.25 indicate substantial overlap among groups, values $0.25 \leq 0.75$ indicate that groups are somewhat distinct from each other, and values > 0.75 indicate distinct separation between groups. Nonmetric multidimensional scaling (MDS) ordination was used to represent average dissimilarities among habitat types and restoration states in Euclidean two-dimensional space.

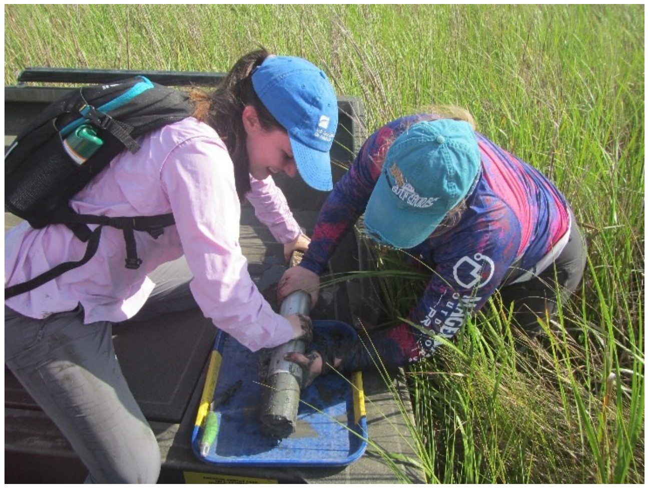


Figure 8. Extraction of a core for infaunal sampling.

Results

<u>Nekton</u>

Nekton abundance was low at all sites and was not clearly linked to restoration state. Four species of fish were identified (Table 3); unknown fish were juveniles that could not be identified in the field. Two families of shrimp were detected (Table 4).

Table 3. Fish collected from each site in May 2022, pooled over three cast net tosses. ND indicates no nekton sampling was conducted due to the lack of accessible subtidal habitat.

Site ID	Restoration state	Total fish	*Lagodon rhomboides*	*Fundulus* sp.	*Poecilia latipinna*	*Cyprinodon variegatus*	Unknown fish
18	BUN	1		1			
13	BUN	2		2			
14	BUN	0					
11	BUO	1			1		
10	BUO	4		1			3
8	BUO	ND					
9	BP	1				1	
12	BP	ND					
16	BP	ND					
23	REF	1				1	
22	REF	0					
21	REF	1	1				

Table 4. Invertebrates collected from each site in May 2022, pooled over three cast net tosses. ND indicates no nekton sampling was conducted due to the lack of accessible subtidal habitat.

Site ID	Restoration state	Total shrimp	*Palaemonetes* sp.	Penaeids
18	BUN	0		
13	BUN	0		
14	BUN	0		
11	BUO	0		
10	BUO	1	1	
8	BUO	ND		
9	BP	3		3
12	BP	ND		
16	BP	ND		
23	REF	0		
22	REF	0		
21	REF	0		

Infauna

Across all sampling sites and dates, the most common groups of infauna included annelid worms, ostracods, foraminiferans, insect larvae, and gastropods (snails). Infauna abundance was highly variable over space and time (Figure 9). The highest infaunal abundances tended to occur in older or reference sites (e.g., veg REF in May; water BUO in October). In May, ANOSIM indicated a high degree of overlap in infaunal community composition among habitat types and across restoration states (Habitat type R = 0.273; Restoration state R = 0.256; Figure 10). A similar outcome occurred in October (Habitat type R = 0.220; Restoration state R = 0.207; Figure 11). Mudflats were excluded from the October ANOSIM model due to very low abundance.

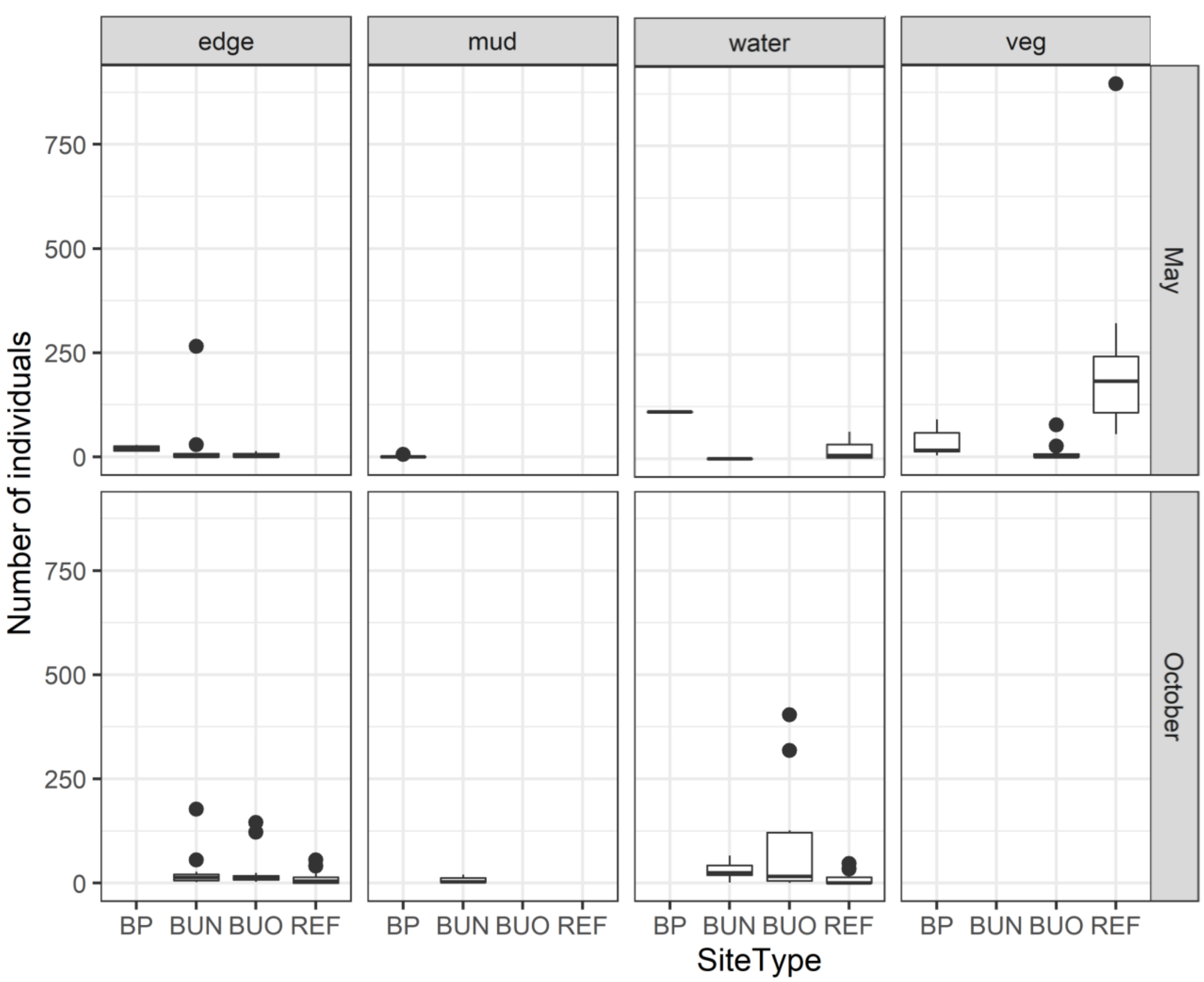


Figure 9. Total infauna abundance per core in different habitat types in May and October 2022. No vegetated habitats or BP sites were sampled in October. BP: Beneficial uses sites created and planted prior to 2015; BUN: Beneficial uses sites created after 2020; BUO: Beneficial uses sites created prior to 2015 but not planted; REF: reference sites.

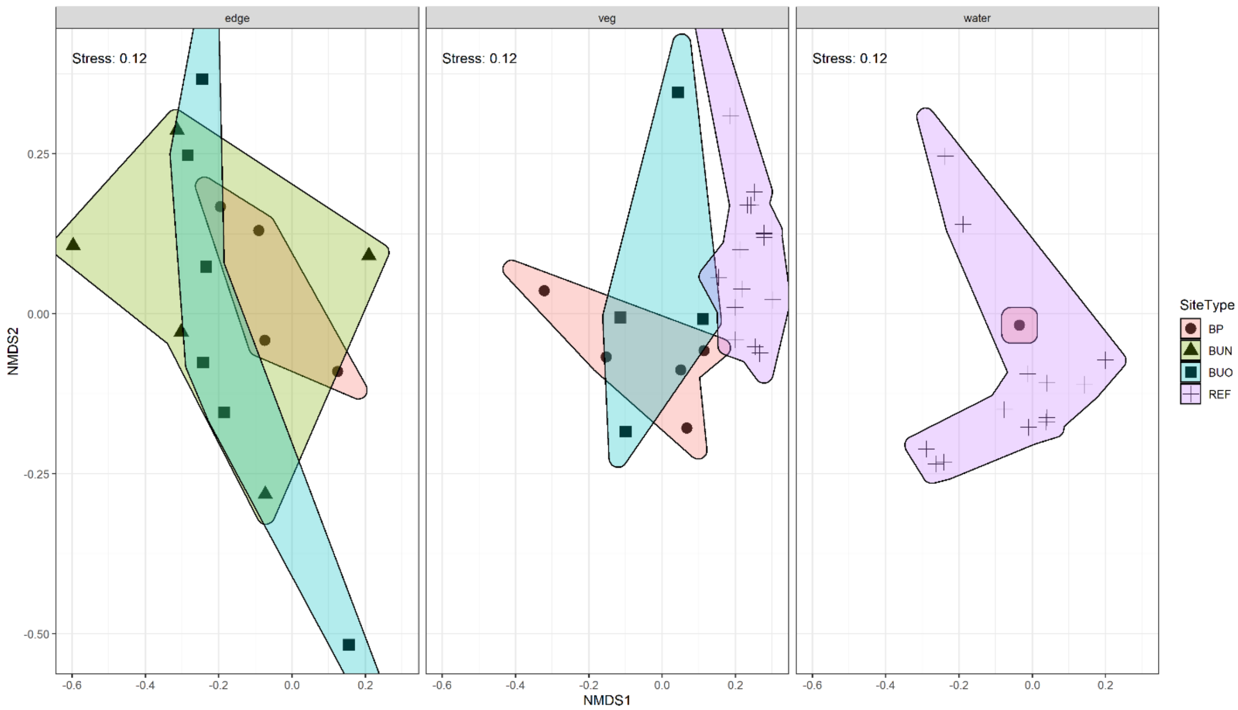


Figure 10. Nonmetric multidimensional scaling ordination plot of infaunal community composition across three habitat types and four restoration states (see Figure 9) in May 2022.

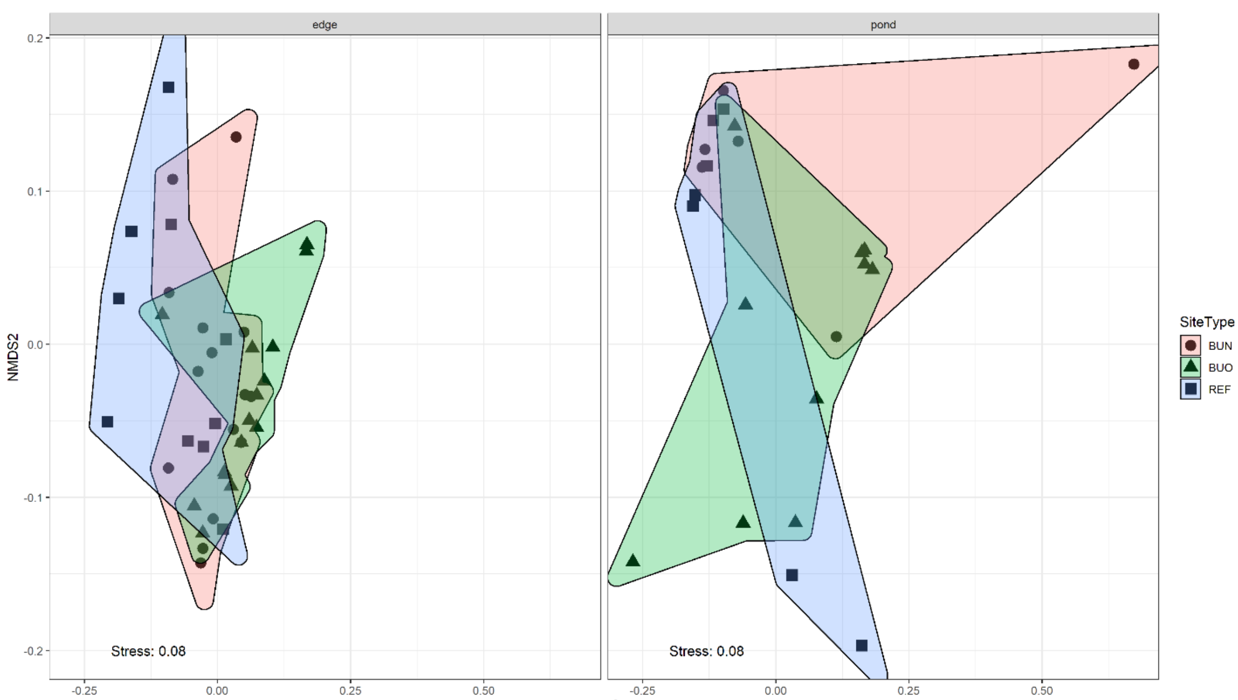


Figure 11. Nonmetric multidimensional scaling ordination plot of infaunal community composition across two habitat types and three restoration states (see Figure 9) in October 2022.

Summary and Conclusions

In restoration theory, the “Field of Dreams” hypothesis posits that if certain biotic or abiotic features of a site are established, then the targeted faunal communities and processes will eventually develop on their own (Palmer et al. 1997). Coastal wetland restoration typically focuses on the reestablishment of tidal flow, adding or removing sediment to a specific elevation, and planting fast-growing emergent marsh elevation (McDonald et al. 2016). After a nominal monitoring period to ensure vegetation survival, wetland restoration sites are typically assumed to continued developing over time, eventually supporting a wide range of ecosystem functions (Matthews and Endress 2008). However, this assumption is rarely tested. In this study, we examined restored sites that were ten years old by using infauna and nekton as proxies to assess if these sites could provide trophic support for wetland-dependent birds.

In general, the highest abundances of infauna tended to be found in older sites or reference areas, though infaunal abundance was highly variable over space and time. In addition, infaunal community composition was similar across all restoration and reference areas. These similarities in terms of relative infauna abundance and assemblage composition suggest some success of the Field of Dreams hypothesis in this area. The conclusions supported by the nekton data were somewhat more equivocal, largely due to low nekton abundances at all sites. This outcome may have been an artifact of the cast net sampling technique, and does not necessarily indicate restoration success or failure.

During our sampling excursions, the research team often observed birds foraging in the area, primarily in nonvegetated mudflat or subtidal habitats. Yet, these nonvegetated areas were most common in newer restored sites; older sites tended to be heavily vegetated. Sites with dense vegetation did have infauna present, but it is not clear if those fauna were accessible and consumed by birds. Thus, upcoming studies will quantitatively evaluate bird use of vegetated and nonvegetated areas using a combination of visual and audio surveys in restored and reference areas. The information from this series of studies will inform future restoration projects by quantifying the value of integrating persistent mudflat and subtidal features into future restoration site designs.

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