INFAUNAL ABUNDANCE IN RESTORED AND REFERENCE MARSHES OF THE NORTHWESTERN GULF OF MEXICO: THE IMPACT OF HABITAT TYPE AND DROUGHT

A Senior Scholars Thesis

by

BRITTNEY LAUREN DAVIS and THEODORE GOTZIAN DRISCOLL IV

Submitted to Honors and Undergraduate Research
Texas A&M University
in partial fulfillment of the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

May 2012

Major: Marine Biology
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Approved by:

Research Advisor: Anna Armitage
Associate Director, Honors and Undergraduate Research: Duncan MacKenzie

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ABSTRACT

Infaunal Abundance in Restored and Reference Marshes of the Northwestern Gulf of Mexico: The Impact of Habitat Type and Drought. (May 2012)

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To date, over 50% of historical tidal marsh habitat in the U.S. has been lost. A widely accepted approach to mitigate the loss of valuable ecological services is marsh restoration, which includes using excavated soil or dredge fill, arranged in either mounds or terraces, to return areas of open water to marsh elevation. Most mitigation projects focus on plant canopy structure and are considered successful within only a few years. However, many aspects of marsh ecology are important including the infaunal community which is much slower to develop. Infaunal organisms are ecosystem engineers that decompose organic matter, oxygenate the soil, and provide trophic support for primary consumers. Site morphology (e.g., elevation, marsh edge, proportion of low marsh habitat) and soil characteristics can strongly influence the infaunal community. Our objective was to determine the links between total soil organic content, marsh design, infaunal densities, and richness in a recently restored brackish marsh in east Texas. Sediment cores were collected at multiple elevations from one reference and four restored areas (*excavated, filled, pumped,* and *terrace*) that varied in shape and sediment type in October 2010, July 2011, and November 2011. No relationship between organic content and infaunal density was present among habitat types during October 2010, July 2011, or November 2011. However, in October 2010, densities were significantly different among habitat types, which suggest that infauna may be influenced by morphology. In July 2011 and November 2011, there were no differences among habitat types. Infaunal densities were highest in the *pumped* sites on all sampling dates except October 2010. In 2011, there was also a qualitative shift in community structure towards stress tolerant organisms such as Capitellids. Community changes in 2011 were likely attributable to stressful environmental conditions caused by an exceptional drought. Therefore, the influence of habitat type on the infaunal community may be most pronounced under environmentally benign conditions and reduced in more stressful conditions such as droughts.

ACKNOWLEDGMENTS

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NOMENCLATURE

LPIL	Lowest Practical Identification Level

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CHAPTER I

INTRODUCTION

Marshes are ecologically productive habitats that support a wide variety of invertebrates, fish and waterfowl, act as filters for pollution, and protect shorelines from erosion and hurricanes (Boorman 1999). Coastal development such as dredging, land reclamation, and extraction of gas, oil, and ground water, has caused over 50% of historical tidal marsh habitat in the U.S. to be lost (Kennish 2001). A widely accepted approach to mitigate the loss of valuable ecological services is marsh restoration (Race and Christie 1982). A common method of restoration includes using excavated soil or dredge fill, arranged in either mounds or terraces, to return areas of open water to marsh elevation (Shafer and Streever 2000; Rozas and Minello 2001; Edwards and Proffitt 2003; Feagin and Wu 2006).

Mitigation projects are usually considered successful within a few years because the current focus of most assessments is on plant canopy structure, which recovers relatively quickly (Levin et al. 1996; Craft et al. 1999; Edwards and Proffitt 2003). However, the ecology of a marsh is not limited to its vegetation. Many other attributes are also important in returning ecological services, including the establishment of a benthic infaunal community. Infauna are ecosystem engineers that decompose organic matter (Sandnes et al. 2000), oxygenate the soil (Blondin and Rosenberg 2006), and add trophic

This thesis follows the style of Marine Ecology Progress Series.

support for primary consumers (Whaley and Minello 2002). Studies of infaunal succession in restored salt marshes along the Atlantic coast suggest that the infaunal community is slower to develop than the marsh plant canopy (Levin et al. 1996; Craft et al. 1999). For example, in a survey of two restored salt marshes in North Carolina, Craft et al. (1999) reported that aboveground biomass of *Spartina alterniflora* was equivalent with that of a nearby reference marsh after only three years but that infaunal communities were not comparable until ten to fifteen years after marsh establishment.

Notable differences in infaunal trophic composition and densities have also been reported for restored and reference marshes (Moy and Levin 1991; Sacco et al. 1994; Levin et al. 1996). In a restored marsh less than three years old, Moy and Levin (1991) found that the infaunal community was dominated by surface deposit feeders such as *Streblospio benedicti* and *Manayunkia aestuarina* while surrounding reference marshes were dominated by subsurface deposit feeders such as *Monopylephorus evertus*. Sacco et al. (1994) reported similar proportions of surface and subsurface feeders in restored (one to seventeen years old) and reference marshes, but densities of each trophic group and total mean densities were significantly lower in the restored marsh. Levin et al. (1996) also reported that total mean densities of infauna remained significantly lower in four year old plots compared to a reference marsh. Conversely, studies have also shown that species richness is often faster to recover and can exceed that of reference marshes within four to eight years (Levin et al. 1996; Craft and Sacco 2003).

The extent to which a restored marsh resembles a reference marsh in terms of morphology (e.g., elevation, marsh edge, proportion of low marsh habitat) and soil characteristics, strongly influences the infaunal community (Moy and Levin 1991; Sacco et al. 1994; Craft et al. 1999; Shafer and Streever 2000; Craft and Sacco 2003; Feagin and Wu 2006). Our objective was to evaluate the influence of different structural designs that incorporated excavated soil and dredge fill on the infaunal communities in a restored marsh and compare to a reference marsh. Additionally, the influence of sediment on the infaunal communities was examined by comparing infaunal densities to total soil organic content. We hypothesized that the design(s) with total organic content similar to the reference marsh would support the largest infaunal community.

CHAPTER II

METHODS

Site description

The project site was a brackish marsh located within the Lower Neches Wildlife Management Area (LNWMA) in Port Arthur, TX USA (Fig.1). As part of the Chenier Plain drainage basin, the reference marsh was historically influenced by fresh water. The construction of the Gulf Intracoastal Waterway and increased channelization during the early 1900's as well as canal maintenance events between 1980 and 2007 led to the introduction of salt water, which subsequently killed more than 600 acres of emergent vegetation.

In a case of off-site mitigation, Chevron initiated restoration in 2008. The restored marsh was created using four structural designs that incorporated a variety of shapes and sediment type(s) (Fig. 2). *Excavated mounds* were created by excavating adjacent benthic sediment. *Filled mounds* were also constructed using adjacent benthic sediment but received additional inputs of dredge material from a nearby canal. To create the *pumped mounds,* dry dredge material from an upland disposal site was pumped on top of benthic sediment. The final water depth surrounding the *excavated mounds* was greater than for the *filled* or *pumped mounds*. *Terraces* were constructed similarly to the *excavated mounds* but were built as single continuous structures (instead of a collection of mounds) around each restoration site to protect the mounds from erosion.

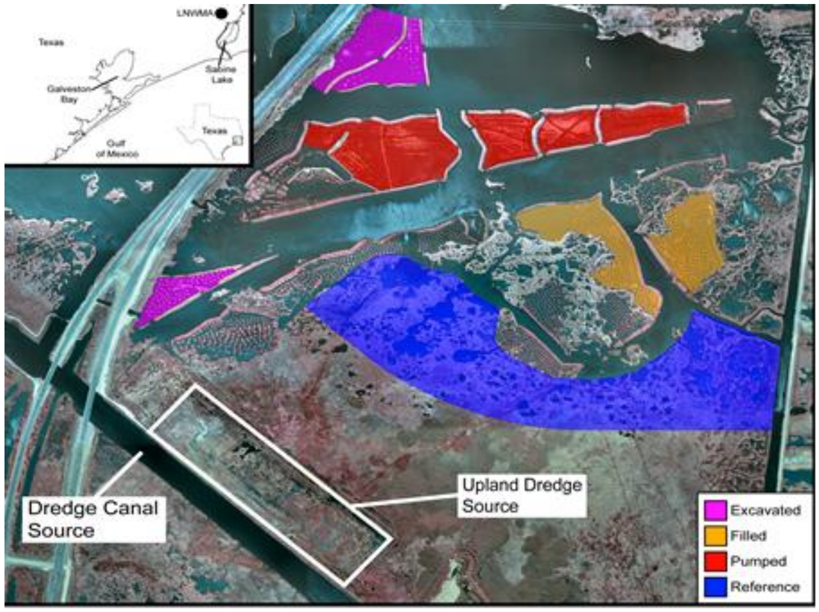

Fig.1. Field sites for the LNWMA. *Terrace*s are not highlighted but surround the *excavated*, *filled*, and *pumped* sites.

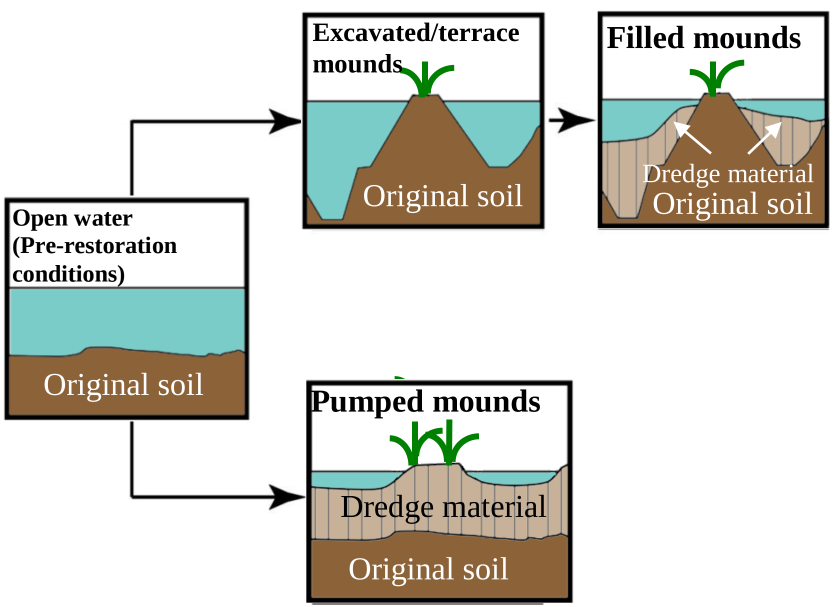

Fig.2. The structural designs (i.e. habitat types) used in the restored areas. *Terraces* were built similarly to the *excavated* mounds but are single continuous structures instead of a collection of mounds. Reference conditions were mostly emergent.

After construction, the restored marsh was planted with the Vermilion strain of *Spartina alterniflora*, which was selected because of its salt tolerance and rapid growth rate. Remnant natural marsh to the south was used as the reference marsh. The four structural designs and one reference area represent a total of five treatments which we refer to as "habitat types".

Infaunal collection

Infaunal were collected in October 2010, July 2011, and November 2011. Sampling effort and collection protocol varied slightly during each sampling period as the methods were refined. In October 2010, a single sediment core (7 cm deep x 4 cm wide) was taken at the marsh edge from 10 randomly selected mounds for each habitat type in the restored area and from 12 randomly selected mounds in the reference area. In 2011, multiple elevations were sampled in order to capture the heterogeneity of the infaunal community, and all data was pooled within each sampling station. In July 2011 sediment cores (5 cm deep x 2.5 cm wide) were taken from the marsh edge, *Spartina alterniflora* vegetated zone (+1m from the marsh edge), and the un-vegetated mudflat zone (-1m from the marsh edge) from 10 randomly selected mounds for each habitat type in the restored area and from 12 randomly selected mounds in the reference area. In November 2011, sediment cores (5 cm deep x 2.5 cm wide) were taken at the marsh edge and the un-vegetated mudflat zone from 5 randomly selected mounds for all the habitat types. All cores were transported to the laboratory in plastic bags on ice and fixed with a 10%

formalin-rose bengal solution. In 2010, the cores were rinsed through a 500 micrometer sieve and in 2011 the cores were rinsed through a 250 micrometer sieve using tap water. Infauna were collected from the material remaining on the sieve and preserved in 70% EtOH. The preserved organisms were counted and identified to the lowest practical identification level (LPIL), which was most frequently to family. To estimate infaunal diversity, we defined “richness” as the number of distinct LPIL taxonomic groups (family or other group) that we could positively identify.

Soil analysis

Additional sediment cores of equal dimension were taken concurrently with the infaunal cores for analysis of total organic content. The sediment was dried to constant mass at 70°C and then weighed before and after loss on ignition at 500°C using a muffled furnace. Total organic content was obtained by subtracting the weight after ignition from the weight before ignition.

Statistical analysis

A one-way analysis of variance (ANOVA) was used to test the hypothesis that different habitat types influenced the infaunal community in the restored marsh areas, where total mean density was the dependent variable. Linear regressions were performed to see if there was a relationship between total soil organic content and infaunal density.

CHAPTER III

RESULTS

A total of nine distinct groups were identified. They consist of polychaete worms in Families Ampharetidae, Capitellidae, Nereididae, and Spionidae, oligochaete worms in Subclass Oligochaeta, crustaceans in Orders Amphipoda and Tanaidacea, larval insects in Class Insecta, and nemertean worms in Phyla Nemertea. Capitellidae and Nereididae were the most abundant families in both the restored and reference marshes (Fig. 3). In October 2010, significant differences existed among habitat types for mean infaunal densities ($p = 0.03$) but not richness ($p = 0.09$) (Figs. 4 and 5). No significant differences were observed in July 2011 or November 2011 for either mean densities ($P = 0.22$; $P = 0.06$) or family richness ($P = 0.09$; $P = 0.40$; Figs. 4 and 5). Densities were highest in the *pumped* sites on all sampling dates except October 2010 when the *pumped* sites had the lowest densities of any habitat type. No relationship between organic content and infaunal density was present among habitat types during October 2010, July 2011, or November 2011 (Fig. 6). In 2011, the relative abundance of capitellids substantially increased which caused a qualitative shift in community structure (Fig. 3).

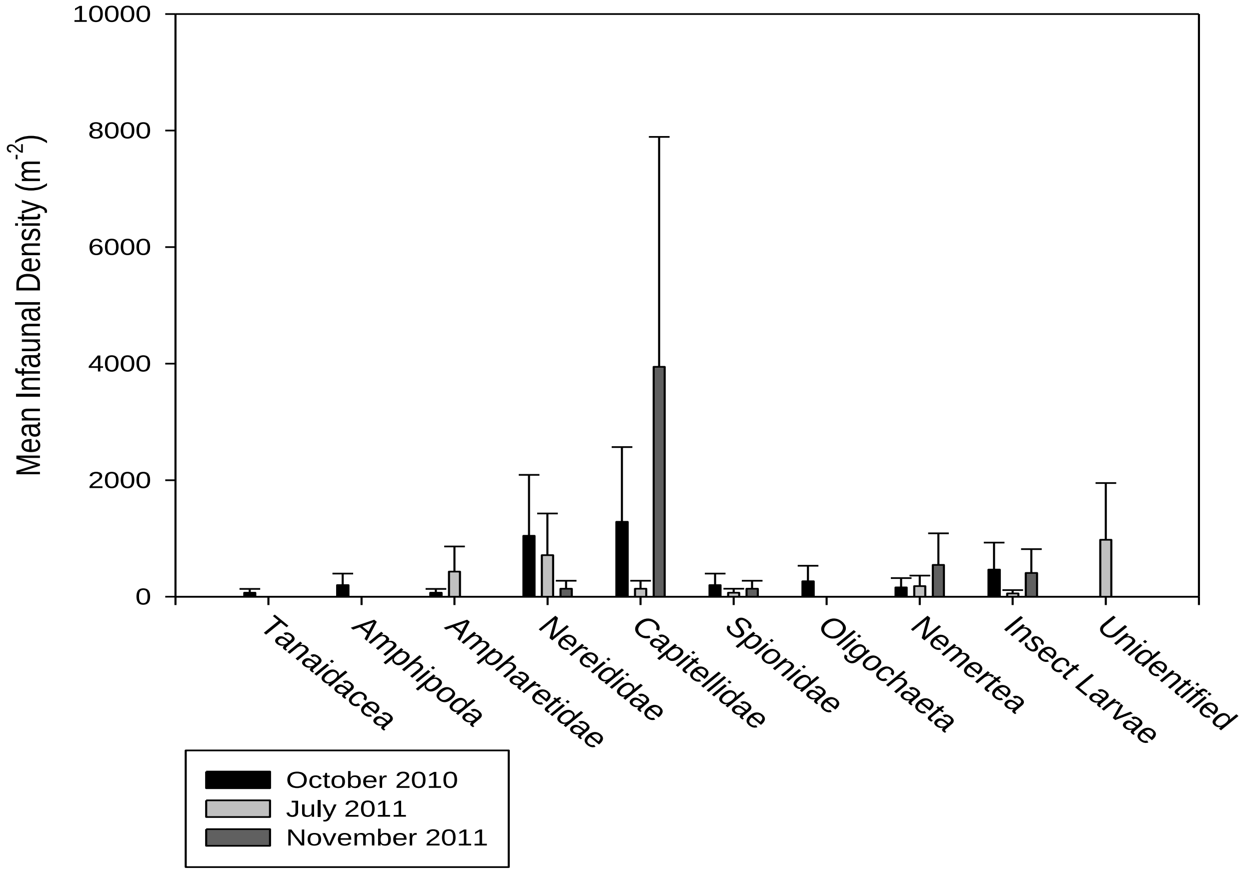

Fig.3. Total mean density (no. m^{-2}) for each LPIL in the reference, *excavated*, *filled*, *pumped*, and *terrace* sites. Data was pooled among elevations and habitat types. Error bars represent standard deviation.

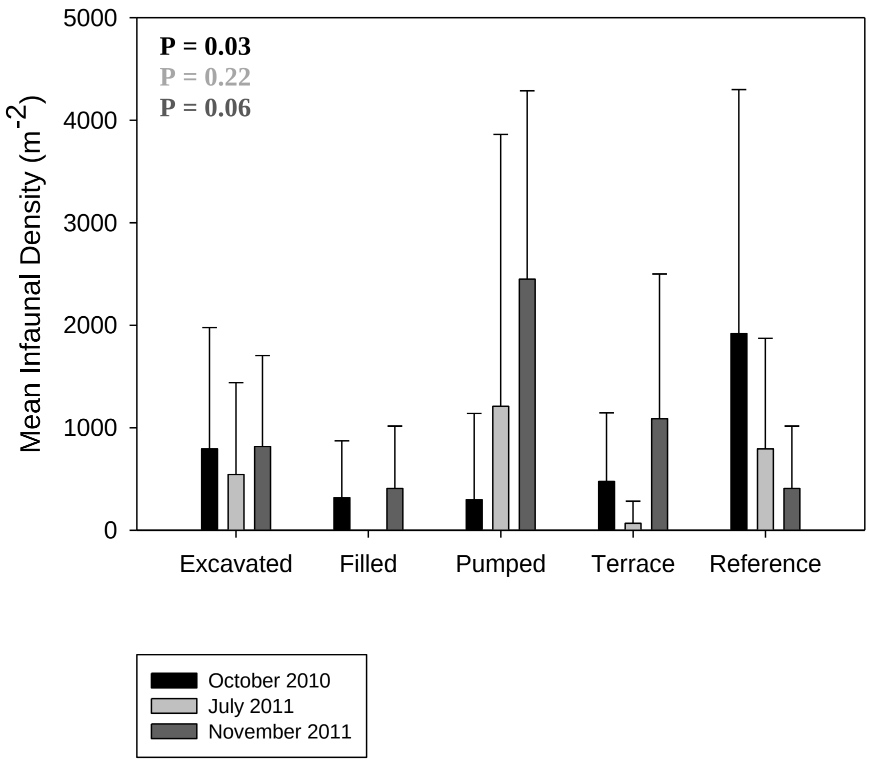

Fig.4. Mean infaunal densities (no. m^{-2}) for the reference, *excavated*, *filled*, *pumped*, and *terrace* sites during October 2010, July 2011, and November 2011. Data was pooled among elevations. Error bars represent standard deviation.

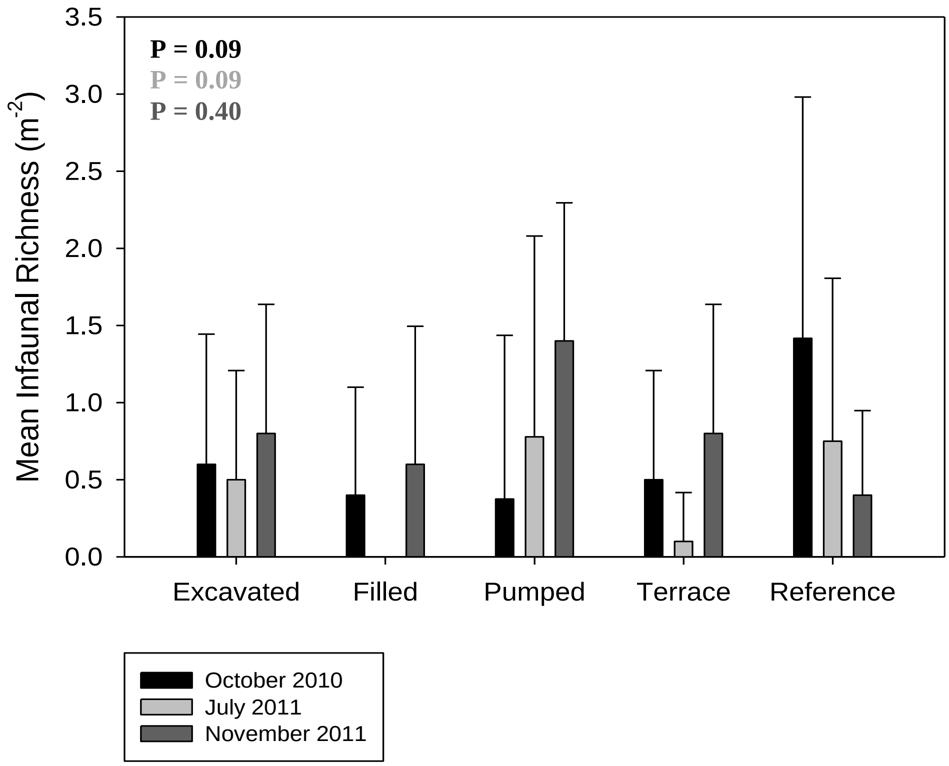

Fig.5. Mean infaunal richness (no. m^{-2}) for the reference, *excavated*, *filled*, *pumped*, and *terrace* sites during October 2010, July 2011, and November 2011. Data was pooled among elevations. Error bars represent standard deviation.

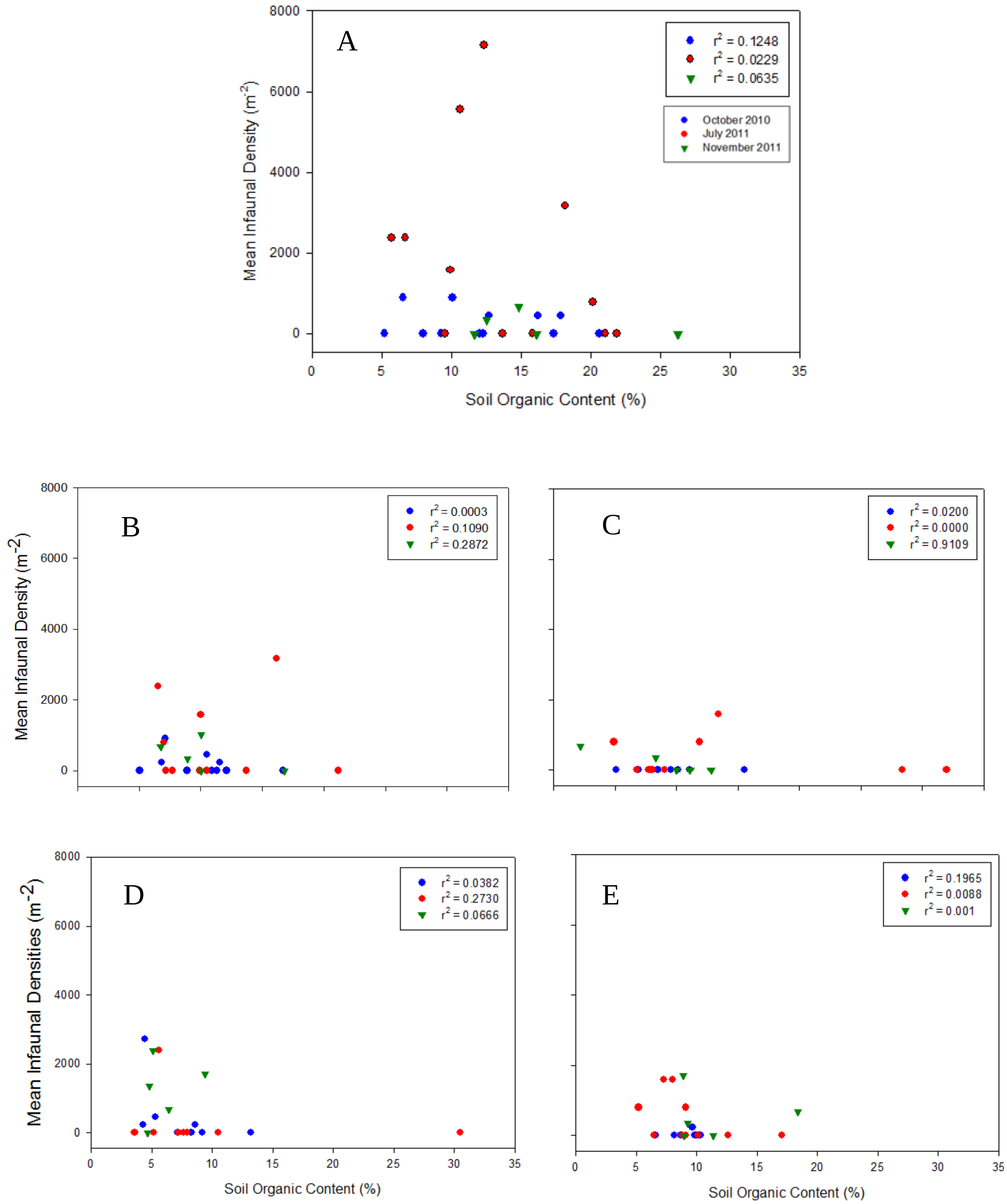

Fig.6. The relationship between infaunal density (no. m^{-2}) and total soil organic content (%) for the (A) Reference, (B) *excavated*, (C) *filled*, (D) *pumped*, and (E) *terrace* sites during October 2010, July 2011, and November 2011. Data was pooled among elevations.

CHAPTER IV

SUMMARY AND CONCLUSIONS

No relationship between infaunal density and total soil organic content was present in this study (Fig.6). Therefore, our initial hypothesis, that the habitat type with the greatest organic content would support the largest infaunal community, was not validated. However, data from October 2010 showed that densities were significantly different among habitat types (P = 0.03), suggesting that infauna were influenced by habitat morphology (Fig.4). Reference and restored marshes can differ in a variety of physical features such as elevation, marsh edge, and proportion of low marsh habitat (Moy and Levin 1991; Shafer and Streever 2000; Feagin and Wu 2006). Feagin and Wu (2006) found that the percent of marsh edge was similar in reference and terrace marshes along Galveston Bay, Texas but that the terrace marsh had fewer total square meters of marsh edge and as a result, had significantly less area of low marsh habitat. Whaley and Minello (2002) have shown that benthic infauna are most abundant one meter from the marsh edge into the *Spartina alterniflora* vegetated zone, which makes the establishment of low marsh habitat important in restoring ecological productivity. Shafer and Streever (2000) found that there were no significant differences in marsh edge to area ratios, but that the geomorphology of the marsh edge varied substantially between reference marshes and marshes restored with dredge fill. For example, the presence of flooded depressions in the reference marshes increased the amount of connected interior marsh edge while the marsh edge in restored areas was long, narrow and unconnected.

Differences in elevation have also been used as an indicator of infaunal abundance. For example, Moy and Levin (1991) found that infaunal abundance was greatest at lower and medium elevations and decreased as elevation increased. However, the majority of studies directly relating infaunal abundance to marsh elevation has been on salt marshes along the Atlantic coast. Further monitoring is required to confirm this trend for marshes along the Gulf of Mexico where studies frequently report that significant differences in elevation between reference and restored marshes is either reduced or absent (Shafer and Streever 2000; Whaley and Minello 2002; Edwards and Proffitt 2003).

In 2011, no significant differences among habitat types were present (Figs. 4 and 5). However, total mean infaunal densities were highest in the *pumped* habitat type on all sampling dates except October 2010 (Fig.4). Pumped dredge material often spreads evenly over the marsh surface (Shafer and Streever 2000), so the addition of dredge fill directly on top of the excavated benthic sediment likely gave the *pumped* mounds a gentler slope, which could have increased the proportion of productive low marsh habitat (Fig. 2). Higher densities in the pumped sites in July 2011 and November 2011 compared to October 2010, is likely due to an increase in sampling effort during 2011.

In 2011, there was a qualitative shift in community structure towards stress tolerant organisms such as Capitellids, which are commonly used as bioindicator species for environmental stress and pollution (Przeslawski et al. 2009). Community changes in 2011 are likely attributable to stressful environmental conditions (e.g., increased salinity, high temperature, lower dissolved oxygen) caused by an exceptional drought that occurred that year. Del Pilar Ruso et al. (2008) found that an increase in salinity can cause a shift in community structure, and Przeslawski et al.(2009) found that high (> 32° C) water temperatures have a lethal effect on infauna. Increased hypoxia may also play a role in community composition by increasing mortality and causing stressed infauna to migrate to the surface of the sediment, thus exposing them to increased risk of predation (Nestlerode and Diaz 1998). Therefore, the influence of habitat type on the infaunal community may be most pronounced under environmentally benign conditions and reduced in more stressful conditions such as droughts.

Other studies of salt marshes along the Atlantic coast have shown that organic content is one of the best predicators of infaunal abundance and attribute lower infaunal abundances to less organic content (Moy and Levin 1991; Sacco et al. 1994; Craft et al. 1999; Craft and Sacco 2003). However, total organic content was relatively the same among habitat types and no relationship with infaunal densities was observed in this study (Fig.6). Dredge fill from ship channels (Shafer and Streever 2000) and excavated benthic sediment obtained with in the vicinity of the reference marsh, often have high nutrient levels. The data collected in this study suggests that the use of dredge fill and excavated benthic sediment, likely resulted in organic content levels in the restored marsh areas which were sufficient enough to support infauna communities comparable to the reference marsh. Other studies of salt marshes along the Gulf of Mexico also show that organic matter is often comparable in restored and reference marshes. For example, Webb and Newling (1985) concluded that it would only take two to five years for percent organic matter to become comparable between a restored and reference marsh in Galveston Bay. Shafer and Streever (2000) also found no significant differences in organic carbon content between reference and restored marshes located along the Texas coast.

In the face of continued habitat loss, marsh restoration will become an increasingly valuable tool in preserving important ecological services. In order for mitigation projects to be successful, many aspects of marsh ecology should be monitored; especially infaunal organisms which are important ecosystem engineers. Our study indicates that habitat morphology can influence the infaunal community, but that patterns of habitat preference were disrupted by stressful environmental conditions caused by an exceptional drought. As a result, continued monitoring in non-drought conditions is necessary to fully understand the response of the infaunal community to habitat morphology.

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