

**The Effects of Dissolved Oxygen, pH, and Light on Seagrass Distributions in  
Corpus Christi Bay and the Mission-Aransas NERR**

Meaghan Cuddy  
GIS in Water Resources, Fall 2015  
The University of Texas at Austin

## I. Introduction

Seagrass beds are dynamic, productive and ecologically valuable coastal marine ecosystems; they support complex food webs, provide habitat for commercially valuable fishes and benthic organisms, reduce coastal erosion, attenuate wave action, and improve water quality by filtering out pollutants (USGS Gulf of Mexico Program, 2004).

Seagrasses cover nearly 12,000 hectares of the Texas Coastal Bend, performing these vital ecosystem services for the Gulf Coast. The Texas coast is home to five seagrass species: the system is dominated by *Halodule wrightii*, *Thalassia testudinum*, and *Syringodim filiforme*, while *Halophila engelmannii* and *Ruppia maritima* cover a smaller area. Seagrass distribution is significantly impacted by water quality; species have highly specific tolerance limits for salinity, oxygenation, light availability, and nutrient richness (USGS Gulf of Mexico Program, 2004).

In spite of their ecological and economic value, however, seagrasses in Texas face significant threats: dredging, eutrophication, and commercial and recreational boating have resulted a loss of 20-50% of the total seagrass beds in the Gulf of Mexico (Audubon Texas et al., 2011). Because of these trends, monitoring and conservation of seagrass beds has become a high priority in the management of marine ecosystems. In Texas, the Texas Statewide Seagrass Monitoring Program, initiated in 2011, conducts annual seagrass bed surveys of 567 sites along the coast of southern Texas geographically stretching from Corpus Christi to Lower Laguna Madre. The monitoring program works in four main areas: the Corpus Christi Bay, Mission-Aransas NERR, Upper Laguna Madre, and Lower Laguna Madre (Wilson et al., 2013). This project, however, will focus exclusively on Corpus Christi Bay and the Mission-Aransas NERR.

These two regions were selected for analysis in this project because of the interesting comparison they provide. While these regions are geographically separated only by the Aransas Channel, conditions in the Bay and the NERR with respect to human interaction are very different. Corpus Christi Bay is surrounded by a built environment, with a significant population living and working right on the coastline. There is also significant boat traffic on the Bay and automobile traffic directly adjacent to it. The NERR, meanwhile, is a federally protected area designated for research, education, and conservation, and therefore has much less human interaction.

This project seeks to understand the relationship between human impact, water quality, and seagrass health in Corpus Christi Bay and the Mission-Aransas NERR. Data collected between 2011 and 2014 by the Texas Seagrass Monitoring Program is used to determine how water quality parameters affect seagrass species distributions and how human proximity might affect water quality parameters. These relationships are modeled using data collected for dissolved oxygen (%), pH, and total suspended solids (TSS), as well as total seagrass benthic coverage and species dominance at each of the 138 sampling sites. It is hypothesized that Corpus Christi Bay, owing to its more built environment and higher level of human-ecosystem interaction, will be a more impacted system. This will be signified by higher TSS values, lower dissolved oxygen levels, more extreme pH values, and lower total seagrass coverage. It is also hypothesized that seagrass species distributions and levels of dominance will be closely related to changes in dissolved oxygen, pH, and TSS.

## II. Methods

## Data Collection

As a part of the Texas Statewide Seagrass Monitoring Program, sampling sites in Corpus Christi Bay (n = 81) and the Mission-Aransas NERR (n=57) are sampled annually. These sites were established in conjunction with the National Oceanic and Atmospheric Administration's field surveys of this area; sites were randomly assigned within a grid of 500m tessellated hexagons. During annual surveying, rapid assessment sampling methods are employed; at each site, water quality conditions are recorded and seagrass percent cover and species distribution is reported from four quadrats. Plant tissue samples are taken for stable isotope analysis and water samples are taken for total suspended solids.

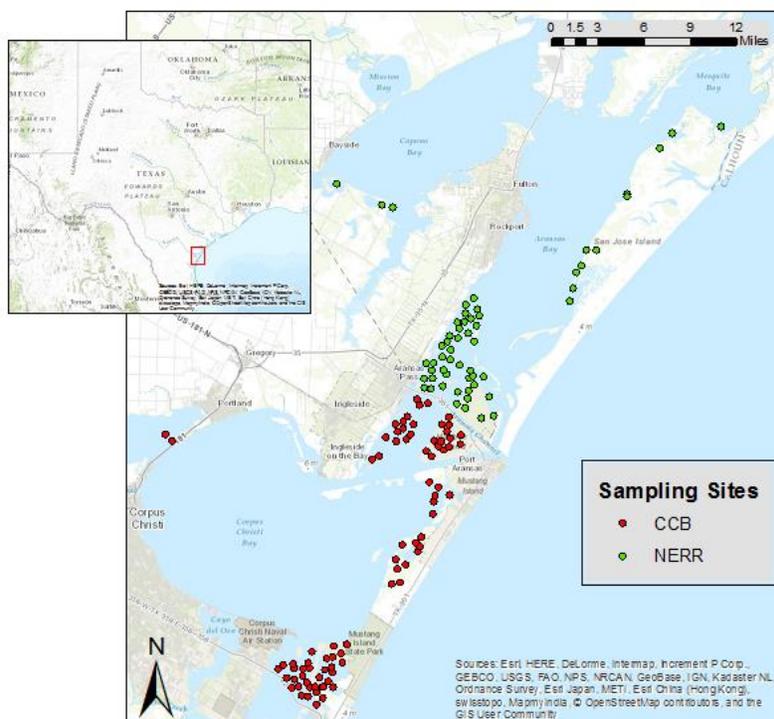


Fig. 1: Corpus Christi Bay and Mission-Aransas NERR Sampling Sites

## Project Parameters and Data Analysis

For this project, overall seagrass benthic percent cover and species dominance in the Corpus Christi Bay (81 sites) and the Mission-Aransas NERR (57 sites) between 2011 and 2014 was assessed. For each site, pH, TSS, and dissolved oxygen (percent) were also analyzed. These variables were selected to be representative of human impact on these systems; since light attenuation data was variable for these two sampling sites, TSS concentrations were used as a proxy for turbidity/light availability. Other possible variables considered for inclusion were total suspended solids and stable isotope data (C:N:P); these were excluded due to incomplete datasets and time constraints. Salinity data was averaged in the same way and added to the analysis after species distributions were visualized in order to provide a more complete explanation for the observed distributions.

Data each field site from 2011-2014 was averaged in order to provide an overview of the conditions at each site. Data from 2015 was not included in this analysis because the dataset for the most recent field season is not fully updated at this time. Species dominance was compared year-to-year; average dominance was assigned by the one or two most dominant species recorded at each site during the four years of surveying.

### GIS Analysis

Latitude and longitude for each of the 138 sites in the project area were added to ArcGIS as XY data onto the World Topographic base map. Each point was visualized with colors differentiating sampling sites within the NERR and sites within Corpus Christi Bay (see Fig. 1). Water quality (pH, TSS, and percent dissolved oxygen) and seagrass data (total percent cover and species distributions) were aggregated in Microsoft Excel, and this table was then added to ArcGIS as well. The table was joined to the site location layer based on the SiteID feature. Dissolved oxygen, pH, TSS, and overall seagrass cover (and later, salinity) were each visualized using a color gradient and species dominance was visualized using a unique category color scale.

The Editor toolbar was used to add create two new polygon layers delineating the area of Corpus Christi Bay and the NERR. Within the “Create Features” window, the Construction tool was used to manually draw these two polygons based on the area of these systems given by the base map.

In order to produce a smooth map that communicated water quality conditions across the Bay and NERR, Empirical Bayesian-Kriging interpolation tool within the Geostatistical Analyst toolset was employed. This method of interpolation was chosen over other possible methods (such as spline or natural neighbor) as it is considered to be the optimal technique for spatial predictions and its ability to accurately depict changes over a relatively small area, as well as the clear map it produces (Krivoruchko, 2012). Rasters symbolizing percent dissolved oxygen, pH, TSS (in dry weight), salinity, and total percent cover were produced and clipped to the extent of the Bay and NERR area polygons. These rasters were then overlaid with the dominant species at each sampling site in order to determine if and how water quality is impacting seagrass distributions.

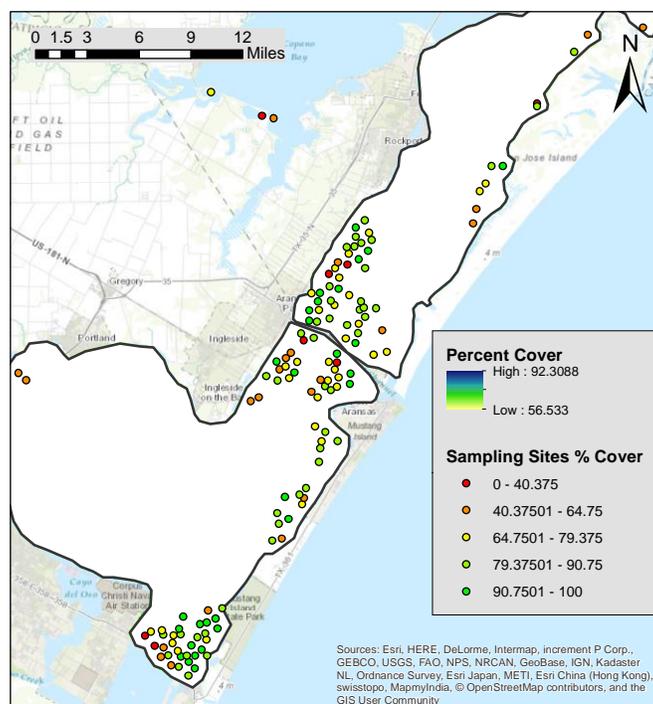
Finally, the statistics function was used to determine the mean and standard deviations for each water quality parameter in both Corpus Christi Bay and the NERR. Statistical software was then used to determine if there was a statistically significant difference between conditions in the two systems.

## III. Results

### Overall Percent Cover

Generally, total seagrass coverage appears to be fairly consistent across Corpus Christi Bay and the Mission-Aransas NERR. Across sampling sites in both systems, coverage across this four year period generally ranges from 60-100%, indicating that seagrass beds in both these systems are doing relatively well and maintaining a significant benthic area (see Fig. 2). There are a few isolated sites of low or non-existent seagrass cover at inland sites, however, it is possible that these sites are historically bare and the low percent cover is not representative of seagrass loss but rather that seagrasses are simply not found at that location.

Coverage is slightly higher in the Mission-Aransas NERR system, with a mean of 76.55% cover ( $SD \pm 17.14$ ), compared to a mean coverage of 68.19% ( $SD \pm 30.03$ ) in Corpus Christi Bay, but this difference is not statistically significant (p-value: 0.059).

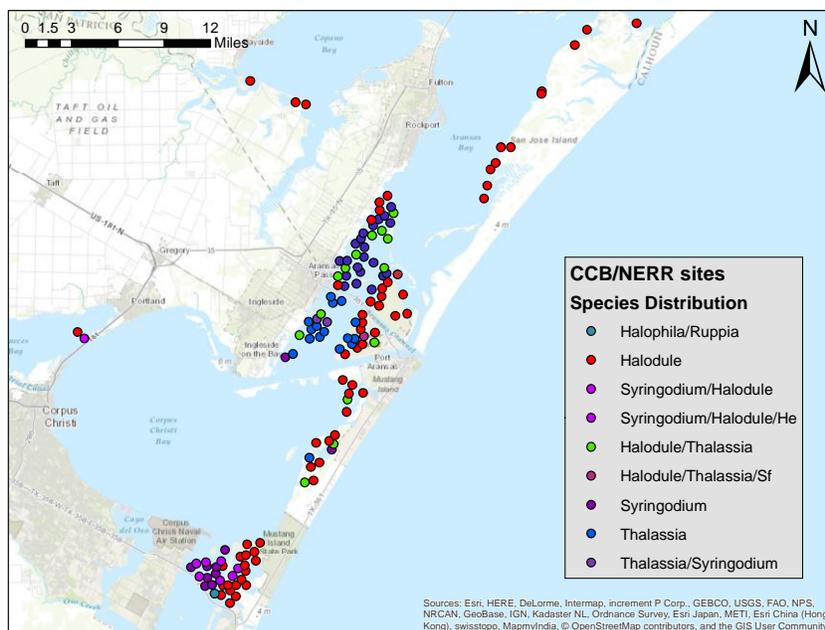


**Fig. 2: Mean Benthic Cover (%), 2011-2014**

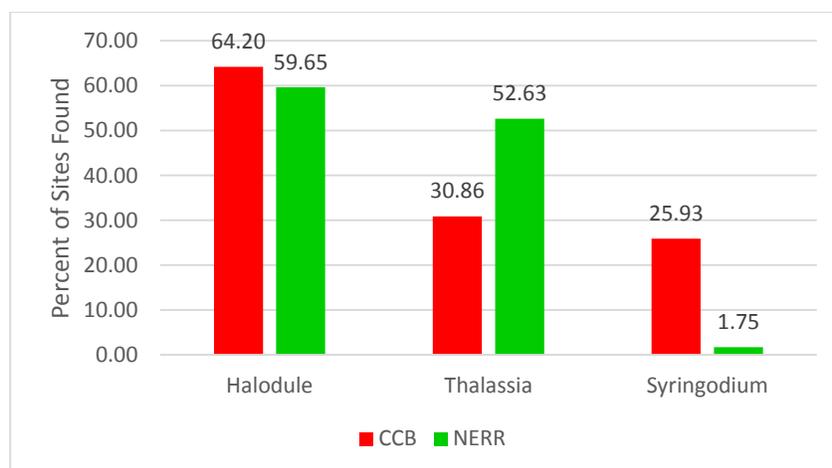
### Seagrass Species Dominance and Distributions

Mapping of the dominant seagrass species at sites in Corpus Christi Bay and the NERR clearly indicated that *Halodule wrightii* is the most dominant species throughout both system, present at 83 of the 138 sites (62% of all sites). It is slightly more prevalent in Corpus Christi Bay than in the NERR. *Thalassia testudinum*, meanwhile, is the second most-common species in this area, found at 55 of the 138 sites (40% of all sites) and is more common in the Mission-Aransas NERR. *Syringodium filiforme*, the third most-common species, is almost solely in Corpus Christi Bay, where it is found at 25% of the sites, while it is found at only 1.75% of sites in the NERR (see fig. 4).

Three prominent trends were identified using this dominance map. Firstly, in addition to being the most common species overall, *H. wrightii* appears to dominate the eastern side of the estuary/bay system, closest to the Gulf of Mexico. *T. testudinum* dominance and a *H. wrightii/T. testudinum* mixed dominance appears to be more common in the NERR system, and, specifically, is aggregated on the eastern side of the bay system around the Aransas Channel. *S. filiforme* is almost completely absent in the NERR, and is present in a prominent cluster in the southernmost area of the Corpus Christi Bay. In order to determine the possible factors influencing these distributional trends, each chosen water quality parameter was mapped and overlain with seagrass dominance at each site.



**Fig. 3: Seagrass Species Dominance/Distributions, Aggregated 2011-2014**



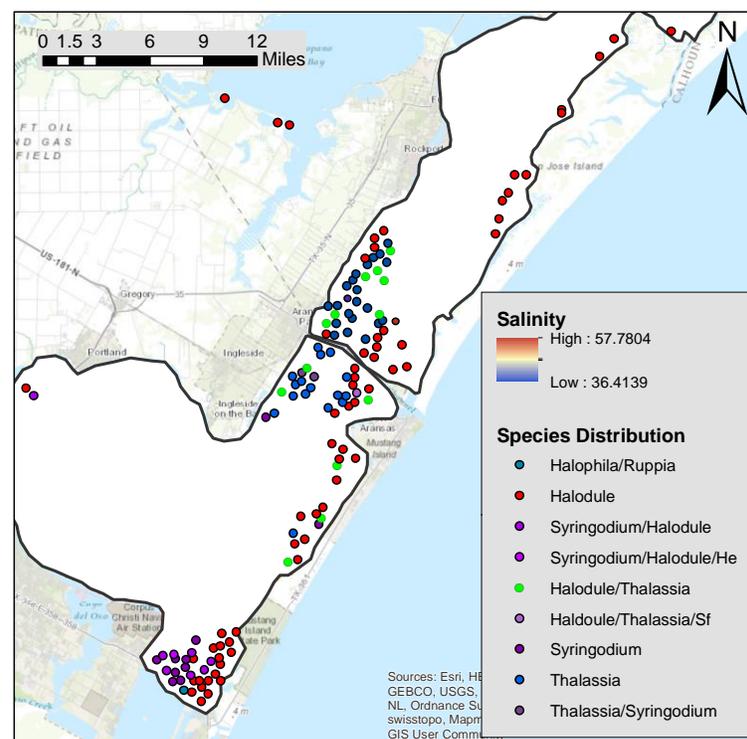
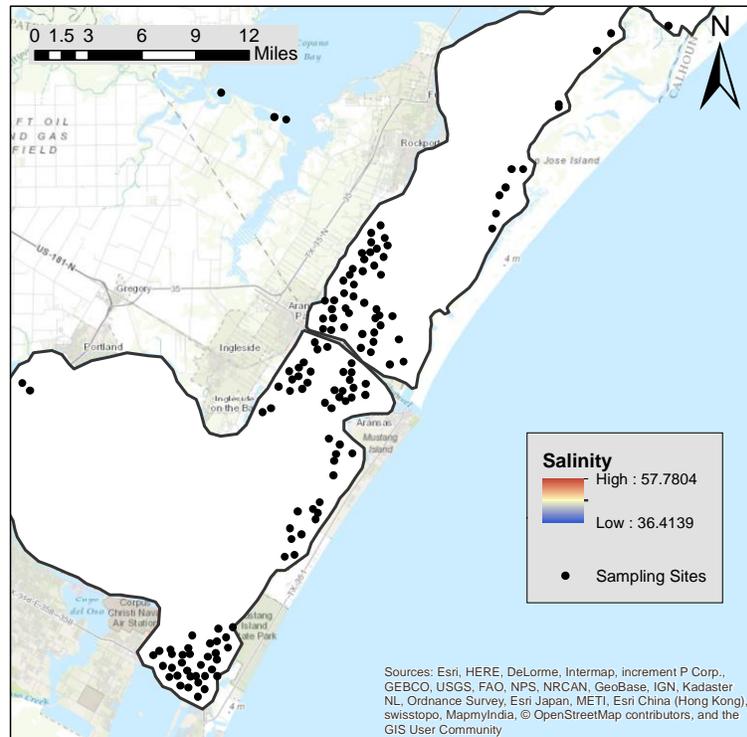
**Fig. 4: Commonness of Dominant Species within NERR and CCB**

### Salinity

*H. wrightii*'s strong dominance of the eastern side of both Corpus Christi Bay and the Mission-Aransas NERR, closest to the Gulf of Mexico, led to the inclusion of salinity as an explanatory variable. It was hypothesized that this trend might be attributable to *H. wrightii*'s salinity tolerance exceeding that of the other seagrasses present in these systems (Lirman and Cropper, 2003). Higher salinities may be excluding other species from settling closer to the Gulf.

Mapping the average salinity of these systems showed that there was a significant difference between Corpus Christi Bay and the NERR, with Corpus Christi Bay having a much higher mean salinity of 42.91 (SD  $\pm$  3.55) than the NERR, with a mean salinity of 38.7 (SD  $\pm$  2.61,  $p$ -value = 0.001). In addition to this difference between the Bay and the NERR, however,

the map also shows a strong gradient of increasing salinity towards the Gulf of Mexico; when mapped with the species dominance, there is a notable consistency between the dominance of *H. wrightii* on the eastern side of the bay and estuary systems and this salinity gradient. It thus appears that salinity has a significant effect of species distribution in these systems.

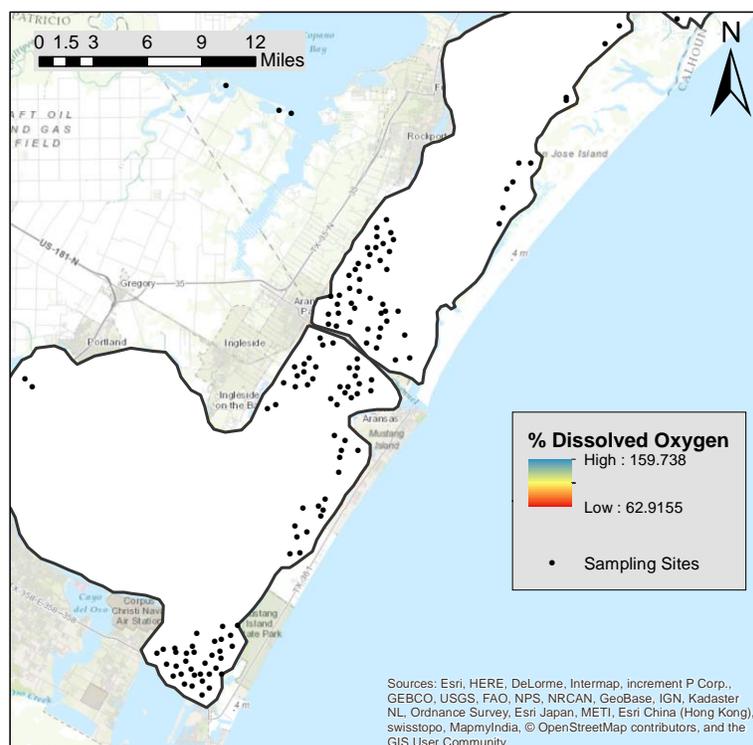


**Figs. 5 and 6: Salinity Gradient Mapped w/ Seagrass Species Distributions, 2011-2014**

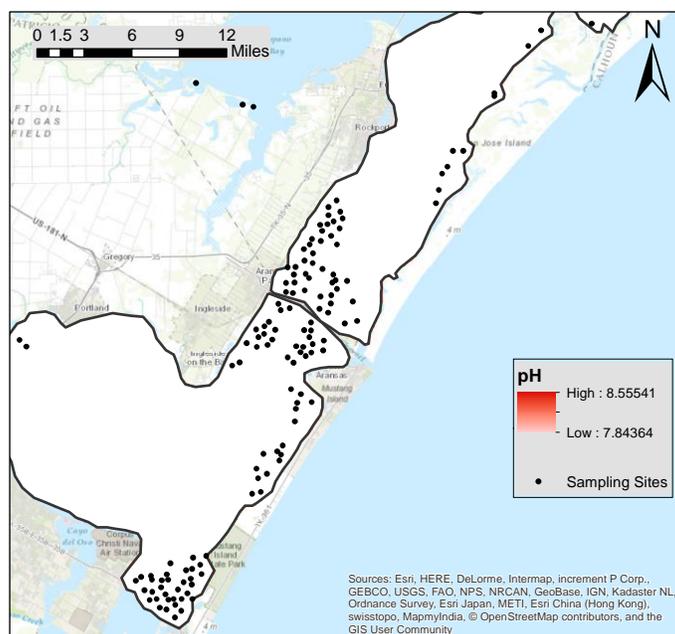
### Dissolved Oxygen (%)

Mapping of the 2011-2014 average of percent dissolved oxygen (% DO) in the NERR and Corpus Christi Bay indicated that there was a significant difference between % DO in these two systems ( $p$ -value = 0.013); mean dissolved oxygen in Corpus Christi Bay was calculated to be 108.27 ( $SD \pm 22.85$ ), while in the Mission-Aransas NERR it was calculated to be 118.9 ( $SD \pm 26.24$ ). There is a notable clustering of low %DO values around the Aransas Channel and the town of Aransas Pass, consistent with the cluster of *Thalassia testudinum* found there. There is also a low %DO cluster in Corpus Christi Bay close to the towns of Port Aransas.

These patterns may be indicative of the effect of human presence on seagrass health and species distribution. The channel and bay areas adjacent to towns see a significant amount of boat traffic; this, along with the proximity of these areas to roadways and a relatively large population likely induce a significant amount of disturbance and nutrient pollution to the marine environment, nutrient inputs, and influencing the low dissolved oxygen found there (Minnesota Pollution Control Agency, 2009). *T. testudinum*, with a longer and broader leaf than any of the other species present in this system, may be best equipped to thrive in a more physiologically stressful environment such as this, explaining its dominance around the channel. In the southern cluster of low %DO near Port Aransas, however, *H. wrightii* maintains a more significant presence than in this area. This may indicate the salinity plays a larger role in excluding seagrass species than oxygen availability; as discussed above, the gradient of increasing salinity from coast to Gulf correlates to the dominance of *H. wrightii* on the eastern edge of both the Bay and the NERR. While *T. testudinum* may indeed dominate areas of stress and low oxygen, the species may be unable to colonize high-salinity regions.







**Fig. 9: Mean pH, 2011-2014**

### Total Suspended Solids

TSS data were used as a proxy for light availability; higher TSS dry weights are indicative of more suspended particles in the water at a particular site, thus increasing turbidity and reducing light availability to seagrasses. There was not a statistically significant difference between TSS in Corpus Christi Bay and the Mission-Aransas NERR (p-value = 0.764). Mean TSS in Corpus Christi Bay

Notably, there is a cluster of low TSS values that corresponds to the cluster of *S. filiforme* found in the southern corner of Corpus Christi Bay. Light, therefore, appears to be an important factor in the settlement of *S. filiforme*. As earlier studies have found, *S. filiforme* has a high minimum light requirement, thus possibly excluding it from more turbid areas in these systems (Kenworth and Fonseca, 1996). However, as noted above, *S. filiforme* is found almost exclusively in Corpus Christi Bay. While the NERR has a slightly lower (though not significant) mean TSS value than Corpus Christi Bay, this, indicates that there is another variable or variables not included in this project that may explain the exclusion of *S. filiforme* from all but a relatively small region of Corpus Christi Bay.

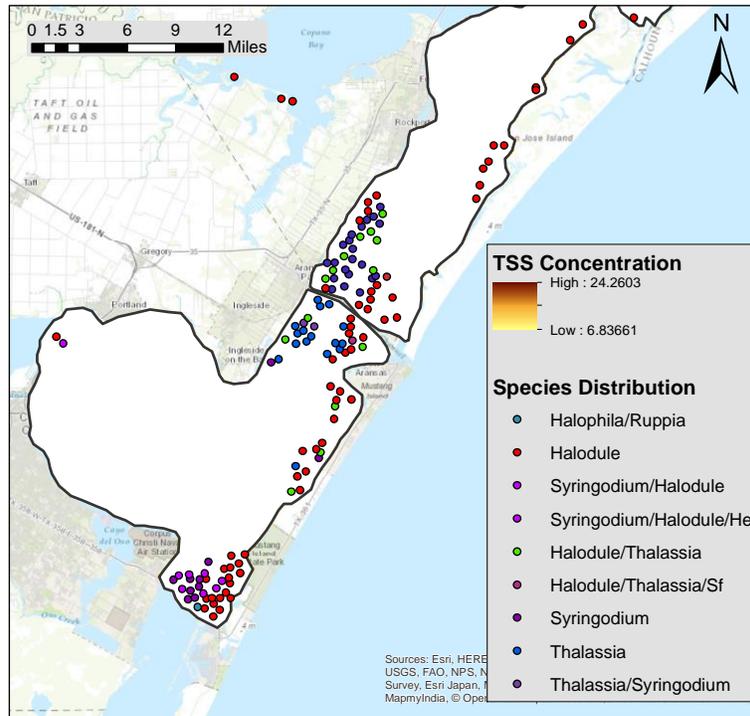
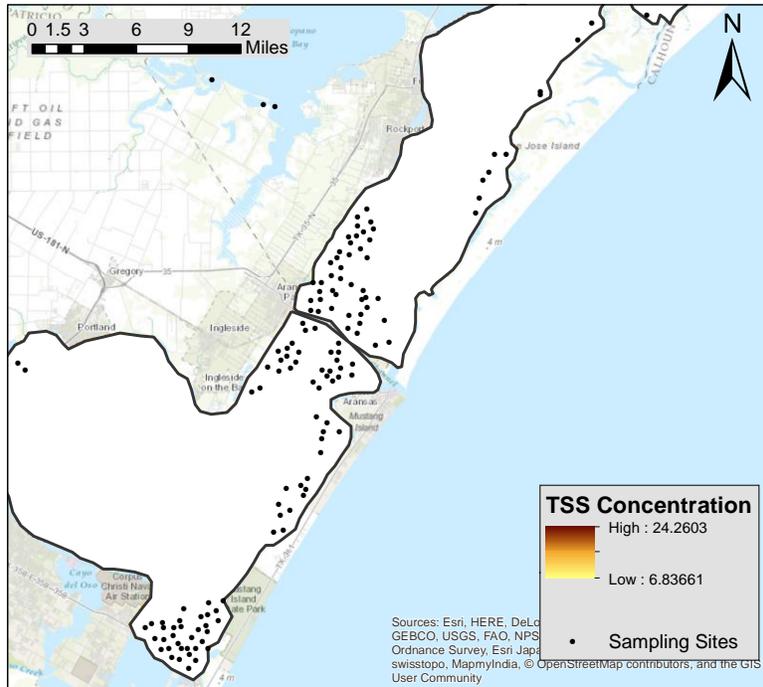


Fig. 10 and 11: TSS (dry weights) Mapped w/ Seagrass Species Distribution, 2011-2014

	NERR (n=57)		CCB (n=81)		2-sided P-value
	$\mu$	$\Sigma$	$\mu$	$\sigma$	
Salinity	38.7	2.61	42.91	3.55	<b>0.0001</b>
% DO	118.9	26.24	108.27	22.85	<b>0.013</b>
% SG Cover	76.55	17.14	68.19	30.03	0.059
pH	8.15	0.18	8.13	0.19	0.535
TSS	13.15	7.09	13.54	8.03	0.764

**Fig. 12: Statistical Summary of Water Quality Parameters and Seagrass Cover (ordered by increasing p-value)**

#### IV. Discussion and Conclusions

##### Corpus Christi Bay/ Mission-Aransas NERR Comparison

Since total seagrass percent cover was fairly similar between the Corpus Christi Bay and the NERR, this analysis focused more heavily of species distributions and how these parameters impact where species are able to flourish. The results of this project indicate that, while total percent seagrass cover does not seem to differ significantly between Corpus Christi Bay and the Mission-Aransas NERR, there are notable differences in both water quality and seagrass species between these two systems. Respective of these water quality parameters, it appears that the hypothesis that Corpus Christi Bay experiences greater human impact (and thus reduced water quality) is, to a certain degree, correct; the Bay exhibits lower dissolved oxygen levels, and higher TSS values (ie., less light availability). Furthermore, the Bay also has lower average total seagrass coverage. However, it is important to note that of these parameters, only the %DO had a statistically significant difference between the two systems. Therefore, it is possible to conclude that while Corpus Christi Bay may in fact be a more impacted system, it only appears to be slightly more impacted than the NERR. This is surprising given that the NERR experiences much less human impact than the Bay. However, water quality and seagrass coverage are impacted by a large suite of factors and, owing to the design of this project, many of these parameters were not included in this analysis. Therefore, these findings should be regarded as an incomplete analysis of the overall health of the seagrasses and level of human impact in these systems.

The hypothesis that seagrass species distributions would vary with changing water quality conditions also appears to be partially correct. While some predictors, like salinity and TSS values, appear to have a rather large effect on seagrass species distributions, others, like pH, do not seem to have a large impact on what species of seagrass will dominate a given area. Others still, such as dissolved oxygen, seem to affect species distributions in tandem with other variables. Additionally, these results indicate that there is a likely a hierarchical manner in which water quality parameters affect seagrass species distributions; for example, of the investigated water quality parameters, it appears that salinity has a significant effect on seagrass species distributions and may even override the effects of other aspects of water quality, as seen in the relationship between dissolved oxygen, *T. testudinum*, and *H. wrightii*.

Owing to the large number of possible variables that may be impacting water quality and seagrass distributions in these systems that have not been modeled in this project, it is difficult to make definitive conclusions about how these water quality parameters specifically impact the seagrass beds in Corpus Christi Bay and the NERR and how human proximity impacts these specific parameters. However, these results make it clear that seagrass species distributions, water quality, and human impact are, in many ways, interrelated.

### GIS Analysis

It is also possible to draw conclusions about the effectiveness and appropriateness of GIS-based analysis from this project's results. The Empirical Bayesian Kriging interpolation method produced clear maps that were useful in drawing conclusions about water quality trends across the Corpus Christi Bay and NERR. However, it is also important to note that the use of GIS tools has the potential to be misleading. In this instance, some of the sites were relatively isolated from the others (for example, the northernmost sites in the NERR and western-most sites in Corpus Christi Bay). Because of this, the effects of some were seen over a much larger areas than the values for sites that were close together, while four sites in the NERR were not included in the interpolation. Since this study area was relatively small, this likely did not have a large impact on the results, but is still a factor to be considered in this analysis.

### Future Work

The findings of this project, while providing some explanation for seagrass distributions in Corpus Christi Bay and the Mission-Aransas NERR, indicate a need for more study. Possible next steps include running a regression model to statistically determine the magnitude to which different water quality components impacts seagrasses. Qualitatively, it appears that factors such as salinity and light availability have a larger impact on seagrass species distribution and dominance than other variables (such as pH), but for the purposes of this project the quantitative magnitudes of effect of these variables were not calculated. Additionally, owing to the likelihood of hierarchical effects, it might be beneficial to test the interaction between water quality parameters in order to determine how they affect one another and if there are any synergistic, antagonistic, or additive effects of different components of water quality occurring simultaneously.

Finally, while a temporal analysis was considered (ie., a comparison of conditions in Corpus Christi Bay and the Mission-Aransas NERR across years), it was ultimately not conducted due to the availability of only four years of data. Four years is likely not an adequate time scale to accurately track changes to the system over time. However, as this data set develops, it will likely become an interesting point of study.

## V. References

- Texas Seagrass Monitoring Program Data: Dunton Lab, University of Texas at Austin Marine Science Institute.
- Audubon Texas et al. (2011). *Texas Gulf Coast restoration priorities*. Retrieved 4 Dec. 2015 from <http://www.sgmsummit.org/stepping-stones/pdf/04-RestorationPriorities.pdf>.
- Kenworth, WJ & Fonseca, MS. (1996). Light requirements of seagrasses *Halodule wrightii* and *Syringodium filiforme* derived from the relationship between diffuse light attenuation and maximum depth distribution. *Estuaries*, 19 (3): 740-750.
- Krivoruchko, K. (2012). Empirical Bayesian Kriging implemented in ArcGIS geostatistical analyst. *ArcUser*, Fall 2012: 6-10.
- Lirman, D. & Cropper, WP. (2003). The influence of salinity on seagrass growth, survivorship, and distribution within Biscayne Bay, Florida: field, experimental, and modeling studies. *Estuaries*, 26 (3): 131-141.
- Minnesota Pollution Control Agency (2009). *Low dissolved oxygen in water causes, impact on aquatic life – an overview*. Retrieved 1 Dec. 2015 from <http://www.pca.state.mn.us/index.php/view-document.html?gid=8545>.
- USGS Gulf of Mexico Program. (2004). *Seagrass habitat in the northern Gulf of Mexico: degradation, conservation and restoration of a valuable resource*. (Publication no. 855-R-04-001). Stennis Space Center, MS.
- Wilson, CJ, Wilson, SS, Whiteaker, DL, & Dunton, KH. (2013). *Assessment of seagrass habitat, quality, and plant condition in Texas coastal waters: 2011 and 2012*. Retrieved 1 Dec. 2015 from <http://texasseagrass.org/doc/2011%20-%202012%20Final%20Edited%20Seagrass%20Report%20for%20Web%20Page.pdf>.