A COMPARISON OF VEGETATION IN ARTIFICIALLY ISOLATED WETLANDS ON WEST GALVESTON ISLAND

A Thesis

by

ASHLEY MICHELLE WILSON

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2011

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Chair of Committee,	R. Douglas Slack
Committee Members,	Thomas L. Linton
	Robert A. Wharton
Head of Department	Thomas E. Lacher, Jr.

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ABSTRACT

A Comparison of Vegetation in Artificially Isolated Wetlands on

West Galveston Island. (May 2011)

Ashley Michelle Wilson. B.S., Texas A&M University

Chair of Advisory Committee: Dr. R. Douglas Slack

The purpose of this study was to compare vegetation systems among three artificially isolated wetlands on the west end of Galveston Island. Sample sites were identified as isolated wetlands, and anthropogenic impact was observed. Wetland plant communities were identified through representative field studies using a modified quadrat method. Species composition, species diversity, evenness, cover and frequency were compared among the three sample sites.

Salinity at all three sample sites remained at 0 ppt through June, July and August. Salinity increased to 10 ppt in both Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary in September. No change in salinity was recorded at Isla Del Sol. At Lafitte's Cove Nature Preserve, the majority of the soil composition included Mustang-Nass. Dos Vacas Muertas Bird Sanctuary consisted of a Mustang fine sand complex, while Isla Del Sol consisted of Mustang fine sand and Nass very fine sandy loam.

Sampling at Lafitte's Cove Nature Preserve produced 15 species. Dos Vacas Muertas Bird Sanctuary added 7 new species while Isla Del sol added 6 new species for a total of 28 species within the three sites. The overall plant species' richness of Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary remained low. A high frequency was observed in *Sesbania drummondii* and *Cyperus odoratus* at Lafitte's Cove Nature Preserve. *Sesbania drummondii* retained the highest percent cover for the site. At Dos Vacas Muertas Bird

Sanctuary, *Phragmites australis* and *Spartina patens* demonstrated a high frequency as well as percent cover. Frequency was highest in *Juncus roemerianus* and *Eleocharis geniculata* at Isla Del Sol. Several plant species exhibited a high frequency, while overall frequency was more evenly distributed in Isla Del Sol than the other sample sites. Percent cover was highest in *Juncus roemerianus* and *Borrichia frutescens*.

Isla Del Sol had the highest species diversity and evenness of all three sample sites. Similarity in species composition was high, with the coefficient for pair-wise comparisons in Isla Del Sol and Lafitte's Cove Nature Preserve being the highest. The three sample sites shared 53% to 73% of their species. Isla Del Sol possessed 6 species that were absent from the other sample sites. Dos Vacas Muertas Bird Sanctuary contained 4 unique species while Lafitte's Cove Nature Preserve had only 3 unique species.

Dos Vacas Muertas Bird Sanctuary had the lowest index score at 10. Lafitte's Cove Nature Preserve had the highest index score at 24, while Isla Del Sol followed closely behind at 22. For the Anthropogenic Activity Index, Lafitte's Cove Nature Preserve still retained the highest score at 14. Results for Isla Del Sol showed an index score of 13 while Dos Vacas Muertas Bird Sanctuary scored only 7.

The results of this study show that although Dos Vacas Muertas Bird Sanctuary had lower levels of disturbance when compared to the other sample sites, it still experienced a lower species diversity. Isla Del Sol had the highest species diversity and evenness of the sites. Lafitte's Cove Nature Preserve had the highest level of disturbance and maintained a low level of diversity as well. When comparing the results to historical data, a reduction in salt marsh plant species was observed. Species that are often associated with freshwater to brackish marsh wetlands have become more dominant in the sample sites.

DEDICATION

To my husband

ACKNOWLEDGEMENTS

I would like to thank Dr. Slack for taking a chance on me and for encouraging me throughout the process. I would also like to thank him for allowing me the freedom to choose my project. I appreciate his guidance in organizing my thoughts for my thesis, and I wish that I had more opportunities to work with him. I would also like to thank Dr. Linton for his great advice and for helping me set up my project. I really enjoyed working with him, and I learned a lot from taking his wetland classes. A special thanks to Dr. Wharton for his tough, but much needed criticism on my thesis. I really appreciated him taking the time to work with me, and his support and guidance was much appreciated.

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A special thanks to Charriss York for helping with my plant species' names. I didn't realize how lost I was in pronouncing the plant names until I sat down to work with her. I really appreciate her taking the time to help me and to answer my questions about vegetation sampling.

Thanks to the Houston Audubon Society, Isla Del Sol Homeowner's Association and the Lafitte's Cove Nature Society for giving me permission to study their amazing wetlands.

Thanks to my family for their support, encouragement and faith. Special thanks to my incredible parents, Kris and Susan Butler, for their constant love and support. Thank you for raising me to believe that I could do anything that I set my mind to. I would also like to thank my second family, my in-laws, for their support as well.

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CHAPTER I

INTRODUCTION

BACKGROUND

Wetlands are characterized by some of the highest rates of primary productivity of any habitats on earth (Dodds 2002).They have been found to cleanse polluted waters, prevent floods, protect shorelines, and recharge groundwater aquifers (Mitsch and Gosselink 2007). Along the coast, wetlands act as buffers during storms. Furthermore, they provide essential habitats for a variety of flora and fauna.

Approximately 70% of the world's population lives in coastal zones (Martin 2003, Cherfas 1990). While Texas has a small proportion of the U.S. coastal population, population by shore mile has doubled between the years 1960 and 2010 to 1,216 people per km (Brody et al. 2008, Culliton et al. 1990). Naturally occurring wetlands are an essential component of the United States' ecological infrastructure and they provide indispensable ecosystem services to human communities (Brody et al. 2008). Because of their close proximity to terrestrial systems, coastal wetlands are vulnerable to land development, pollutants, and many other human activities (Stedman and Dahl 2008). The expanding population of the United States places additional pressures on wetlands, and changes in water flow, pollution and habitat fragmentation may increase wetland loss and degradation (Stedman and Dahl 2008). Consequently, there have been many conservation programs developed to monitor and preserve our nation's wetlands. However, the problem with conservation programs is that there is no single, indisputable,

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This thesis follows the style of Wetlands.

ecologically sound definition for wetlands (Sharitz and Batzer 1999, Dodds 2002).

The Army Corps of Engineers (1987) define wetlands as “those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas”. The U.S. Army Corps of Engineers uses this definition for permitting purposes under Section 404 of the Clean Water Act. Cowardin et al. (1979) define wetlands as “lands that are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year” (Cowardin et al. 1979). This definition of a wetland is commonly used by the U.S. Fish and Wildlife Service for the National Wetland Inventory.

Wetlands are difficult to define precisely, not only because of their vast geographical extent, but also because of the broad variety of hydrologic conditions in which they are found. Uplands are an essential part to wetland systems; however, they are often overlooked because they do not fall under the definitions adopted by the U.S. Army Corps of Engineers and the Environmental Protection Agency. The frequency of flooding is a term that is often disputed or misunderstood. Although regulations and permitting have been created to conserve our nation’s wetlands, we continue to lose wetlands across the U.S. at an alarming rate. Galveston Bay salt marshes have decreased by 21% from the 1950’s resource level (White et al. 1993). Subsidence due to oil, natural gas and groundwater withdrawal, rise in relative sea-level, shoreline erosion and land development are foremost causes of marsh disappearance (White et al. 1993). Future loses are projected to be significant if sea level rise continues and upland areas transition into coastal marshes (Bigford 1991, Titus 1991, Delaney et al. 2000).

Wetlands and aquatic habitats are critical components of the biologically productive Galveston Island estuarine system. The most widely distributed wetland environments in the Galveston Island system are marshes, the majority of which are brackish (White and Paine 1992). Brackish marshes make up roughly 65% to 70% of the marsh system on Galveston Island. Salt marshes are 25 to 30% while freshwater marshes comprise of 5 to 10% of the system (White and Paine 1992).

VEGETATION CHARACTERISTICS

Vegetation on the west end of Galveston Island is distinctive, varying according to location and wetland type, containing a large amount of emerged vegetation instead of submerged grassbeds as its major estuarine vegetative form (White et al. 1993). Coastal wetlands flooded once or twice daily support "low marsh" vegetation, while areas flooded less frequently support "high marsh" species. Transition wetlands can be found above the high marsh, in areas flooded less frequently than twice a month (Titus 1991). Tidal salt marshes are often dominated by the grasses *Spartina spp.* in the low intertidal zone and *Juncus spp.* in the upper intertidal zone. *Salicornia spp.*, *Distichlis spicata* and *Batis maritima* are also indicators of salt marsh systems (Fisher 1973). Tidal freshwater marshes are usually dominated by a variety of grasses and by annual and perennial broadleaved aquatic plants (Mitsch and Gosselink 2007). Nontidal freshwater wetlands share some of the same vegetation of tidal freshwater wetlands. Depending on the hydroperiod, or duration of flooding, freshwater wetlands may be dominated by submerged and floating leaf herbaceous (White and Paine 1992). Freshwater wetlands with moderate hydroperiods may be dominated by *Typha spp.*, *Eleocharis spp.* and *Juncus spp*.

Brackish marshes can be characterized by *Spartina* grasses, *Distichlis spicata, Cyperus spp*. and *Typha angustifolia* (Fisher 1973).

ISOLATED WETLANDS

While most wetland scientists would agree that there is no such thing as an isolated wetland from an ecological standpoint, Tiner (2003a and 2003b) defines isolated wetlands as "wetlands that are completely surrounded by upland." Although the term "isolated wetlands" has appeared in several works of literature, it is not always consistently defined. In general, the term is defined as "wetlands with no apparent surface-water connection to perennial rivers and streams, estuaries, or the ocean. They are surrounded by dry land" (Tiner 2003a). The National Research Council defines isolated wetlands as "nontidal waters of the United States that are not part of the navigable waters of the United States and that are not adjacent to tributary bodies of water" (NRC 1995). Isolated wetlands are an important source for many species of plants and animals including several endangered or threatened species.

Isolated wetlands can be defined by geographical, ecological, or hydrological processes. Some isolated wetlands may have connections to other wetland through temporary surface-water connection and/or soil-water pathways (Lebowitz 2003). With others, groundwater may play a stronger role in hydrologic processes. Although hydrology is a major contributing factor in determining the characteristics of isolated wetlands, vegetation communities may also contribute to defining habitat characteristics. The term "artificial" is used in this study to describe wetlands that have been isolated through human development or influences.

PAST AND FUTURE PROJECTS

To compensate for the loss of wetlands several approaches have been pursued, including de novo creation of wetlands and restoration of wetlands that have been modified or degraded. However, because of the complexity and uniqueness of natural wetlands, creation and restoration projects are not generally accepted as a sound means for equitable replacement of the functionality of these natural systems (Delaney et al. 2000).

Of the six bay systems in the Texas Barrier Island region, Galveston Bay is the most affected by human activity (White and Paine 1992). Salt marsh restoration has become an increasingly important component of coastal management, because of the historical loss (Feagin and Wu 2006, Broome et al. 1988, Mitsch et al. 1998, Mitsch and Gosselink 2000) and predicted future losses as a result of anthropogenic disturbance and relative sea-level rise (Feagin and Wu 2006, Mitsch and Wu 1995, Moorhead and Brinson 1995). There are several restoration projects currently being conducted in the surrounding areas of the selected sample sites. Two of these, Delehide Cove and Starvation Cove are located just east of Eckert's Bayou and Lafitte's Cove. Another project, Snake Island Cove is located just east of Sea Isle and the Dos Vacas Muertas Bird Sanctuary. In 2007, a program conducted by Fish America and Gulf of Mexico Foundation partnerships installed geotubes and created 4.85 ha of intertidal marsh and sandflat islands just north of the Isla Del Sol subdivision. These projects represent both restoration as well as creation of new marsh habitats. Another growing concern on the west end of Galveston Island is wetland alteration. When large housing communities are developed many retain small parcels of land for wetland "preservation". However, in many cases the wetlands are altered from their natural state through isolation, dredging, vegetation removal or other practices. The three sample sites selected for the present study can be seen as both a product of wetland destruction and wetland alteration because they have been reduced to smaller isolated wetlands.

There have been several studies of wetlands on the west end of Galveston Island. The Galveston Bay National Estuary Program produced a report on wetland plant communities of Galveston Island and the Galveston Bay System (White and Paine 1992). Later in 1993, White et al. discussed the trends and status of wetland and aquatic habitats in the Galveston Bay system.

Delineated wetlands were based on the earlier aerial photographs taken in the 1950's, 1979, and 1989. These aerial photos were also used by the U.S. Fish and Wildlife Service to delineate wetlands for the National Wetland Inventory program. The classification of wetland communities in Galveston Bay is further discussed by Fisher et al. (1972 and 1973), Diener (1975), Lazarine (n.d.), Adams and Tingley (1977), Benton et al. (1979), Cowardin et al. (1979), and White et al. (1989). Although wetland communities of Galveston Island have been discussed in numerous works of literature, studies on isolated wetlands remain poorly documented.

PURPOSE OF THE STUDY

The purpose of this study is to compare vegetation systems among artificially isolated wetlands on the west end of Galveston Island. Mapping and defining the composition of wetland habitats are essential steps in determining their status and in measuring and anticipating the effects of numerous activities than can directly and indirectly influence them. Each selected site demonstrates different characteristics as well as different levels of human influence. The chosen sample sites are unique because they exhibit characteristics of both freshwater and saltwater marshes. Although they remain as freshwater, they still retain salt water characteristics because of their proximity to salt water. The wetland sample sites lack tidal influence but are fed by precipitation, runoff, and groundwater. All three sites are protected from further development and are monitored by homeowner associations and societies.

OBJECTIVES OF THE STUDY

1. Identify past wetland sites using aerial photos and historical data.
2. Identify present wetland sites and determine isolated status.
3. Determine anthropogenic impact and change to wetland sites.
4. Characterize wetland plant communities through representative field surveys.
5. Compare wetland plant communities among sites as well as against historical information.

CHAPTER II

STUDY AREA

GALVESTON ISLAND

Galveston Island is a barrier island in the upper Texas Gulf of Mexico. The island is approximately 48.3 kilometers long and averages at 4.83 kilometers in width (Figure 1). The Galveston Bay Estuarine System is a 1,554-km^2 estuary that consists of four major bays: East Bay, West Bay, Galveston Bay, and Trinity Bay. It is the seventh largest estuary in the United States and the largest in Texas (Delaney et al. 2000). It encompasses almost 163,000 ha of estuarine open water and 52,800 ha of marsh (White et al. 1993) This study focuses on the southern portion of the Galveston Bay Estuary System including the West Bay region (Figure 2). The climate of Galveston is predominately marine, with periods of modified continental influence during the colder months, when cold fronts reach the coast (Delaney et al. 2000, Webb et al. 1978). Exchange of marine waters with bay-estuary-lagoon waters in the Galveston Bay system occurs primarily through two major tidal inlets, Bolivar Roads at the north end of Galveston Island, and San Luis Pass at its south end (White et al. 1993). Salinities in the Galveston Bay system are generally highest in West and Christmas Bays where mean salinities are typically above 20 ppt and may range into the 30’s (White et al. 1993, Pulich et al. 1991, Orlando et al. 1991).

A wide variety of fish, wildlife, plant and invertebrate species either reside in or periodically inhabit the Galveston Bay system and surrounding areas. Galveston Island has been identified as a regionally significant reserve site for migrating shorebirds. The most common shorebirds are *Himantopus mexicanus*, *Limnodromus scolopaceus*, *Calidris alpina*, and *Catoptrophorus semipalmatus* (Lester and Gonzalez 2002). Galveston Island is also home to many migratory waterfowl including *Anas crecca*, *Aythya affinis, Anas discors* and *Aythya collaris* . Freshwater marsh feeders such as *Egretta caerulea*, *Ardea herodias*, *Bubulcus ibis*, and *Eudocimus albus* are commonly found throughout the island. The selected test sites are considered hotspots for avid birdwatchers and all the listed species above can be found at any location. Benthos in the Galveston Bay are comprised of generally the same species found in other Gulf Coast estuaries, with over 90 % of the infauna species consisting of marine worms and small crustaceans (Lester and Gonzalez 2002, Green et al. 1992). The Freshwater wetlands contain several species of annelids and peracarids. Larvae of dipteran species including crane flies and mosquitoes as well as aquatic stages of damselflies and dragonflies (Odonata) may be present depending on flooding. Backswimmers and water boatman (Hemiptera) may also be present. Some common land mammals include the *Sylvilagus aquaticus, Rattus rattus* and *Sciurus carolinensis*. *Myocaster coypus* has also been identified as a management problem for some of the island's wetlands.

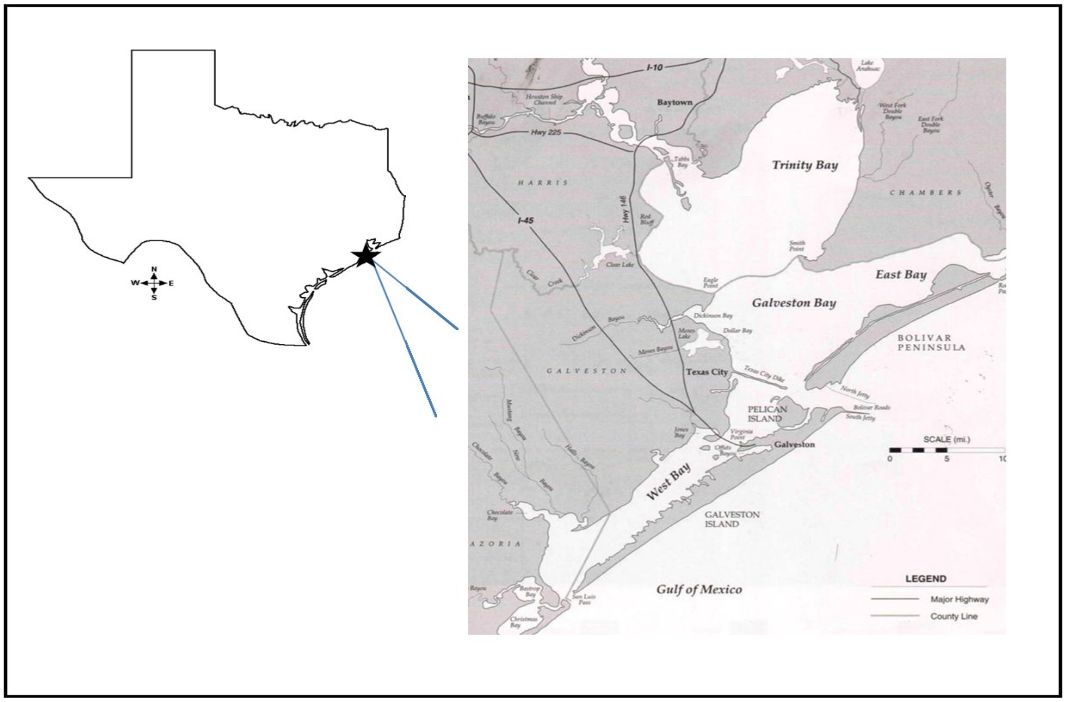

Figure 1. Location of Galveston Island, TX. (Source: GBNEP 2006)

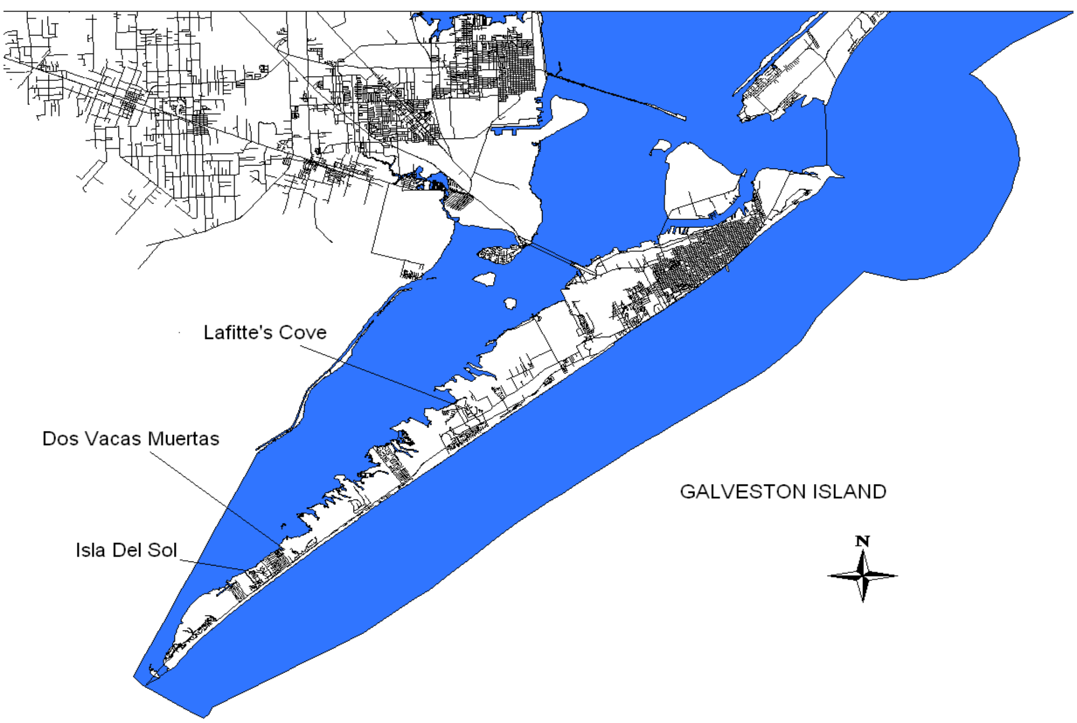

Figure 2. Location of the sample sites on Galveston Island.

LAFITTE'S COVE NATURE PRESERVE

Lafitte's Cove Nature Preserve is adjacent to Eckert's Bayou on the west end of Galveston Island (Figure 2). It is located within the large housing community of Lafitte's Cove. Mitchell Development Corporation acquired the land and applied for a permit from the U.S. Corps of Engineers in 1974 to dredge canals that would lead to Galveston West Bay. Protests from local homeowners and environmental groups led to a large lawsuit, Fritiofson v. Alexander, 772 F. 2^{nd} 1225 (5^{th} Cir. 1985). Mitchell Development Corporation agreed to several changes in its plans, which included setting aside 12.9 ha to preserve a sample of the original woods and wetlands. The land was deeded to the City of Galveston and the Lafitte's Cove Nature Society was formed in 1992 to maintain the land. Before the development of Lafitte's Cove, the area was documented as both tidal salt marsh and tidal freshwater marsh with a large oak mott in the northeast corner (Figure 3). With the development of canals and homes, the area now includes several isolated freshwater wetlands. There are two designated freshwater ponds located on the east and west corners of the sample site. The selected sample site is located on the west side of Eckert's Road and within the preserve. The north and south wetlands were selected for transect locations. The selected wetlands are approximately .93 ha. Transect one runs along the northern most section of the wetland while the second transect runs along the southern portion. Transect locations were selected to show the most representative plant communities as well as the highest diversity for plants within the wetland. Ponded locations on the east and west corner of the sample site lacked a sufficient amount of vegetation for sampling and the amount of open water was at a maximum for the site. Wetlands on the east side of Eckert's Road were not selected because of a high level of human disturbance that occurred through the creation of walking trails and boardwalks. The selected wetland is 90 m from the nearest dredged canal connected to West Galveston Bay. It is approximately 440 m from Eckert's Bayou and approximately 620 m from the nearest salt marsh system. The open water of West Galveston Bay is located over 1000 m away. Most homes average a distance to the wetland between .50 m to 4 m.

Figure 3. Lafitte's Cove Nature Preserve in 2010. (Source: Google 2010)

DOS VACAS MUERTAS BIRD SANCTUARY

The land was donated to the Houston Audubon Society in 2001 by Mr. and Mrs. George Clayton. The bird sanctuary is 2.4 ha and is located approximately 8 km from San Luis Pass (Figure 2). The bird sanctuary is comprised of both saltwater marshes and freshwater wetlands (Figure 4). The saltwater marsh and freshwater wetland are separated by a sand ridge whose vegetation currently consists of *Tamarix spp.* (salt cedar). Over time, *Tamarix spp*. has invaded the area and now grows along the fence that encompasses the freshwater wetland in the sanctuary. The reason for the establishment of *Tamarix spp*. is currently unknown. The freshwater wetland has been isolated over time through sand dispersal and human impact. The selected sample site is approximately .6 ha and includes the freshwater pond and adjacent wetlands within the bird sanctuary. The site also retains a small live oak stand on the southwest corner. Transect one was located on the northern edge of the ponded area and included the dense stands of *Phragmites australis* and *Typha spp*. that are flooded more frequently. Transect two was located on the southern edge of the ponded area and included some of the high marsh species that may not flood as frequently as in Transect one. Transect locations were selected to represent the range of plant species present by sampling through both high marsh and low marsh within the sample site. Dos Vacas Muertas Bird Sanctuary is approximately 30 m from the adjacent salt marsh and approximately 430 m from open water connected to West Galveston Bay. The closest homes are located on the west side at approximately140 m to 180 m.

Figure 4. Dos Vacas Muertas Bird Sanctuary in 2010. (Source: Google 2010)

ISLA DEL SOL

Isla Del Sol is located 6.4 km east of San Luis Pass on the west end of Galveston Island (Figure 2). The housing community was constructed in the mid-1980's and includes several dredge canals on the north side of the property. A restoration project was recently conducted by the Fish America and Gulf of Mexico Foundation partnerships to restore the salt marshes located north of the housing community. Within the housing community, over 24.2 ha of both salt and freshwater wetlands were preserved by the City of Galveston. The west side of the housing community includes both a tidal salt and freshwater wetland. The selected sample site lies just east of this area and includes a large freshwater pond and adjacent wetlands. The sample site is approximately .8 ha and is located within the 8 ha section that is also owned by the City of Galveston (Figure 5). Unlike the Lafitte's Cove Preserve, the preserved area includes a buffer zone of vegetation and sand flats between development and the designated wetland. This allows for the preservation of associated upland or high marsh species. Transect one is located on the west side of the pond and includes a portion of the high marsh and sand flat area. Transect two is located perpendicular to transect one and runs along the south edge of the pond. Only a few homes are located less than 20 m from the wetland. Most homes average a distance of 100 m to 200 m to the wetland. The nearest dredged canal connected to Galveston Bay is located approximately 87 m from the wetland. The restored salt marsh north of Isla Del Sol is located at approximately 389 m and the open water (outside of the geotubes) of West Galveston Bay is located at approximately 675 m.

Figure 5. Isla Del Sol in 2010. (Source: Google 2010)

CHAPTER III

METHODS

Physical characteristics of the wetlands were determined through the use of geographic information systems (GIS), Vector-based National Wetland Inventory (NWI) maps and historical aerial photos supplied by the Texas General Land Office (TGLO). ArcGIS as well as MAPINFO were used to convert images to raster data. Historical images were compared to current data to evaluate physical changes along with vegetation changes. Wetlands were originally delineated on mid 1950's, 1979, and 1989 photographs as part of the U.S. Fish and Wildlife Service National Wetlands Inventory program using the Cowardin et al. (1979) wetland classification system. The 1950's photographs were black-and-white stereo-pair, scale 1:24,000 from the U.S. Department of Agriculture. The 1979 photographs were NASA color-infrared stereo-pair, scale 1:62,500. The 1989 photos were also NASA color-infrared stereo-pair, scale 1:62,500 (White and Paine 1992, TGLO 2006). Additional aerial photos from 1954, 1969, 1974, 1987, and 2010 were examined further to determine wetland trends.

DATA COLLECTION

Three sample sites were chosen to represent different levels of human impact. Sample sites were isolated with no tidal influence and were similar in size at less than 1 hectare. Before selecting transects within the sample sites, the sample sites were examined to determine a representative sample of species present. The selected areas were mapped and measured using ArcGIS. Vegetation data were collected between June 2010 and July 2010. Vegetation sampling was done during the peak growing season to increase the chances of complete samples. The sample technique included a modified quadrat method using line transects.

Within each site, two 50 m transects were marked using wooden stakes and string (Figures 6-8). Fifteen quadrat samples were collected for each transect. The points along the transect were randomly generated to reduce bias. A three square meter quadrat was used for sampling. The quadrat was placed at the corner of the chosen points along the transects. The large distance between quadrat samples allowed the quadrats to be considered independent sampling units. Plant species were documented within the quadrat. Plants falling on one of the boundary lines of the quadrat were counted only if more than one-half of the plant was within the quadrat (Smeins and Slack 1982). Each plant was identified to the lowest taxonomic level possible using vegetative, fruiting, and floral characteristics. Any plant species that was difficult to identify on site was collected for later identification. References used in plant identification included Field Guide to Coastal Wetland Plants of the Southeastern United States (Tiner 1993), Common Texas Grasses (Gould 1978), and PLANTS Database (USDA 2010).

Figure 6. The two transect locations for Lafitte’s Cove Nature Preserve. (Source: Modified from Google 2010)

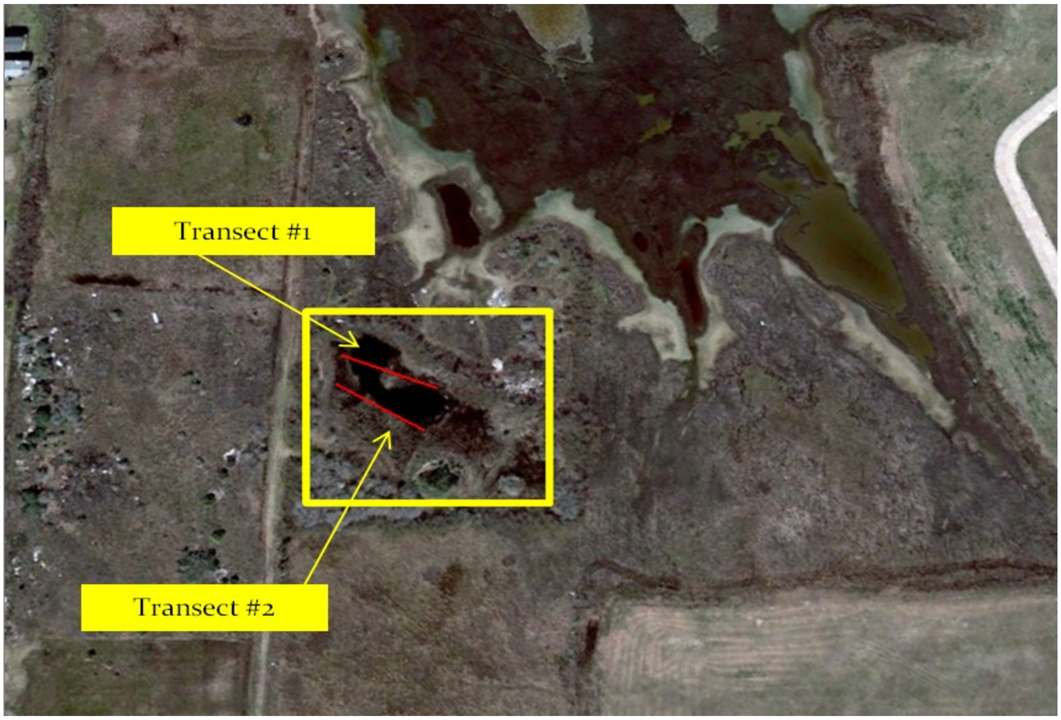

Figure 7. The two transect locations for Dos Vacas Muertas Bird Sanctuary. (Source: Modified from Google 2010)

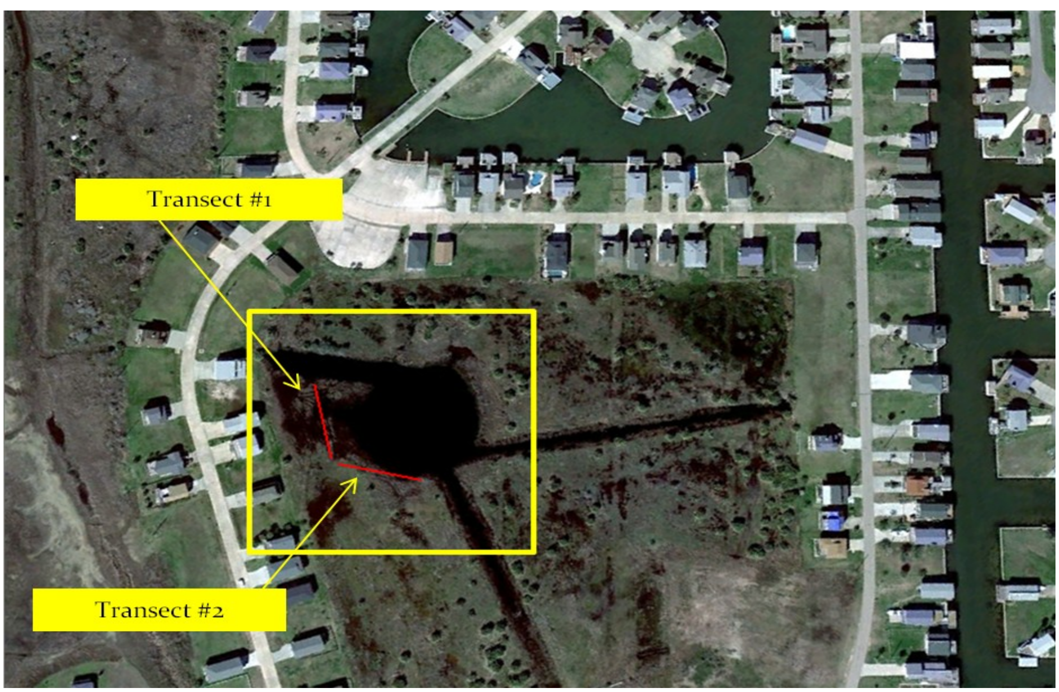

Figure 8. The two transect locations for Isla Del Sol. (Source: Modified from Google 2010)

Salinity was measured using a temperature compensating hand-held refractometer. Measurements were taken between June 2010 and September 2010. Water samples were taken from two locations within each site. Salinity levels were compared to precipitation to explain any discrepancies found. Precipitation was collected from rain gauges and compared to the National Oceanic and Atmospheric Administration (NOAA) weather reports.

County soil surveys were used to define and characterize soils at the selected sample sites. Information obtained from the soil surveys included salinity, soil type, drainage, position of the water table, and frequency of flooding. Soil data were also used to study predicted vegetation morphology. The soil information was synthesized from current soil data reports provided by the National Resource Conservation Service (Soil Survey Staff 2010).

DATA ANALYSIS

Percent cover was determined for each species documented within the samples. Cover Values (Table 1) were assigned using the Daubenmire Class System (Daubenmire 1959). Once sampling was completed, species cover was estimated by multiplying the number of times a class was recorded by the midpoint of the cover class, adding the results for each class, and calculating an average by dividing by the total number of quadrats sampled (Daubenmire 1959). Species composition was calculated by dividing the percent cover of each plant species by the total cover of all plant species sampled (Coulloudon et al. 1999). Next, frequency was calculated by dividing the number of occurrences of a plant species by the total number of quadrats sampled (Coulloudon et al. 1999). Relative frequency was then determined by dividing the frequency of a species by the total frequencies for all species sampled (Smeins and Slack 1982). The results for each sample site were used to compare dominant species within the selected sample sites.

Table 1. Daubenmire Cover Classes. (Source: Daubenmire 1959)

Cover Class	**% Percent Cover**	**% Midpoint of Class**
1	0 – 5%	2.5%
2	5 – 25%	15.0%
3	26 – 50%	37.5%
4	51 – 75%	62.5%
5	75 – 95%	85.0%
6	96 – 100%	97.5%

Similarity of species composition among the selected sites was calculated using Sorensen's Coefficient of Community (Krebs 1999).The total number of plant species were calculated for each sample site. The plant species were then compared between the sample sites and the total shared plant species were then determined. Sorensen's Coefficient of Community was first calculated between Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary, then between Lafitte's Cove Nature Preserve and Isla Del Sol. Finally, Sorensen's Coefficient of Community was calculated using Dos Vacas Muertas Bird Sanctuary and Isla Del Sol. The number of unique species for each sample site was evaluated and compared among the sample sites.

QS = Sorensen's Coefficient

A = Number of species in site 1

B = Number of species in site 2

C = Number of species shared by both sites

$QS = 2C/(A + B)$

Species diversity was assessed using the Shannon Diversity Index (Brower et al. 1998, Krebs 1999). Species diversity is the number of different species in a particular area (species richness) weighted by some measure of abundance such as a number or percent of individuals.

(Krebs 1999) The total number of plant species occurrence within the sample quadrats were calculated for each sample site. The proportion of each individual plant species was then determined. The proportion of each species relative to the total number of species documented in the sample site (P_i) was calculated and multiplied by the natural logarithm of the proportion ($\ln P_i$). All species products were then summed and multiplied by -1.

H = Shannon's Diversity Index

P_i = Proportion of each species in a sample

$H = -\sum P_i (\ln P_i)$

Evenness was determined as the ratio of heterogeneity to maximum heterogeneity (Brower et al. 1998, Krebs 1999). Species evenness is a diversity index that measures the abundance with which each species is represented in an area (Mulder et al. 2004). Communities with greater evenness are considered to have greater species diversity. Evenness is based on the product of the Shannon Diversity Index.

H' = product of Shannon's Diversity Index

H_{max} = total number of the species occurrences for the site

$E = H'/H_{max}$ or $E = H'/\ln(S)$ where (S) is H_{max}

Two methods were used to rank the level of human disturbance as each sample site. The first method, Anthropogenic Activity Index (AAI), is a modification of the index used by Minnesota Department of Environmental Quality (Gernes and Helgen 2002) and includes sections from the Ohio disturbance ranking system (Mack 2001). Sites were evaluated using five different metrics (Appendix A). The metrics were then divided into four categories, which were scored 0 to 3 (Herman 2005). Sites that scored 0 were considered to have low levels of disturbance. Sites that scored a 3 represented the highest level of disturbance. Sites that scored a 3 on all five metrics received a total score of 15 for the index. A total score of 15 was seen as the highest level of impact for the Anthropogenic Activity Index. The second method, Disturbance Index (DI), was developed in Ohio and is comprised of a three-tiered hierarchical flow chart (Herman 2005, Lopez and Fennessy 2002). Sites were ranked from 1 to 24. Sites with a score of 1 represented the lowest level of disturbance (Appendix B). On the other end, sites with a score of 24 represented the highest level of human impact.

CHAPTER IV

RESULTS

There were both gains and losses in Galveston Island wetlands from the 1950's to the 2000's. However the net trend points towards wetland loss in Galveston Island. This downward trend is illustrated by the losses in wetland vegetation resulting from the conversion of open water and flats as well as uplands in Galveston Island (White et. al. 1993). This trend can often be seen in the creation of canals for housing communities. When examining aerial photos of Lafitte's Cove Nature Preserve and Isla Del Sol, prior to development, slight variations in wetland loss are observed. Natural processes as well as subsidence and relative sea level rise can help to explain these particular wetland losses. Each test site was originally connected to tidal waters as seen by photos and historical data (Figures 9-11).

Figure 9. Lafitte's Cove Nature Preserve in 1954. (Source: TGLO 2006)

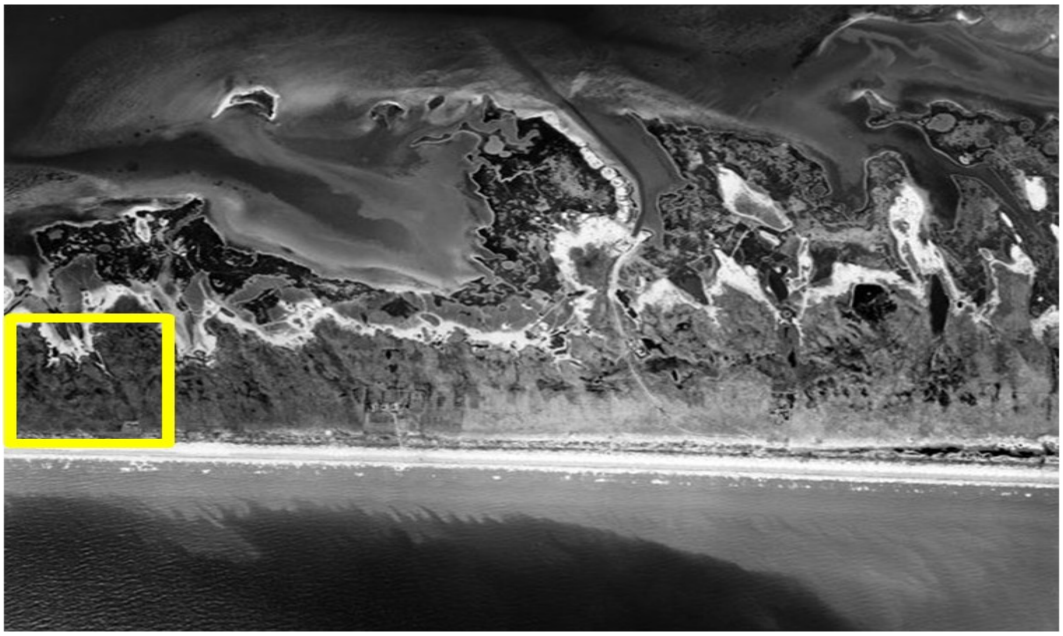
Figure 10. Dos Vacas Muertas Bird Sanctuary in 1954. (Source: TGLO 2006)

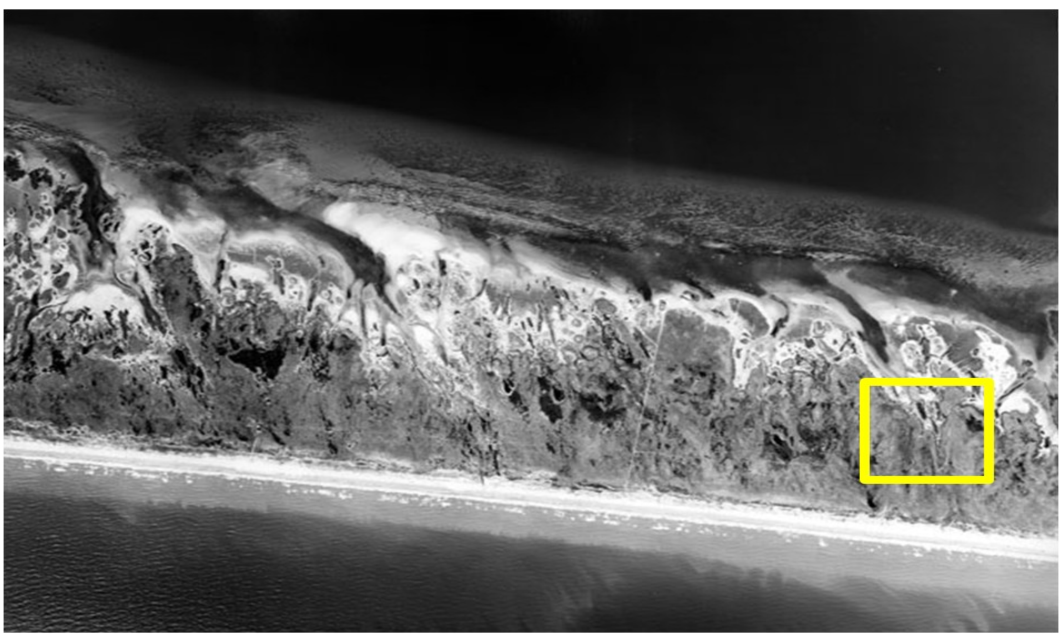
Figure 11. Isla Del Sol in 1954. (Source: TGLO 2006)

WETLAND HYDROLOGY

Hydroperiod, or the hydrologic signature of a wetland, is the balance between inflows and outflows of water (Mitsch and Gosselink 2007). Hydroperiods for the sample sites resulted from the interaction of direct rainfall, local runoff, and changes in evapotranspiration rates in all three sample sites. Rainfall was below average during the three months prior to vegetation sampling (Figure 12). During the sample months, rainfall was below average in June and above average in July (Figure 13). Precipitation in June of 2010 was approximately 6.8 cm, while approximately 12.1 cm fell in July of 2010. In August of 2010, precipitation dropped well below average with only 1.3 cm recorded. Precipitation in September 2010 increased to 11.7 cm, falling slightly below the monthly average. Wetlands remained inundated throughout the vegetation sampling period as well as through the sampling period for salinity. The hydroperiod of the study sites was largely determined by the maximum depth of the standing water. As evapotranspiration increased and rainfall decreased during the late summer months, the sample sites began to dry in some of the shallower areas.

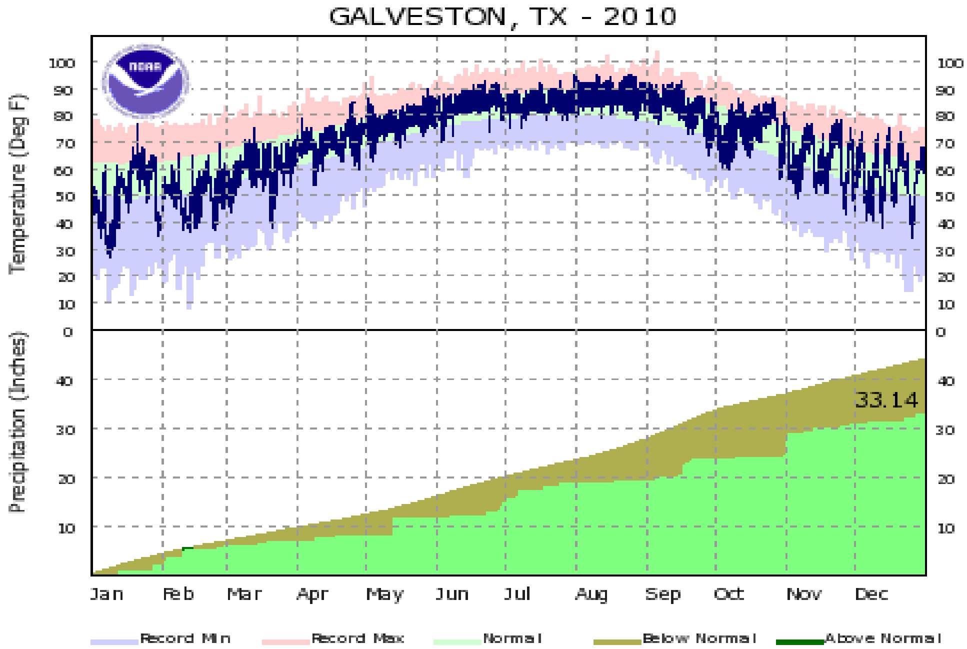

Figure 12. Precipitation for Galveston in 2010. (Source: NOAA 2010)

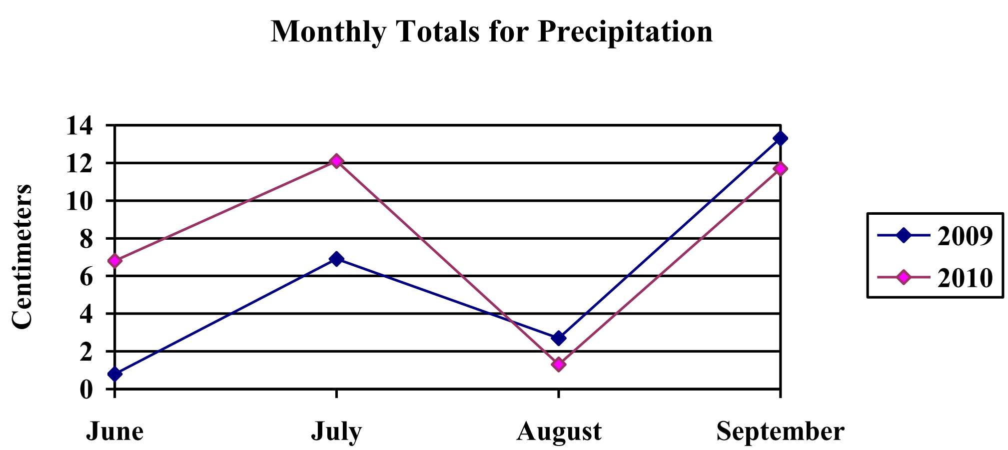

Figure 13. Precipitation for the selected months of 2009 and 2010. (Source: NOAA 2010)

WETLAND SALINITIES

Salinities within the sample sites were a result of soil composition and salt spray. Salinity at all three sample sites remained at 0 ppt through June, July and August. A substantial amount of rain in early September had a slight effect on salinities at Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary. Salinity increased to 10 ppt in both Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary during September but no change in salinity was recorded in Isla Del Sol. The heavy rains in September were produced by large storms that were associated with Tropical Storm Hermine in the gulf. Strong winds and high tides in the area increased the amount of salt spray. Prior high temperatures in August reduced the water levels of the wetlands and the salts were concentrated by evaporation.

WETLAND SOILS

The major soils of Galveston Island included the Galveston and Mustang series. Most of the soils were nonsaline, but salt spray can affect vegetation. Wetland soils can be seen as both the medium in which many of the wetland chemical transformations happen and the primary storage of available chemicals for most wetland plants (Mitsch and Gosselink 2007). The soils found at each sample site were defined as hydric soils. Hydric soils are "soils that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part" (Mitsch and Gosselink 2007, NRCS 1998).

At Lafitte's Cove Nature Preseve the majority of the soil composition included Mustang-Nass (Figure 14). Over ninety percent of the soil composition was comprised of fine sand while the remaining percentage included clay. The soil was poorly drained and the depth to the water table was shallow at 8 cm. Flooding may occur after December and continue throughout the year depending on precipitation. The frequency of flooding was described by the soil survey as occasional to seasonal while the frequency of ponding was described as occasional in several locations along the sample site (Soil Survey Staff 2010). The ponded areas were more associated with the Nass complex with a slightly loamy sand composition. The salinity was low in the Mustang soils that made up the majority of the soil composition (0.0-4.0 mmhos/cm). The Nass soils that can be found under the ponded areas carried an higher soil salinity at 2.0-16.0 mmhos/cm (Soil Survey Staff 2010).

Figure 14. Soil type for Lafitte’s Cove Nature Preserve. (Source: Modified from Soil Survey Staff 2010)

Dos Vacas Muertas Bird Sanctuary consisted of a Mustang fine sand complex (Figure 15). It was nearly level and poorly drained. Over ninety percent of the soil composition consisted of fine sand while only five percent was considered clay. The depth to the water table was also shallow at 8 cm. According to the soil survey, the frequency of flooding was classified as occasional with ponded areas present on site. The salinity of the soil was low at 0.0-4.0

mmhos/cm (Soil Survey Staff 2010). Mustang fine sand (slightly saline-strongly saline) complex was found on the north corner of the site but was not included in the quadrat samples.

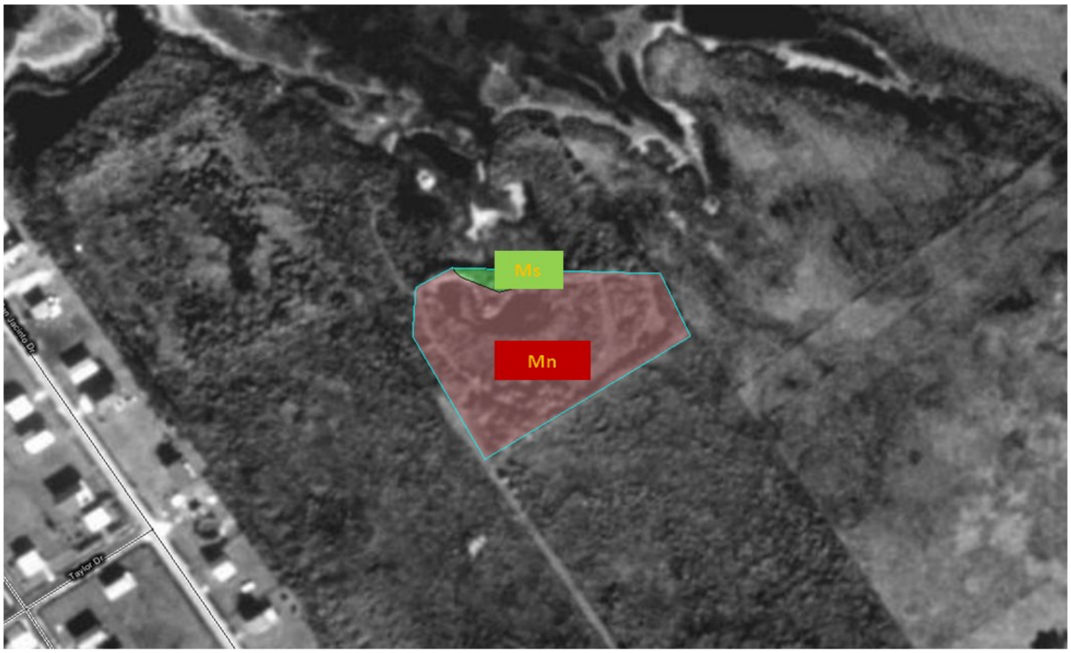

Figure 15. Soil type for Dos Vacas Muertas Bird Sanctuary. (Source: Modified from Soil Survey Staff 2010)

Isla Del Sol consisted of Mustang fine sand and Nass very fine sandy loam (Figure 16). The Nass sandy loam complex was a mixture of sand, silt and clay. It was also poorly drained and found to flood occasionally like its counterpart Mustang fine sand. Nass very fine sandy loam was slightly saline to strongly saline depending on the depth (4.0-25.0 mmhos/cm). Nass very fine sandy loam was located along transect one. The salinity of the Mustang fine sand was low at 0.0-4.0 mmhos/cm (Soil Survey Staff 2010). Mustang fine sand was included in the majority of transect two. Depth to the water table for each soil type was 8 cm.

Figure 16. Soil type for Isla Del Sol. (Source: Modified from Soil Survey Staff 2010)

WETLAND VEGETATION

A small layer of dead plant material was present on the bottom of Isla Del Sol and Dos Vacas Muertas Bird Sanctuary. Dos Vacas Muertas Bird Sanctuary involved dead plant material from *Phragmites australis* and *Typha spp*. Isla Del Sol did produce some die-back from drawdown occurring over the summer months. Sampling at Lafitte's Cove Nature Preserve produced 15 species. Dos Vacas Muertas Bird Sanctuary added 7 new species while Isla Del sol added 6 new species for a total of 28 species among the three sites (Figures 17-19). Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary both produced 15 total species while Isla Del Sol contained 20 species.

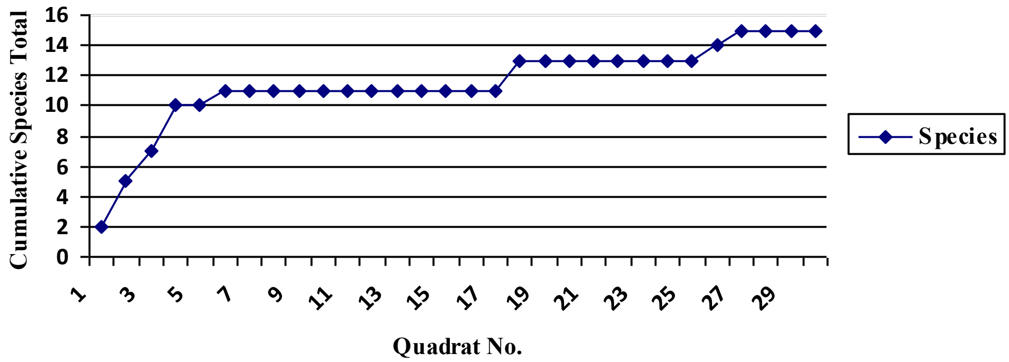

Figure 17. Cumulative species totals for Lafitte's Cove Nature Preserve.

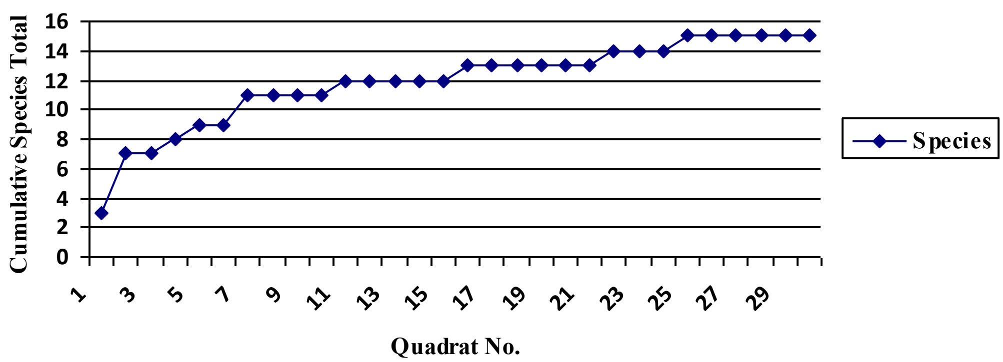

Figure 18. Cumulative species totals for Dos Vacas Muertas Bird Sanctuary.

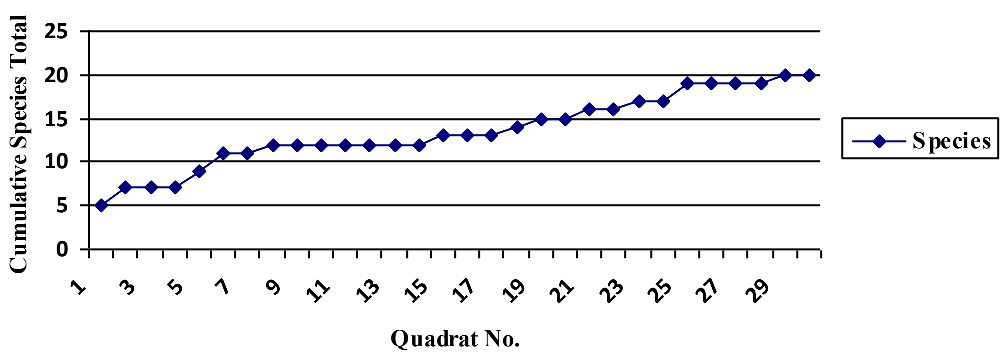

Figure 19. Cumulative species totals for Isla Del Sol.

When evaluating wetland status, it was observed that most species were classified as OBL or FACW(+/-).The exceptions were *Agalinis purpurea* and *Eustoma exaltatum* that were classified as FAC and FAC-. *Ambrosia artemisiifolia* was classified as FACU. Indicator status reflects the range of estimated probabilities of a species occurring in a wetland versus a non-wetland (USDA 2010) (Table 2). Most of the species found at all three sample sites were classified as perennial or both perennial and annual (Table 3). Only five species were classified as annual. These included *Agalinis purpurea*, *Ambrosia artemisiifolia*, *Ammania coccinea*, *Eleocharis geniculata* and *Setaria magna*. Warm temperatures often remain throughout the year while winter's temperatures remain mild. Therefore most plant species persisted throughout the year.

Table 2. Wetland Indicator Categories (Source: USDA 2010)

Indicator Status	**Wetland Type**	**Description**
OBL	Obligate Wetland	Occurs almost always (99%)
FACW	Facultative Wetland	Usually occurs (67% - 99%)
FAC	Facultative	Likely to occur (34% - 66%)
FACU	Facultative Upland	Unlikely (1% - 33%)
(-)		(+) indicates a frequency to higher end of category\ (-) indicates a frequency to lower end of category

Table 3. List of plant species found in all three sample sites.

Scientific Name	Growth Form	Duration	Indicator Status
Agalinis purpurea	Forb/herb	Annual	FAC
Ambrosia artemisiifolia	Forb/herb	Annual	FACU-
Ammannia coccinea	Forb/shrub	Annual	OBL
Bacopa monnieri	Forb/shrub	Perennial	OBL
Batis maritima	Subshrub	Perennial	OBL
Borrichia frutescens	Subshrub	Perennial	FACW+
Cyperus odoratus	Graminoid	Annual/Perennial	FACW
Cyperus polystachyos	Graminoid	Annual/Perennial	FACW
Distichlis spicata	Graminoid	Perennial	FACW+
Eclipta prostrata	Forb/herb	Annual/Perennial	FACW
Eleocharis geniculata	Graminoid	Annual	FACW+
Eleocharis obtusa	Graminoid	Annual/Perennial	OBL
Eustoma exaltatum	Forb/herb	Annual/Perennial	FAC-
Fimbristylis castanea	Graminoid	Perennial	OBL
Heliotropium curassavicum	Forb/subshrub	Annual/Perennial	FACW
Iva frutescens	Subshrub/forb	Perennial	FACW
Juncus roemerianus	Graminoid	Perennial	OBL
Lycium carolinianum	Shrub	Perennial	FACW
Paspalum vaginatum	Graminoid	Perennial	FACW
Phragmites australis	Subshrub/Graminoid	Perennial	FACW
Pluchea odorata	Subshrub/forb	Annual/Perennial	OBL

Table 3. Continued

Scientific Name	Growth Form	Duration	Indicator Status
Schoenoplectus americanus	Graminoid	Perennial	OBL
Sesbania drummondii	Subshrub/forb	Perennial	FACW
Sesuvium portulacastrum	Forb/herb	Perennial	FACW
Setaria magna	Graminoid	Annual	FACW
Spartina patens	Graminoid	Perennial	FACW
Spartina spartinae	Graminoid	Perennial	FACW+
Typha spp.	Forb/herb	Perennial	OBL

The plant species' richness of Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary remained low. Dos Vacas Muertas Bird Sanctuary and Lafitte's Cove Nature Preserve were dominated by one or two plant species. A high frequency was observed in *Sesbania drummondii* (70.0%) and *Cyperus odoratus* (73.3%) at Lafitte's Cove Nature Preserve (Figure 20). *Lycium carolinianum* (3.3%) and *Eleocharis geniculata* (3.3%) had the lowest frequency (Figure 21). Although *Cyperus odoratus* (11.0%) exhibited a high frequency and was found in more quadrat samples, its percent cover scored lower than *Paspalum vaginatum* (16.0%). *Sesbania drummondii* (18.0%) still retained the highest percent cover while *Paspalum vaginatum* came in close second (Table 4). Species composition was highest in *Sesbania drummondii* and *Paspalum vaginatum* which was expected given their high percent cover.

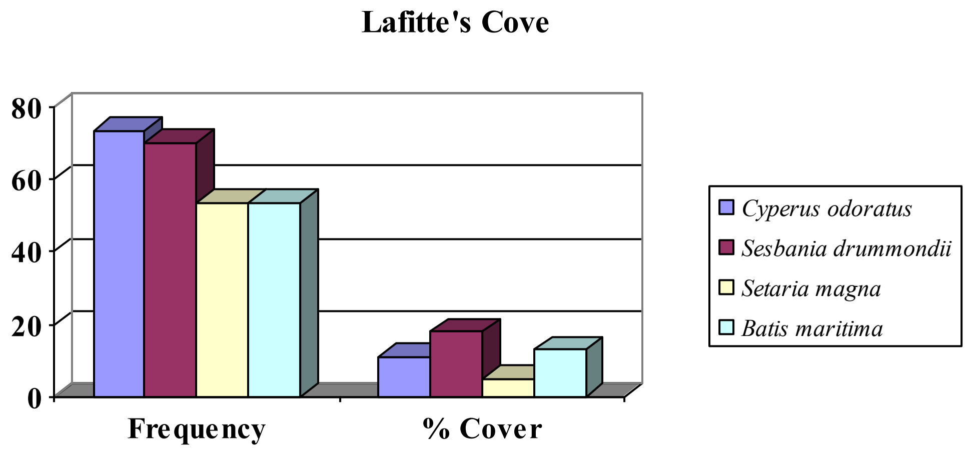

Figure 20. Comparison of % cover with species with the highest frequency in Lafitte's Cove Nature Preserve.

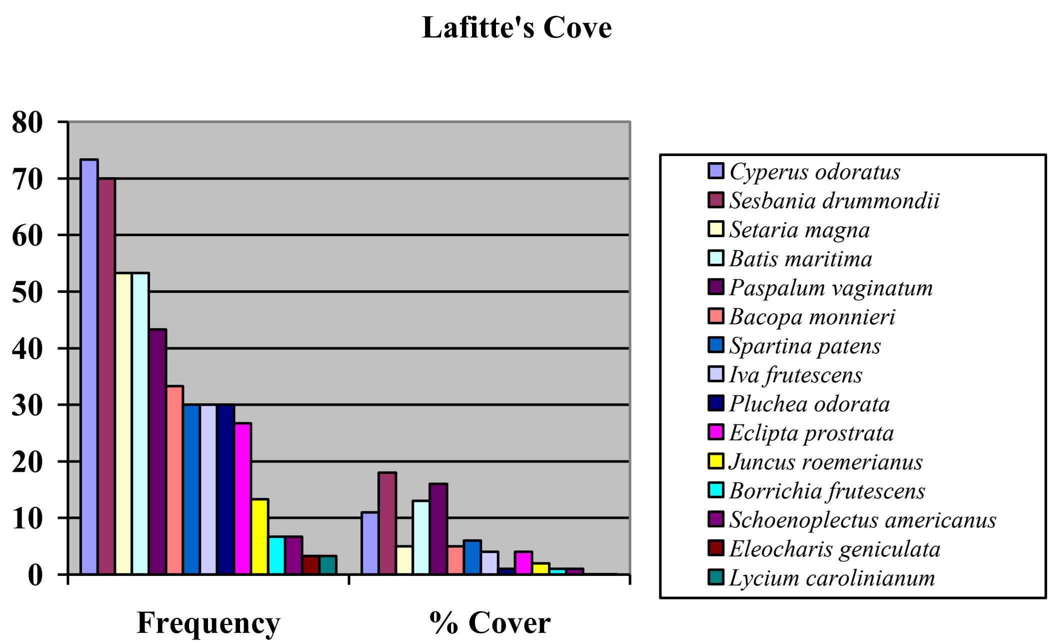

Figure 21. Comparison of frequency and % cover between all species at Lafitte's Cove Nature Preserve.

Table 4. Comparison of vegetation species in Lafitte's Cove Nature Preserve (Freq. = Frequency, Rel. Freq. = Relative Frequency, Sp. Comp. = Species Composition).

Species	**% Freq.**	**% Rel. Freq**	**% Cover**	**Sp. Comp**
Cyperus odoratus	73.3	15.38	11.0	13.0
Sesbania drummondii	70.0	14.69	18.0	21.0
Setaria magna	53.3	11.18	5.0	6.0
Batis maritima	53.3	11.18	13.0	16.0
Paspalum vaginatum	43.3	9.08	16.0	18.0
Bacopa monnieri	33.3	6.98	5.0	6.0
Spartina patens	30.0	6.29	6.0	7.0
Iva frutescens	30.0	6.29	4.0	4.0
Pluchea odorata	30.0	6.29	1.0	1.0
Eclipta prostrata	26.7	5.6	4.0	4.0
Juncus roemerianus	13.3	2.79	2.0	3.0
Borrichia frutescens	6.7	1.4	1.0	1.0
Schoenoplectus americanus	6.7	1.4	1.0	1.0
Eleocharis geniculata	3.3	0.69	0.08	0.09
Lycium carolinianum	3.3	0.69	0.08	0.09

At Dos Vacas Muertas Bird Sanctuary, *Phragmites australis* (73.3%) and *Spartina patens* (63.3%) were found to be more frequent then the other species in the sample site (Figure 22). The lowest frequencies were observed in *Eleocharis geniculata* (3.3%) and *Agalinis purpurea* (3.3%) (Figure 23). Percent cover was also highest in *Phragmites australis* (16.0%) and *Spartina patens* (15.0%). Species composition was highest in *Phragmites australis* and *Spartina patens*. With the exception of *Pluchea odorata* (10.0%), percent covers for the remaining species were lower than the dominant species, *Phragmites australis* and *Spartina patens* (Table 5).

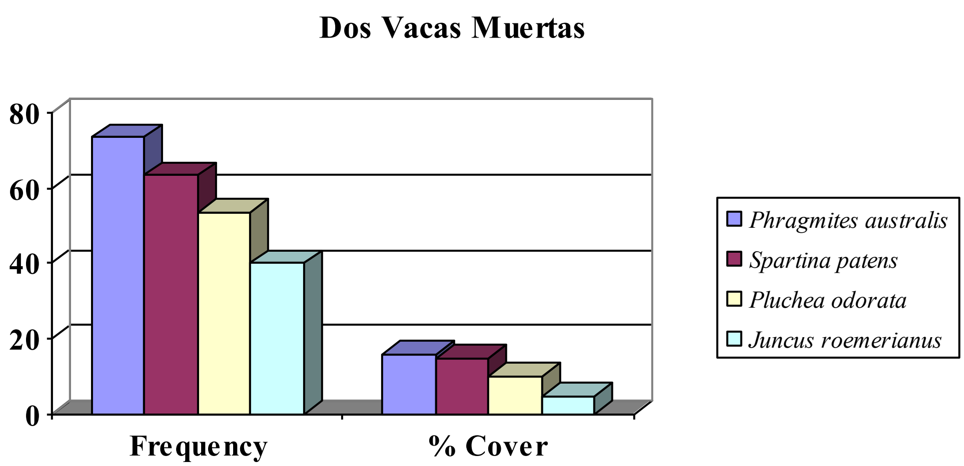

Figure 22. Comparison of % cover with species with the highest frequency in Dos Vacas Muertas Bird Sanctuary.

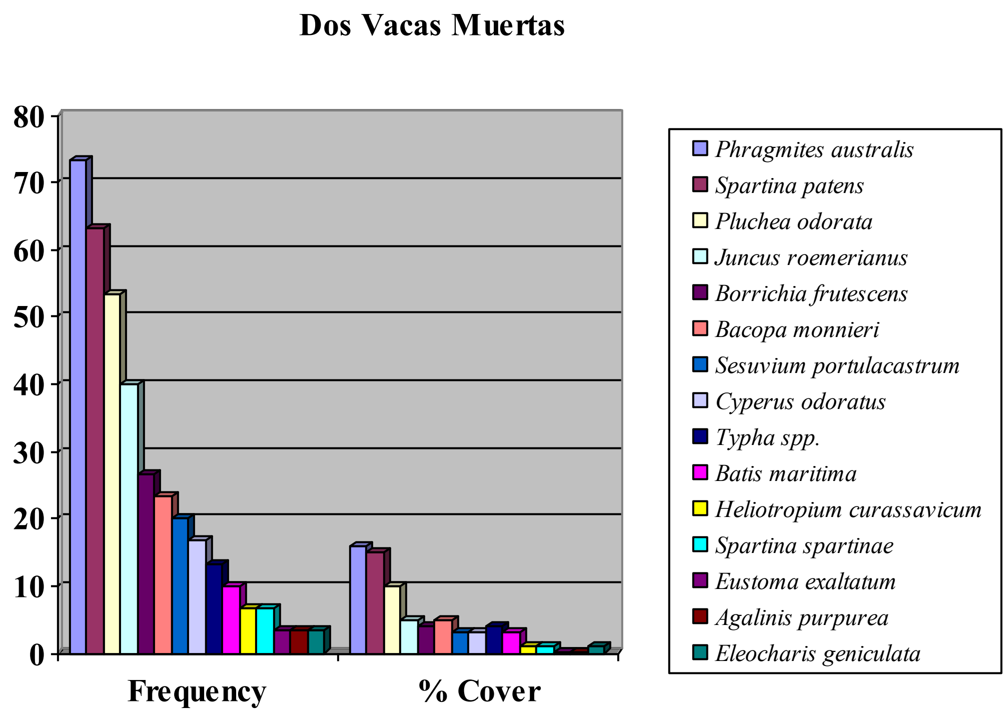

Figure 23. Comparison of frequency and % cover between all species in Dos Vacas Muertas Bird Sanctuary.

Table 5. Comparison of vegetation species in Dos Vacas Muertas Bird Sanctuary (Freq = Frequency, Rel. Freq. = Relative Frequency, Sp. Comp. = Species Composition).

Species	% Freq.	% Rel. Freq.	% Cover	Sp. Comp.
Phragmites australis	73.3	20.2	16.0	22.0
Spartina patens	63.3	17.4	15.0	22.0
Pluchea odorata	53.3	14.7	10.0	14.0
Juncus roemerianus	40.0	11.0	5.0	7.0
Borrichia frutescens	26.7	7.4	4.0	5.0
Bacopa monnieri	23.3	6.4	5.0	7.0
Sesuvium portulacastrum	20.0	5.5	3.0	4.0

Table 5. Continued.

Species	**% Freq.**	**% Rel. Freq.**	**% Cover**	**Sp. Comp**
Cyperus odoratus	16.7	4.6	3.0	5.0
Typha spp.	13.3	3.7	4.0	6.0
Batis maritima	10.0	2.8	3.0	5.0
Heliotropium curassavicum	6.7	1.8	1.0	1.0
Spartina spartinae	6.7	1.8	1.0	1.0
Eustoma exaltatum	3.3	0.91	0.08	0.1
Agalinis purpurea	3.3	0.91	0.08	0.1
Eleocharis geniculata	3.3	0.91	1.0	1.0

Frequency was highest in *Juncus roemerianus* (53.3%) and *Eleocharis geniculata* (50.0%) in Isla Del Sol (Figure 24). Several plant species exhibited a high frequency and overall frequency was more evenly distributed than the other sample sites. Frequency was lowest in *Eustoma exaltatum* (3.3%), *Distichlis spicata* (3.3%), *Ambrosia artemisiifolia* (3.3%), and *Eleocharis obtusa* (3.3%). Over half of the plant species had a frequency over 20% (Figure 25). Percent cover was highest in *Juncus roemerianus* (17.0%) and *Borrichia frutescens* (18.0%). Although *Eleocharis geniculata* was documented in more quadrat samples, its percent cover was only 11.0%. *Borrichia frutescens* demonstrated a higher total percent cover (Table 6). Species composition was highest in *Juncus roemerianus* and *Borrichia frutescens*.

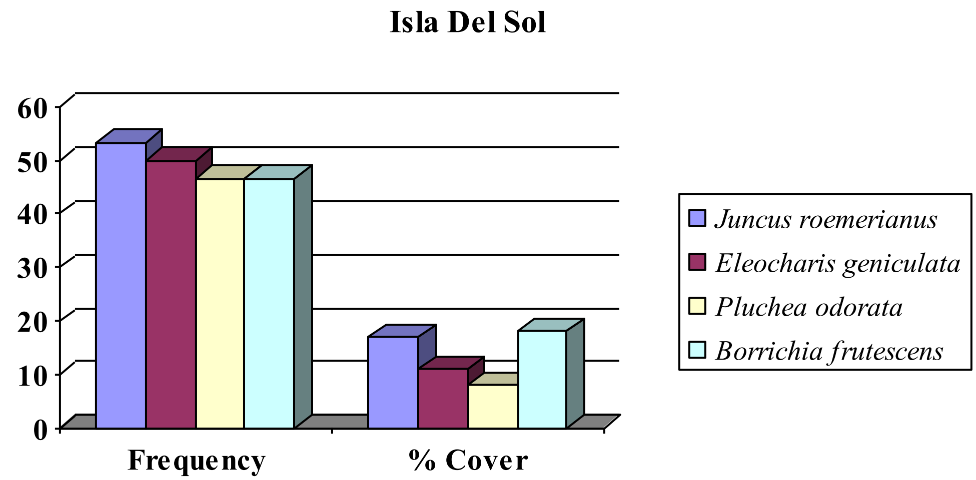

Figure 24. Comparison of % cover with species with the highest frequency in Isla Del Sol.

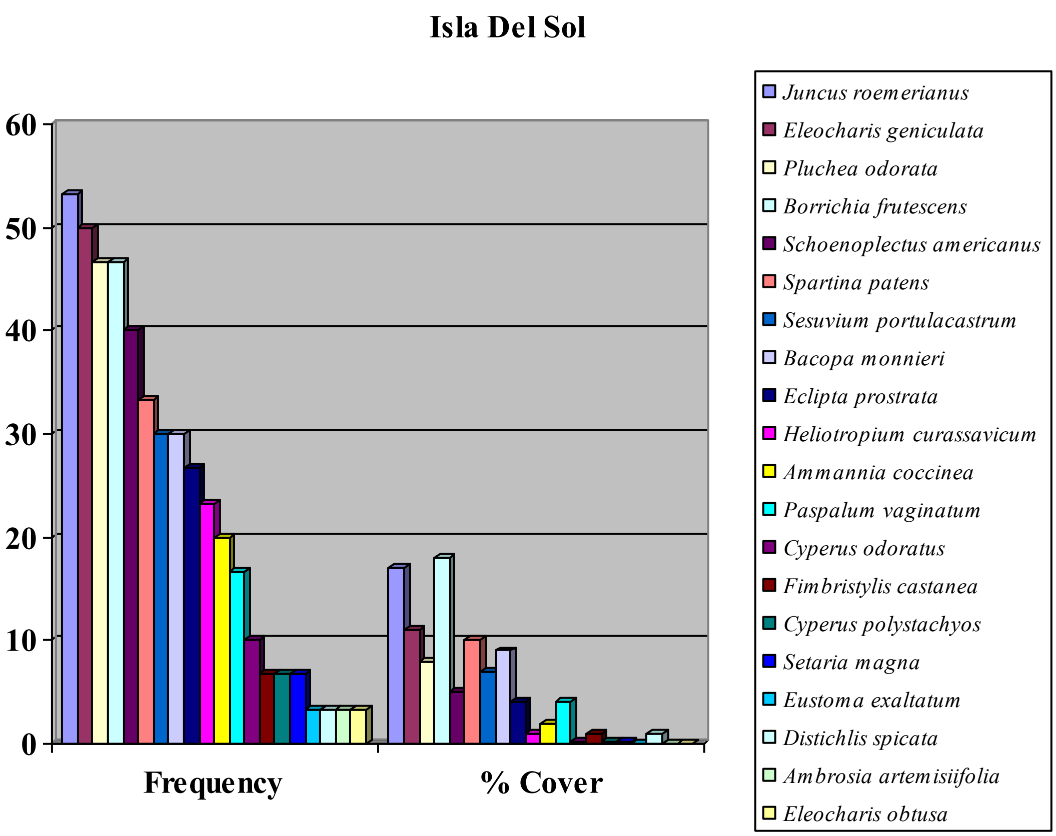

Figure 25. Comparison of frequency and % cover between all species at Isla Del Sol.

Table 6. Comparison of vegetation species in Isla Del Sol (Freq = Frequency, Rel. Freq. = Relative Frequency, Sp. Comp. = Species Composition).

Species	% Freq.	% Rel. Freq.	% Cover	Sp. Comp.
Juncus roemerianus	53.3	11.6	17.0	17.0
Eleocharis geniculata	50.0	10.9	11.0	11.0
Pluchea odorata	46.7	10.2	8.0	8.0
Borrichia frutescens	46.7	10.2	18.0	18.0
Schoenoplectus americanus	40.0	8.7	5.0	5.0
Spartina patens	33.3	7.2	10.0	10.0
Sesuvium portulacastrum	30.0	6.5	7.0	7.0
Bacopa monnieri	30.0	6.5	9.0	9.0
Eclipta prostrata	26.7	5.8	4.0	4.0
Heliotropium curassavicum	23.3	5.1	1.0	1.0
Ammannia coccinea	20.0	4.4	2.0	2.0
Paspalum vaginatum	16.7	3.6	4.0	4.0
Cyperus odoratus	10.0	2.2	0.25	0.25
Fimbristylis castanea	6.7	1.5	1.0	1.0
Cyperus polystachyos	6.7	1.5	0.16	0.16
Setaria magna	6.7	1.8	0.16	0.16
Eustoma exaltatum	3.3	0.72	0.08	0.08

Table 6. Continued.

Species	% Freq.	% Rel. Freq.	% Cover	Sp. Comp.
Distichlis spicata	3.3	0.72	1.0	1.0
Ambrosia artemisiifolia	3.3	0.72	0.08	0.08
Eleocharis obtusa	3.3	0.72	0.08	0.08

Isla Del Sol had the highest species diversity (2.68) of all three sample sites as well the highest evenness (0.543) (Table 7). Dos Vacas Muertas Bird Sanctuary (2.29) and Lafitte's Cove Nature Preserve (2.44) had the lowest species diversity. The level of diversity for a sample site was increased by having a larger number of species or by having a larger species' evenness. Evenness for the sample sites was determined by examining the results from the Shannon Diversity Index. Evenness in Lafitte's Cove Nature Preserve (0.491) and Dos Vacas Muertas Bird Sanctuary (0.487) were both lower than Isla Del Sol (0.543). There were several dominant species documented for the site including *Juncus roemerianus, Eleocharis geniculata, Pluchea odorata* and *Borrichia frutescens*. On the other hand, Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary were dominated by a single species or pairs of species. Since Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary were dominated by a few species their evenness was lower than Isla Del Sol.

Table 7. Species diversity using Shannon's Diversity Index

Test Site	Diversity (H)	Evenness (E)
Lafitte's Cove Nature Preserve	2.44	0.491
Dos Vacas Muertas Bird Sanctuary	2.29	0.487
Isla Del Sol	2.68	0.543

Similarity in species composition was high with the coefficient for pair-wise comparisons in Isla Del Sol and Lafitte's Cove Nature Preserve being the highest. The three sites shared 53% to 73% of their species (Table 8). There were several species that were unique to a certain sample site and absent from the other sites. This result was consistent from the results found by using Shannon's Diversity Index. Isla Del Sol possessed 6 species that were absent from the other sample sites. Dos Vacas Muertas Bird Sanctuary contained 4 unique species while Lafitte's Cove Nature Preserve had only 3 unique species. *Sesbania drummondii*, *Lycium carolinianum*, and *Iva frutescens* were found only in Lafitte's Cove Nature Preserve, where *S. drummondii* was a dominant species. Dos Vacas Muertas Bird Sanctuary contained *Agalinis purpurea*, *Typha spp.*, *Phragmites australis*, and *Spartina spartinae*. *Phragmites australis* was a dominant species while *Agalinis purpurea* and *Spartina spartinae* were found in low frequencies. Isla Del Sol, which had the highest number of unique species, contained *Fimbristylis curassavicum* , *Ammannia coccinea*, *Eleocharis obtusa*, *Distichlis spicata*, *Ambrosia artemisiifolia* and *Cyperus polystachyos*. Most of the species, with the exception of *Ammania coccinea*, had low frequencies for Isla Del Sol.

Table 8. Similarity of species among sites using Sorensen's Coefficient of Community.

	Lafitte's Cove	**Dos Vacas Muertas**	**Isla Del Sol**
Lafitte's Cove Nature Preserve	-	.533	.629
Dos Vacas Muertas Bird Sanctuary	.533	-	.571
Isla Del Sol	.629	.571	-

WETLAND DISTURBANCE RANKING

The test sites were qualitatively scored in reference to the amount of disturbance in and surrounding areas of their boundaries by two different methods, the Disturbance Index (Table 9) and the Anthropogenic Activity Index (Table 10). Disturbance index scores ranged from 10 to 24. Dos Vacas Muertas Bird Santuary had the lowest index score at 10. Lafitte's Cove Nature Preserve had the highest index score at 24 while Isla Del Sol followed close behind at 22. A major factor that contributed to the high scores of Lafitte's Cove Nature Preserve and Isla Del Sol was the presence of development. In comparison, the high level of development was lacking in Dos Vacas Muertas Bird Sanctuary. For the second method, Anthropogenic Activity Index, Lafitte's Cove Nature Preserve still retained the highest score at 14 out of a possible 15. Results for Isla Del Sol showed a slightly lower index score at 13 but still higher than Dos Vacas Muertas Bird Sanctuary, which scored only 7.

Table 9. Disturbance Index scores for sample sites.

	Lafitte's Cove Nature Preserve	**Dos Vacas Muertas Bird Sanctuary**	**Isla Del Sol**
Tier 1	Urban Land Cover Surrounding Site	Fallow Crop Land or Pasture Land Cover Surrounding Site	Urban Land Cover Surrounding Site
Tier 2	No Buffer	Grass Buffer	Grass Buffer
Tier 3	Altered Hydrology by Human Activity	Altered Hydrology by Human Activity	Altered Hydrology by Human Activity
Final Score	24	10	22

Table 10. Anthropogenic Activity Index scores for sample sites.

	Lafitte's Cove Nature Preserve	**Dos Vacas Muertas Bird Sanctuary**	**Isla Del Sol**
Surrounding Land Use Intensity	3	2	3
Intactness and Effectiveness of Buffer	3	1	2
Hydrologic Alteration	3	1	3
Habitat Alteration	3	2	3
Habitat Quality and Microhabitat Heterogeneity	2	1	2
Total	14	7	13

CHAPTER V

DISCUSSION

WETLAND PARAMETERS

Hydrology for the sample sites consisted of precipitation, evapotranspiration, surface flow and groundwater fluxes. The majority of the water in the sample sites was a result of rainfall. Therefore, it was initially fresh when it fell but it may have became progressively more brackish as water evaporated in the summer months and the remaining standing water accumulated salt from wind transport. Consequently, the salinity of the wetland sites may have changed according to rainfall and evaportranspiration. Wetlands at all of the sample sites were dry several times of the year especially during drought seasons. Rainfall in 2010 was significantly below normal during the summer as well as within the rest of the sampling period. Salinity levels in soils were also documented as higher in the designated ponded areas located within the sample sites.

Hydrology can be a primary factor in determining wetland structure and function, and alterations to the hydrologic regime may affect these natural processes which can result in an impaired wetland functioning or wetland loss (Kuhn, Mendelssohn an Reed 1999). Most isolated wetlands encompass a wide range of hydrological conditions that may lead to a diversity of habitat types and quality (Leibowitz 2003, Laubhan and Fredrickson 1997, Sharitz 2003). Alterations in the shape of the slopes of the wetland margins can affect water-gathering or water-disseminating properties (Ehrenfeld 2000). All three sample sites have at least one ponded area. The percent of open water varies depending on the site. Isla Del Sol had a large amount of open water (approximately 50%-75%) with vegetation concentrated on the margins. Dos Vacas Muertas Bird Sanctuary had a smaller amount of open water (approximately 25%) with stands of

Typha spp. and *Phragmites australis* contributing to vegetation. In Lafitte's Cove Nature Preserve the amount of open water (approximately 25%-50%) was reduced by the presence of *Sesbania drummondii*.

Since the survival and competition of plants in wetland ecosystems are found to be sensitive to water fluctuations (Muneepeerakul et al. 2008), species composition varied in response to the water table levels. Certain species were found in higher frequencies near water when compared to sample quadrats that were located farther from the lower flooded areas. *Bacopa monnieri*, *Paspalum vaginatum*, and *Batis maritima* were a few species that had higher frequencies in the low flooded areas as opposed to the higher and less frequently flooded areas. Overall, variances in water levels may affect species diversity within the sample sites and water fluctuations throughout the year may reduce or increase species' frequencies.

VEGETATION IN LAFITTE'S COVE NATURE PRESERVE

The vegetation of Lafitte's Cove Nature Preserve varied slightly with proximity to water. Transect one, located on the north section of the sample site, had a large frequency and percent cover for *Paspalum vaginatum*. The plant species was found along the water's edge and was often associated with *Bacopa monnieri* and *Batis maritima*. *Bacopa monnieri* and *Batis maritima* had large frequencies and represented a large portion of the plant species in the lower marsh areas. *Bacopa monnieri* and *Paspalum vaginatum* are often found in sandy brackish and tidal freshwater marshes (Tiner 1993). As the distance from water increased, the frequency and percent cover for the two species decreased. *Paspalum vaginatum* was less present in transect two, on the southern section of the sample site. *Sesbania drummondii* was another species that was dominant in and near the water's edge. Areas with *Sesbania drummondii* had little vegetation underneath the dense stands of the species. *Sesbania drummondii* is often associated with areas with sandy wet soils or brackish marshes (Tiner 1993). *Sesbania drummondii* was more dominant in the second transect and covered a large majority of the water. Another species that was dominant throughout the sample site was *Cyperus odoratus,* a grass-like plant that is found in both tidal and non tidal freshwater marshes (Tiner 1993). *Cyperus odoratus* was sampled outside of the *Sesbania drummondii* domain and further from the water's edge. *Cyperus odoratus* was a dominant species in both transects. Large stands of *Setaria magna* were found with *Cyperus odoratus* in both transects. *Setaria magna* is a tall annual grass that can be found in brackish and tidal freshwater marshes (Tiner 1993). Within the sample site, *Setaria magna* was often associated with *Spartina patens*. *Borrichia frutescens*, *Eclipta prostrata* and *Iva frutescens* were sampled at .5 m to 1 m from the water's edge. *Pluchea odorata* was often sampled with *Eclipta prostrata. Pluchea odorata* was not a dominant species in Lafitte's Cove Nature Preserve which differed from Dos Vacas Muertas Bird Sanctuary and Isla Del Sol. Frequencies for *Juncus roemerianus* and *Borrichia frutesens* were also low when compared to Dos Vacas Muertas and Isla Del Sol. Overall, vegetation characteristics for Lafitte's Cove Nature Preserve differed from Isla Del Sol and Dos Vacas Muertas Bird Sanctuary, who shared several of their dominant species.

VEGETATION IN DOS VACAS MUERTAS BIRD SANCTUARY

The first transect sampled along the northern section of the ponded area and *Phragmites australis* was found to be dominant throughout the transect. Stands of *Typha spp*. were sampled alone or mixed with *Phragmites australis*. *Bacopa monnieri*, *Sesuvium portulacastrum* and *Heliotropium curassavicum* were sampled along the water's edge. *Bacopia monnieri* and *Sesuvium portulacastrum* were found in higher frequencies then *Heliotropium curassavicum*. *Bacopia monnieri* is often associated with sandy brackish and tidal freshwater marshes while *Sesuvium portulacastrum* is associated with irregularly flooded salt flats or sandy borders of salt marshes (Tiner 1993). *Heliotropium curassavicum* is often found in regularly flooded and irregular flooded salt and brackish marshes (Tiner 1993). A few individuals of *Cyperus odoratus* were found more than 1 m from the water's edge. Frequency for *Cyperus odoratus* was less then Lafitte's Cove, where it was seen as a dominant species for the site. *Spartina patens* was sampled in dense stands 2 m to 4 m from the water's edge. The species was the second most dominant species for the site. *Juncus roemerianus* was often found mixed with *Spartina patens* and in a few cases, *Spartina spartinae*. *Spartina patens* and *Spartina spartinae* are commonly found in brackish marsh communities (White and Paine 1992). Only one individual of *Eustoma exaltatum* and *Agalinis pupurea* were found within the quadrats. Both species area associated with irregularly flooded salt and brackish marshes (Tiner 1993). The species were sampled in close proximity (less than 1 m) to each other and were found in the high marsh area, which is less likely to flood. Overall, Dos Vacas Muertas Bird Sanctuary was dominated by *Phragmites australis* along the water's edge and *Spartina patens* in the associated high marsh areas. *Phragmites australis* was unique to the sample site. Most of the plant species sampled were more associated with salt marsh and brackish marsh communities, with the main exceptions being *Phragmites australis* and *Typha spp*.

VEGETATION IN ISLA DEL SOL

There were several dominant species within the sample site. *Juncus roermerianus* was found in several locations, but its highest percent cover was sampled near the water's edge where it was mixed with *Spartina patens* and *Borrichia frutescens*. Vegetation near the water's edge was very dense and the quadrat samples held many individuals. *Juncus roemerianus* was also sampled in smaller stands at more than 5 m from the ponded area. *Eleocharis geniculata* was also a dominant species for the site. *Eleocharis geniculata* was found along the water's edge but was more dominant in the sandy flats and high marsh area. The species blanketed the ground underneath some of the larger species, *Pluchea odorata*, *Borrichia frutesens* and *Ammannia* *coccinea*. Along the water's edge, *Eleocharis geniculata* was associated with *Paspalum vaginatum* and *Bacopa monnieri*. *Cyperus odoratus* and *Cyperus polystachyos* were sampled near the water. This differed from the other sites where *Cyperus odoratus* was often found farther from the low marsh areas. *Schoenoplectus americanus* was also found along the water's edge with *Cyperus odoratus*. *Schoenoplectus americanus* was more dominant in Isla Del Sol when compared to the other sample sites. *Pluchea odorata* was another dominant species for the site and it was found in a large portion of the quadrats with *Borrichia frutescens*. *Pluchea odorata* is a typical brackish marsh species that can often be seen in saline conditions. Only one sample of *Distichlis spicata*, a common salt marsh species, was found in higher marsh area where it floods less frequently. Single samples of *Eustoma exaltatum*, *Eleocharis obtusa*, *Fimbristlylis castanea*, and *Ambrosia artemisiifolia* were found within the site. *Eleocharis obtusa* was found near the water's edge with *Paspalum vaginatum*. *Eleocharis obtusa*, *Ambrosia artemisiifolia*, and *Fimbristlylis castanea* were found in the higher marsh areas.

WETLAND VEGETATION OVERVIEW

Since sampling for plant composition was done only once it is unclear if there were seasonal variations in any of the factors studied. It may be deemed as unlikely since most species were present throughout the year. The majority of the species sampled were perennials. Most of the annual species found were of low importance to the sample site. Only two species were considered to have high frequencies in the sample sites, *Setaria magna* and *Eleocharis geniculata*. *Setaria magna* had a high frequency in Lafitte's Cove Nature Preserve. However, percent cover was lower for *Setaria magna* than most species and it was not considered dominant in Lafitte's Cove Nature Preserve. A high frequency and percent cover for *Eleocharis geniculata* was found only in Isla Del Sol.

Most of the species documented at each of the sample sites are commonly associated with similar wetlands that have been sampled throughout Galveston Island (White et al. 1993). When compared to sampling done by the Galveston Bay National Estuary Program in 1993 (White et al.1993), several species have been documented as naturally occurring. As observed by comparing similarities in species diversity, a significant amount of species were present on all sample sites. However, when compared to historical data of the sample sites we see a slight shift in species composition with the influence of freshwater and lack of tidal influence.

All plant species were classified as native species to Galveston Island, Texas. *Phragmites australis* is not a state mandated invasive species but is often considered invasive because of its tendency to displace other native plant species. Low water levels and the disappearance of existing plant communities, often seen in disturbed areas, can favor the establishment of *Phragmites australis* (Whyte et al. 2008). Therefore, *Phragmites australis* is often seen in disturbed areas like roadside ditches and retention ponds. *Sesbania drummondii* is a native species that has been documented in Lafitte's Cove Nature Preserve prior to development. It is not classified as invasive but dense stands of the species can displace native vegetation if not monitored. *Sesbania drummondii* pods are toxic and do not provide a good food source to wildlife (USDA 2010). *Tamarix spp.* was present at all three sites but was not included in the quadrat samples. *Tamarix spp.* is considered an introduced species and is considered to be highly invasive (USDA 2010). The wetland in Dos Vacas Muertas Bird Sanctuary was surrounded by stands of *Tamarix*. Isla Del Sol had a few individuals of *Tamarix spp.* spread throughout the site while Lafitte's Cove Nature Preserve had a dense stand at the southwest corner. *Typha spp.* can also grow in dense stands and displace native species but competition from *Phragmites australis* limited the species in Dos Vacas Muertas Bird Sanctuary.

Since all three sites were originally connected to tidal marshes, a loss of several *Spartina* grasses as well as an overall decrease in *Juncus roemerianus* was observed. *Spartina alterniflora* was originally documented in Isla Del Sol prior to development. Homes were built over *Spartina* marshes and *Spartina alterniflora* is now relatively rare from the site. *Spartina patens* was still abundant in Isla Del Sol and dense stands of the species were found outside the sampling area. *Spartina spartinae* was found in Isla Del Sol but was not included in the sample quadrats. High marsh areas that were less likely to flood had larger stands of the species in Isla Del Sol. *Spartina spartinae* was relatively rare in Lafitte's Cove Nature Preserve but was documented at a low frequency in Dos Vacas Muertas Bird Sanctuary. *Spartina patens* was also less abundant in Lafitte's Cove Nature Preserve when compared to the other sample sites. *Spartina alterniflora* was relatively rare in Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary and was not included in any quadrat samples. *Spartina alterniflora* was documented prior to housing development in Lafitte's Cove Nature Preserve.

White and Paine (1992) described vegetation communities of low emergent wetlands as including *Typha spp.*, *Cyperus articulates*, *Spartina patens*, *Bacopa monnieri*, *Eleocharis spp.*, and *Schoenoplectus americanus*. Some plant species are able to tolerate a large range of salinities and the types of species can overlap between the freshwater and brackish marsh communities, as well as between the brackish marsh and the salt marsh communities (White and Paine 1992, Penfound and Hathway 1938, Chabreck 1972). Although the sample sites were classified as freshwater wetlands they do retain characteristics that are often associated with the brackish marshes on the island. Seaward brackish marshes can often resemble the upper high marsh zone of the salt marsh (Tiner 1993) and vegetation characteristics may often mirror this behavior. Transect one, in Isla Del Sol, sampled along a sand flat which had a higher soil salinity. Therefore, plants species that were commonly associated with salt marsh systems or brackish marshes were found in the area. These species included *Distichlis spicata, Spartina patens, Spartina spartinae, Juncus roemerianus,* and *Sesuvium portulacastrum.* Some individuals of *Salicornia spp*. were observed in Isla Del Sol but were not included in the sample quadrats.

Juncus roemerianus is a species that is commonly associated with brackish marsh communities and it can be found in all three sample sites (White and Paine 1992). *Juncus roemerianus* often exhibits three different growth forms. The tall form can be seen at 1.5 m to 1.8 m. The intermediate form is .91 m and the dwarf form is .3 m (Tiner 1993). The tall form of *Juncus roemerianus* was found only in Isla Del Sol near the edge of the pond in transect two. The intermediate form of *Juncus roemerianus* was observed in Dos Vacas Muertas Bird Sanctuary, Lafitte's Cove Nature Preserve, and Isla Del Sol. In Isla Del Sol, *Juncus roemerianus* typically forms monotypic stands with other dominant marsh species giving the marsh a mosaic appearance (Tiner 1993). Monotypic stands were observed in Isla Del Sol when closest to the large ponded area. *Juncus roemerianus* was sampled in clumps with *Borrichia frutescens* and *Spartina patens*. *Juncus roemeiranus* was sampled in smaller clumps in Dos Vacas Muertas Bird Sanctuary when compared to Isla Del Sol. The species was often found with *Pluchea odorata* and *Spartina patens* in Dos Vacas Muertas Bird Sanctuar. Lafitte's Cove Nature Preserve had a much lower frequency and percent cover for *Juncus roemerianus* when compared to both Dos Vacas Muertas Bird Sanctuary and Isla Del Sol. Only a few small single patches of the species were found scattered throughout the site.

Sesbania drummondii was a major factor in limiting the species diversity of Laffite's Cove Nature Preserve. *Sesbania drummondii* can overpopulate an area and its height may make it difficult for some of the smaller species, like grasses, to grow. In comparison, the majority of Dos Vacas Muertas Bird Sanctuary was covered by *Phragmites australis*. The species diversity was lower in both Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuar when compared to Isla Del Sol. Overall Isla Del Sol had a higher species diversity, frequency and evenness. Isla Del Sol had more total plant species then both Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary. A greater evenness may be biologically equivalent to having more species, since a species that is present in smaller numbers may be more unlikely to contribute much to the biomass (Mulder et al. 2004). There were several dominant species documented for Isla Del Sol and species frequencies were more equal when compared to the other sample sites. The amount of dominant species for the site helped to increase the species diversity which also raised the species evenness for the site. Isla Del Sol had a higher number of unique species which also increased the species diversity for the sample site. There were only slight variations when comparing species diversity and evenness between Dos Vacas Muertas Bird Sanctuary and Lafitte's Cove Nature Preserve. Diversity for Lafitte's Cove Nature Preserve was slightly higher than Dos Vacas Muertas Bird Sanctuary. The smaller size of Dos Vacas Muertas Bird Sanctuary may have contributed to the smaller species diversity.

When compared to similar wetlands in the area (White and Paine 1992), Isla Del Sol appeared to retain many of the same characteristics that may have been present before isolation. Although Dos Vacas Muertas Bird Sanctuary had a lower level of human disturbance, vegetation diversity was impacted by the presence of *Phragmites australis*. In the case of Lafitte's Cove Nature Preserve, the proximity of human disturbance and the abundance of *Sesbania drummondii* reduced the amount of vegetation that was historic to the area (White and Paine 1992). Lafitte's Cove Nature Preserve is maintained by the Lafitte's Cove Nature Society and alterations to the wetlands often occur during the winter months when dead vegetation is removed. In comparison, Isla Del Sol and Dos Vacas Muertas Bird Sanctuary are relatively unmaintained throughout the year.

Buffers are an important resource as well as a protective measure for wetlands. A buffer typically consists of a band of vegetation along the perimeter of a wetland. High marsh species are considered important to marsh systems and may help to act as a buffer to the wetland. High marsh species grow in areas that are less likely to flood unless precipitation is high for the season. High marsh species may include several *Spartina* grasses and even shrubs like *Iva frutescens* or *Borrichia frutescens* (White and Paine 1992). In the case of Lafitte's Cove Nature Preserve a loss of high marsh species was observed. There was little to no buffer present as documented in the Disturbance Index and Anthropogenic Activity Index. Most homes were located between .50 m and 4 m from the wetland site. Isla Del Sol had a larger buffer zone with most homes being between 100 m to 200 m from the wetland. Only a few homes were less than 20 m from the wetland. A larger diversity of high marsh species was observed in Isla Del Sol. Dos Vacas Muertas Bird Sanctuary had a larger buffer then Lafitte's Cove Nature Preserve with most of the surrounding area undisturbed by human development. The closest homes were located on the west side at approximately 140 m to 180 m. A fence line of *Tamarix* surrounding the wetland and occasional mowing did cause some impact to the existing buffer. *Spartina spartinae* and *Spartina patens* were a few of the high marsh species present on the site.

WETLAND ALTERATION

Wetland alteration is an element that was present at all three sample sites. Because of their close proximity to terrestrial systems, coastal wetlands can be vulnerable to land development, pollutants, and many other human activities (Stedman and Dahl 2008). When examining wetland alteration, three factors may influence wetland ecosystem health. Factors include water level, nutrient status and natural disturbances. Through human activity, the modification of any one of these facets may be considered as wetland alteration (Mitsch and Gosselink 2007). In the case of the selected sample sites, the wetlands were disturbed by the decrease in water levels as well as downstream drainage impediments. Dredging, modification of hydrology regime and road construction all played a part in the alteration of the wetlands.

DISTURBANCE INDEX

Although Dos Vacas Muertas Bird Sanctuary scored lower on both of the disturbance indices, it was still impacted by the presence of *Phragmites australis,* which decreased the level of species diversity at the site. Dos Vacas Muertas' location caused it to have a lower level of human disturbance when compared to the other sample sites because of the lack of ongoing human development in close proximity to the site. Initial alteration was done by the landowners to isolate the wetland but since then the site has been preserved by the Houston Audubon Society. Occasional mowing around the perimeter for birdwatchers is the only constant anthropogenic impact in place.

Isla Del Sol had a higher Anthropogenic Activity Index level when compared to Dos Vacas Muertas Bird Sanctuary because of development around the wetland site. Development caused the surrounding land use metric score to be higher. The intactness and effectiveness of the buffer metric, examined by the Anthropogenic Activity Index, was lower than Lafitte's Cove Nature Preserve because of the larger vegetative buffer surrounding the wetland. Only a few homes were found in close proximity to the ponded area on the northwest corner of the site. Some dredging has been conducted in the ponded areas to increase the depth of the water. Dredging has also increased the total amount of open water present.

Lafitte's Cove Nature Preserve had the highest Anthropogenic Activity Index score and human disturbance score. As previously discussed, Lafitte's Cove Nature Preserve had a limited vegetative buffer around the wetland. Fences and manicured lawns were often located less than 1m from the wetland margin. Therefore, there is no effective barrier around the site and runoff has been altered. As in the case of Isla Del Sol, some dredging has been conducted to increase the depth of the water and to model the wetland to its original state before isolation. When examining the microhabitat heterogeneity in Lafitte's Cove Nature Preserve, we see a low level of variation among plant species. Although the amount of overall open water was less at Lafitte's Cove Nature Preserve than in Isla Del Sol, there was still a substantial amount in the east and west corners of the wetland.

Hydrological features of wetlands, such as drainage and circulation patterns, may make wetlands more sensitive to impacts from highway construction (Liu and Cameron 2001). This statement is especially true given the isolated state of the sample wetlands. Construction of canals and roads can help to establish permanent barriers to the growth of particular vegetation. Barriers may also change the nature of the interaction with adjacent patches of vegetation and prevent certain patches of vegetation from becoming dominant in a landscape (Liu and Cameron 2001, Forman and Godron 1986). Both Lafitte's Cove Nature Preserve and Isla Del Sol were surrounded by roads and dredged canals were found in close proximity. Dos Vacas Muertas Bird Sanctuary did not possess any dredged canals on or near the site. Only a small gravel road was present at the entrance of the sanctuary.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on the sampled data, Isla Del Sol scored highest when comparing species diversity and percent cover. When considering Shannon's Diversity index, Isla Del Sol had the highest overall species diversity and evenness. Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary had similar results and were both lower than Isla Del Sol. Sampling in Isla Del Sol found 20 species within the quadrat samples. In comparison, Lafitte's Cove Nature Preserve and Dos Vacas Muertas Bird Sanctuary had only 15 species present. When comparing plant species among the sites, it was found that Isla Del Sol had 6 species that were not found in the other sample sites. Dos Vacas Muertas Bird Sanctuary had 4 unique species while Lafitte's Cove Nature Preserve had only 3 unique species. When looking at similarities among plant species in the sample sites, several species were found to be dominant throughout all three sample sites. *Juncus roemerianus*, a common brackish-marsh species, was a dominant species for all three sample sites. The plant species was often found in clumps which may have accounted for the large percentages found in the sample sites. *Pluchea odorata*, *Cyperus odoratus*, *Spartina patens* and *Borrichia frutescens* were found in high frequencies in all three sample sites.

Lafitte's Cove Nature Preserve was dominated by *Sesbania drummondii* making it difficult for other species to thrive under its domineering condition. Lafitte's Cove Nature Preserve also suffered from a lack of adequate vegetative buffer conditions which reduced the amount of high marsh species present as well as the overall species diversity for the site. Lafitte's Cove Nature Preserve scored the highest in both the Disturbance Index and the

Anthropogenic Activity Index because the site was surrounded by a high level of development including roads, homes and man-made canals.

Dos Vacas Muertas Bird Sanctuary was dominated by *Phragmites australis* which is often considered an invasive species because of its ability to quickly overtake an area and block out native species. Dos Vacas Muertas Bird Sanctuary scored better than the other test sites in both the Disturbance Index and the Anthropogenic Activity Index. Given its location, it did not suffer from the increased level of human development that plagues the other test sites. Although it did have a lower level of anthropogenic impact, the level of diversity and evenness remained lower when compared to Isla Del Sol. The low diversity and evenness may have been influenced by the presence of *Phragmites australis*. The site was also smaller than the other sample sites which could have reduced the number of species present.

Species diversity and species richness was higher in Isla Del Sol when compared to the other sample sites. Of the 20 species found, several dominant species were observed and frequencies for the species were more equal when compared to the other sample sites. Although there were some dominating species found, evenness was found to be higher than the other sample sites. A large part of the success for the site was the presence of high marsh species. When approaching the margins of the water, clumps of *Juncus roemerianus* were dominant. However, as the distance from the water margins was increased, species diversity began to vary and a wider range of species were documented. Dos Vacas Muertas Bird Sanctuary also exhibited the same behavior with *Phragmites australis* but it was not as obvious as seen in Isla Del Sol.

Hydrology of a wetland can play a large part in the types of vegetation present. The duration and seasonality of flooding and soil saturation may play a strong part in the type and distribution of plants and plant communities within the wetlands. It was difficult to document the overall vegetation changes throughout the test sites because of a lack of vegetation sampling prior to the early 90's. When vegetation sampling was done by White and Paine in 1990 and 1991, early aerial photos were compared. For the most part, only slight variations were found throughout the years prior to 1990's. These slight variations can often be attributed to natural factors including drought or storms. Subsidence has also claimed and created several acres of emergent wetlands. However, when development started to increase in the areas in the mid 1980's and 1990's changes became more evident. The changes were more apparent in Lafitte's Cove Nature Preserve and Isla Del Sol. When the areas were developed, large sections of wetlands were preserved and placed under control of the City of Galveston. Development around the sites has continued to increase throughout the years and the amount of undeveloped land has decreased throughout the island. As the level of technology increases it may become easier to obtain yearly aerial photos and document landscape changes overtime.

RECOMMENDATIONS

Management activities of the sample sites should be aimed at maintaining the existing vegetative communities and hydroperiods. The wetlands in Lafitte's Cove Nature Preserve and Isla Del Sol are both owned by the City of Galveston, therefore it is unlikely that the areas will be developed any further. Dos Vacas Muertas Bird Sanctuary is owned by the Houston Audubon Society and it will continue to be preserved as well. Currently there are some home sites available for sale on the west side of Dos Vacas Muertas Bird Sanctuary. On the east side of the site over 250 acres are owned by Texas A&M University. Given their location, Isla Del Sol and Lafitte's Cove Nature Preserve cannot be expanded. This makes improving a vegetative buffer zone highly unlikely for Lafitte's Cove Nature Preserve, which may affect the wetland in the future. Altered or artificially isolated wetlands can be harder to maintain then naturally occurring wetlands. To better understand the status of the selected wetlands, several studies may need to be conducted to monitor the different wetland parameters.

Since vegetation sampling was done only once in this study to identify and compare species cover and frequency, it may be beneficial to sample vegetation at different times of the year. Vegetation can be sampled before and after drawback to determine if different species persist at different times of the year (Coulloudon et al. 1999). This may aid in determining the vegetation succession in the wetlands. Seasonal analysis may also include plant biomass sampling.

In reference to anthropogenic disturbance, another way to monitor how wetlands are functioning is to observe invertebrate populations. Invertebrate sampling may be done once a year to observe the different functional states of the wetlands. Species composition may aid to monitor the status of the wetland as well as the water quality (EPA 1995).

Given the isolated status of all three sample sites, monitoring water levels throughout the year may be beneficial. Monitoring the effects of fluctuating water levels may also aid in understanding invertebrates and bird use. All three sample sites are major bird watching locations for the island, therefore past bird counts can be easily obtained if need be.

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APPENDIX A

ANTHROPOGENIC ACTIVITY INDEX (AAI)

ANTHROGPOGENIC ACTIVITY INDEX

Site: Study: Date:

Metric 1: Surrounding Land Use Intensity (500 m surrounding site)

_____ **Points**

	Very-Low-as expected at reference site	No evidence of disturbance, grassland, freshwater wetland	0
	Low-mostly undisturbed, some human influence	Old fields, secondary forest, shrubby woodlots	1
	Moderate- significant amount of human influence	Active pasture, high road density, newly fallowed fields, other intermittent agricultural practices	2
	High-Intensive use of land up to buffer or wetland margin	Urban, residential, industrial operations, other intensive agricultural operations	3

Metric 2. Intactness and Effectiveness of Buffer (up to approximately 50 m surrounding site)

_____ **Points**

	Best- ~50m wide, as expected for reference site	Mature forest, grassland, freshwater wetland	0
	Moderate -50-25m wide, some human influence	Mixture of grassland and secondary forest, old fields, shrubby woodlots	1
	Fair-25-10m wide with significant human influence	Active pasture, newly fallowed field, adjacent roads, other intermittent agricultural practices	2
	Poor-no effective buffer	Row cropping, turf vegetation, adjacent urban development, other intensive agricultural practices	3

Metric 3. Hydrologic Alteration

_____ **Points**

	Very Low- as expected at reference site	No evidence of disturbance	0
	Low-low intensity alteration	Or past alteration not currently affecting wetland	1
	Moderate- significant, visible influence	Current and active	2
	High- intensive activity	Major disturbance currently and actively effecting hydrology	3

Subtotal from this page: ______

ANTHROGPOGENIC ACTIVITY INDEX

Site: Study: Date: _________

Metric 4. Habitat alteration (within wetland)

_____ Points

	Very Low- as expected from reference	No evidence of human activity	0
	Low- low intensity, or not currently affecting wetland	Some removal of vegetation, but vegetation is recovering	1
	Moderate- significant alteration of either vegetation or substrate	Vehicle use, grazed livestock hooves, woody debris removal, mowed	2
	High- intensive disturbance of vegetation and substrate	Dredging, filling, tiling, vehicle use, tree/shrub removal, removal of emergent vegetation	3

Metric 5. Habitat Quality and Microhabitat Heterogeneity

_____ Points

	Best- large amount of habitat heterogeneity, high diversity of microhabitats	Small proportion of open water, 0-25%, large amount of emergent and submerged vegetation and coarse woody debris, some standing dead trees	0
	Moderate- significant amount of habitat heterogeneity	25-50% open water, some woody debris	1
	Fair- small amount of habitat heterogeneity	50-75% open water, no woody debris	2
	Poor- small amount of habitat heterogeneity	75-100% open water	3

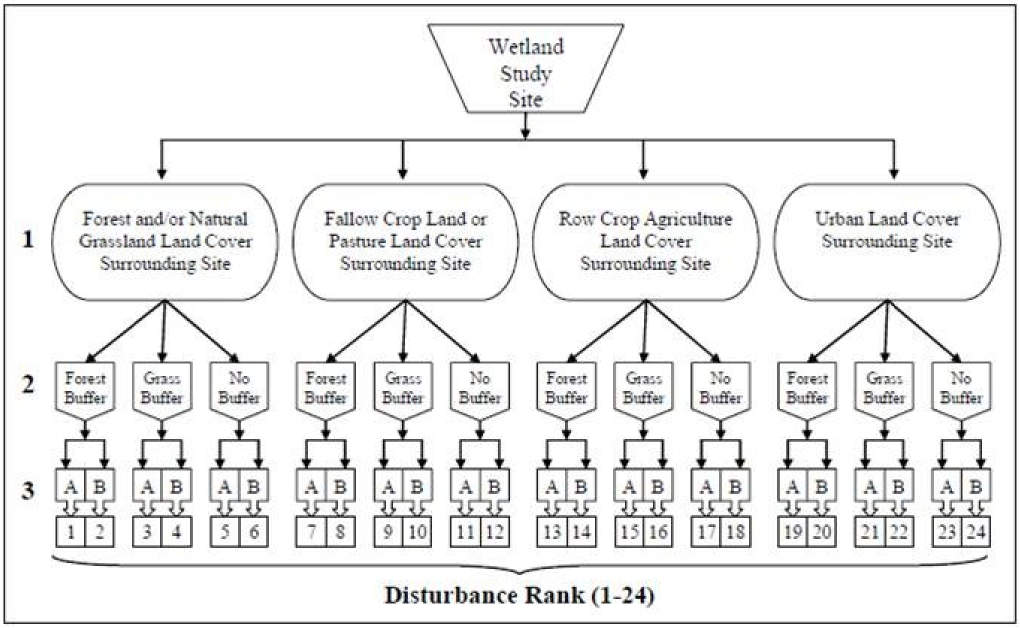
Subtotal from this page: ______

Total Anthropogenic Activity Index Score

Redrawn from Herman 2005, Gernes and Helgen 2002, and Mack 2001.

APPENDIX B

DISTURBANCE INDEX (DI)



A hierarchical flow chart used to rank wetland sites based on three types and intensities of human activities. A = unmodified, naturally occurring and B = altered hydrology by human activity. (Herman 2005, Lopez and Fennessy 2002)

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