Investigating the effects of nutrient limitation, light, and salinity upon seagrass cover in the lower Laguna Madre

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Introduction

Laguna Madre is a hypersaline lagoon along the bottom coast of Texas, one of roughly six such lagoons in the world (NPS). The Laguna Madre is home to the most expansive seagrass beds in the western Gulf of Mexico and has historically been the most productive Texas bay fishery (Onuf 1996). Specifically, seagrass beds are important areas of primary productivity and form the base for coastal ecosystems. They support complex food webs, provide protection for juvenile commercially important fish and improve water quality (Fry and Barker, 1979).

The process of photosynthesis in seagrasses requires an input of nutrients and sunlight. Focusing on nutrients, the three main requirements are Carbon, Nitrogen and Phosphate, which seagrasses often obtain from the water column and sediment pore water. The ideal amount of each nutrient required for growth is described with the seagrass Redfield ratio of 550:30:1 in the order of Carbon:Nitrogen:Phosphorus (Atkinson and Smith 1983). When the available nutrients are in that ratio seagrasses are able to use all the available nutrients. Deviations from that ratio indicate the environment is limited in one or more of the nutrients and once the limited nutrient is depleted they are unable to grow. Focusing upon Nitrogen to Phosphate concentrations, the ideal ratio is 30:1 (Atkinson and Smith 1983). When the ratio is lower than 30, the area is nitrogen limited and when the ratio exceeds 30 the area is phosphorus limited.

Additional factors that affect seagrass growth are light attenuation and salinity. Light is a requirement for photosynthesis, and decreased light attenuation due to past dredging has been found to lower seagrass cover in the Laguna Madre (Onuf 1994). Conversely, seagrasses that receive too much sunlight and high temperatures in shallow areas can reduce their rate of photosynthesis (Campbell et al 2006). Due to the hypersaline nature of the Laguna Madre, seagrasses have adapted to tolerate a high salinity and have been shown to decline after a reduction in salinity (Quammen and Onuf 1993).

Along the lower Laguna Madre there are two common seagrasses; *Thalassia testudinum* and *Halodule wrightii*. Specifically, *Halodule* is an important food source for multiple species of diving ducks while both *Thalassia* and *Halodule* support overall coastal ecosystems (Quammen and Onuf 1993). This project focuses upon seagrass in lower Laguna Madre to investigate the variables that lead to changes in seagrass cover in this extremely productive ecosystem. The selected variables to explain percent cover are nutrient limitation, light attenuation and salinity. This project seeks to determine if there is nutrient limitation of either nitrogen or phosphorous and subsequently explore the relationship between that limitation and percent cover. It is hypothesized that there will be lower percent cover in regions with nutrient limitation, lower light attenuation and lower salinity.

Methods

Data Collection

The data used in this project were collected from the Texas Statewide Seagrass Monitoring Program. This program is a statewide effort to record the health of seagrass by measuring a wide variety of parameters at 567 permanent stations starting in the Aransas and Redfish Bays down to the lower Laguna Madre. The scientists collect light attenuation, dissolved oxygen, salinity, chlorophyll, pH, percent cover, temperature, total suspended solids and samples for later nutrient isotope analysis at each site. Specifically, this project focused upon the sampling sites within the lower Laguna Madre as defined by NOAA shapefiles (Figure 1). Light attenuation was measured by calculating the light attenuation coefficient Kd_m-1, salinity was measured using a SONDE probe and nutrient ratios were measured using samples collected, dried and ground up for isotope analysis.

Fig1: Lower Laguna Madre area of interest along the Texas Coast

<u>Data Analysis</u>

For this project, data were collected from the sampling sites within the lower Laguna Madre from the years 2011-2015. Salinity, percent cover, and irradiance (N=285) have information available for 2011-2017, however the nutrient ratios only have information for 2011-2015 due to the time required for isotope analysis (N= 69). In order to accurately combine the data, information for 2011-2015 for each variable was compiled, averaged in Excel, and put into ArcGIS Pro. Each sampling site had an associated latitude and longitude that was inputted using the add data function. Once the table was added, the exact values were plotted using the Add XY Data tool.

In order to create a smooth basemap of percent cover, the Empirical Bayesian-Kriging tool was used to interpolate percent cover across the lower Laguna Madre region for both *Halodule* and *Thalassia*. EBK was chosen to interpolate the data points because it is most accurate kriging method for small datasets and is able to more accurately account for errors of prediction. Light attenuation, salinity, and N:P ratios were visualized using graduated symbols placed upon the two seagrass percent cover backgrounds. Next, the hoptspot analysis tool was used to identify areas of statistically high or low values for each variable. These areas of significance are displayed on the seagrass base maps to visually correlate the variables to regions of high and low percent cover.

Finally, light attenuation, N:P ratios, and salinity were put into a linear model to quantify the effect of each variable on the percent cover for *Halodule* and *Thalassia*. The model was run on the points that had complete N:P ratio information (N=69). These methods were influenced by work done on this dataset by past students and have been applied to nutrient data not previously available.

Results

Nitrogen to phosphorous ratios were plotted over *Halodule* and *Thalassia* seagrass percent cover. The N:P values for *Halodule* range from 27.9 to 64.5 with a mean of 45.7 (SD ± 9.43) (Figure 1). The hotspot analysis shows an area of significantly low values over a red area of higher percent cover, while it also shows an area of high values over another area of high percent cover (Figure 2). This is the opposite of the expected correlation between low values and higher percent cover. The N:P values for *Thalassia* range from 26.06 to 67 with a mean of 38.9 (SD ± 9.48) (Figure 3). The hotspot analysis shows a clustering of significantly lower N:P ratios over areas of increased percent cover and high values over decreased cover as would be expected based on Redfield's ratio (Figure 4).

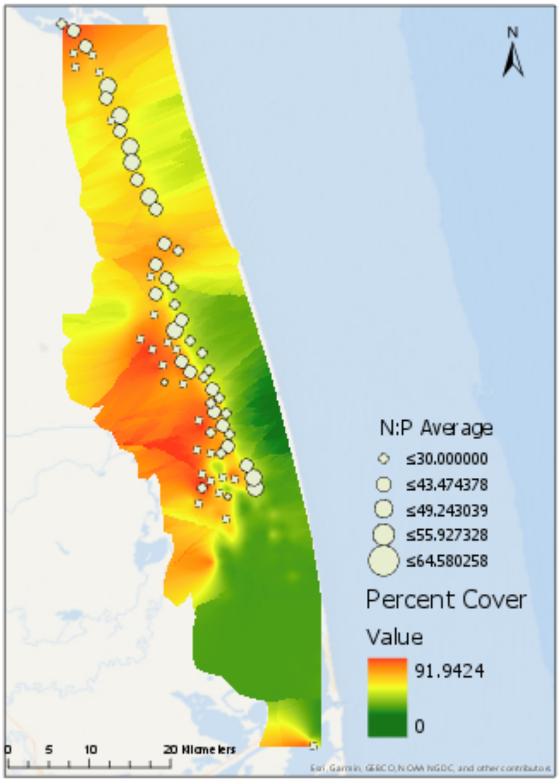

Fig 2: *Halodule* N:P ratio over Percent Cover

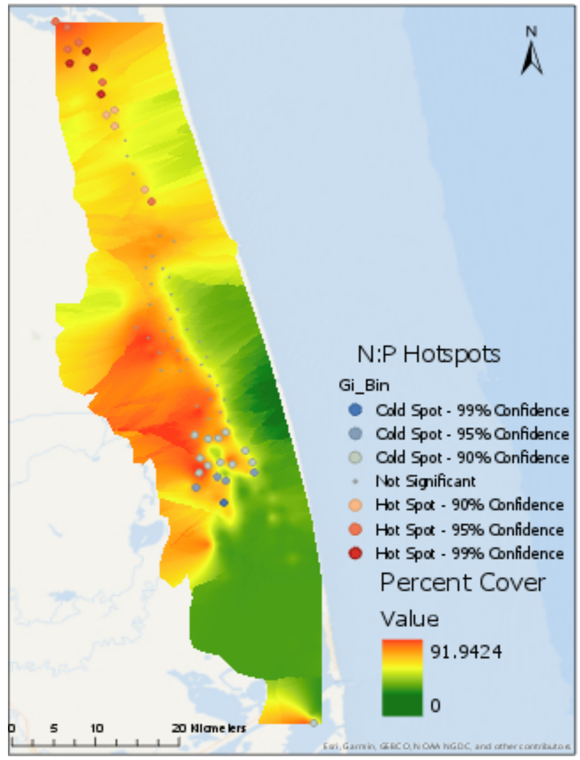

Fig 3: *Halodule* N:P ratio Hotspots over Percent Cover

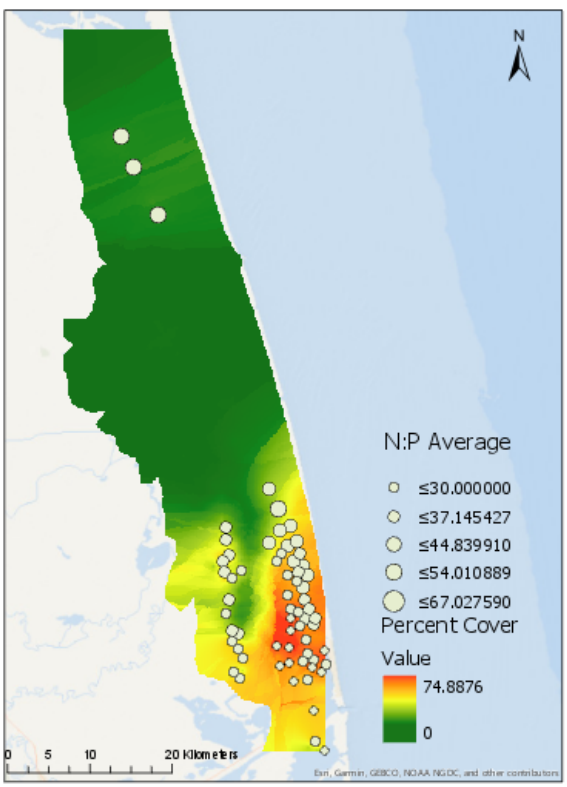

Fig 4: *Thalassia* N:P ratio over Percent Cover

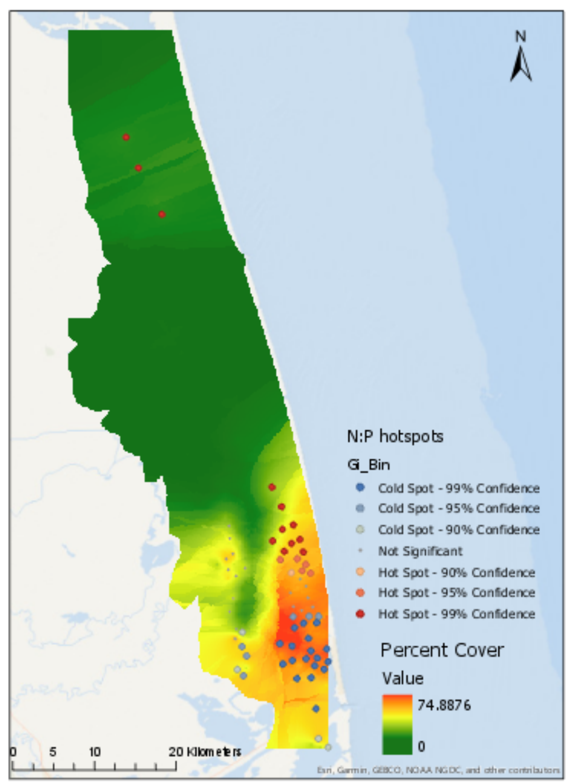

Fig 5: *Thalassia* N:P ratio over Percent Cover

Salinity was plotted over *Halodule* percent cover with a range from 25.66 to 47.12 and a mean of 35.35 (SD ± 2.89) (Figure 6). The hotspot analysis shows an area of significantly low values over both red areas of increased percent cover and areas of lower cover (Figure 7). This is the opposite of the expected correlation between low salinity and higher percent cover. The salinity for *Thalassia* ranges from 34.51 to 47.46 with a mean of 36.65 (SD ± 1.72) (Figure 8). The hotspot analysis shows a clustering of significantly lower salinity values correlating to areas of higher *Thalassia* percent cover (Figure 9).

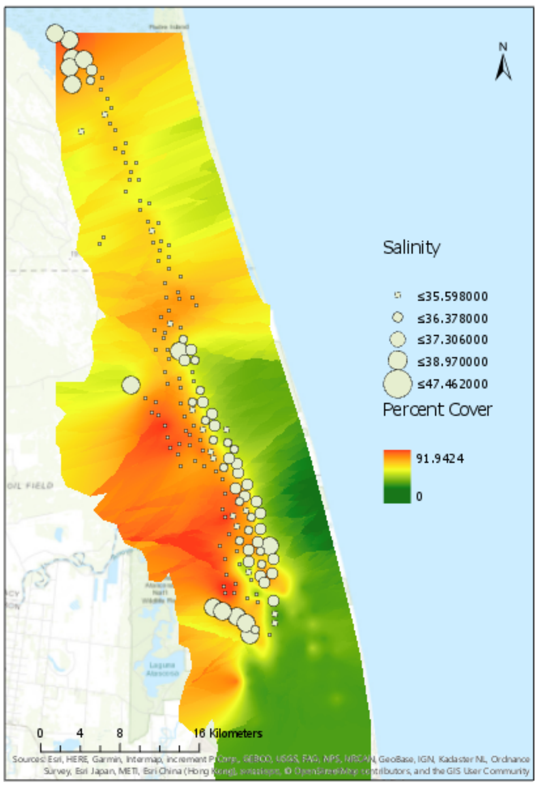

Fig 6: *Halodule* Salinity values over Percent Cover

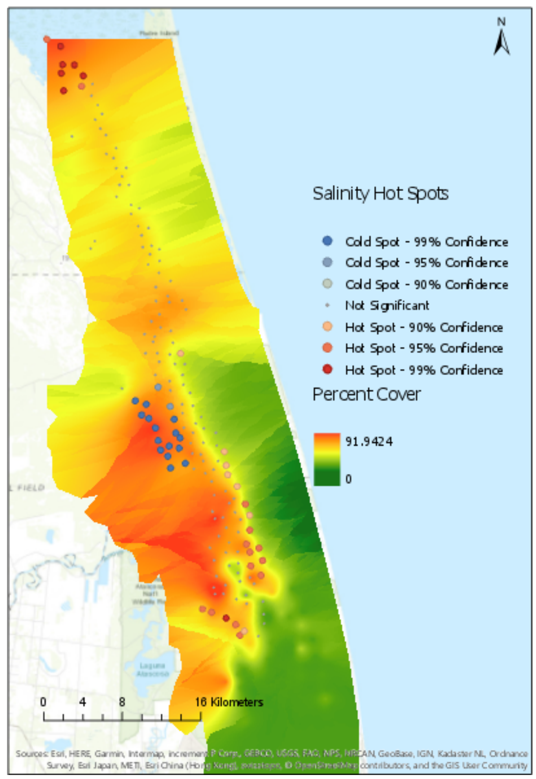

Fig 7: *Halodule* Salinity Hotspot values over Percent Cover

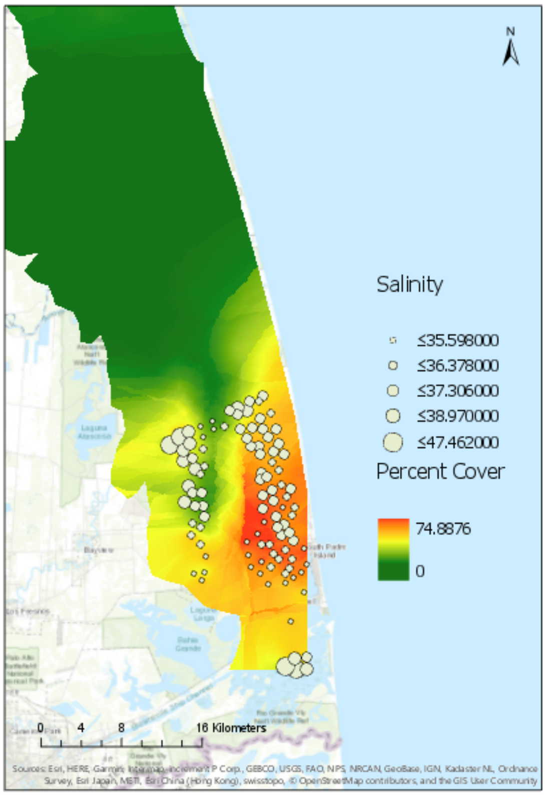

Fig 8: *Thalassia* Salinity values over Percent Cover

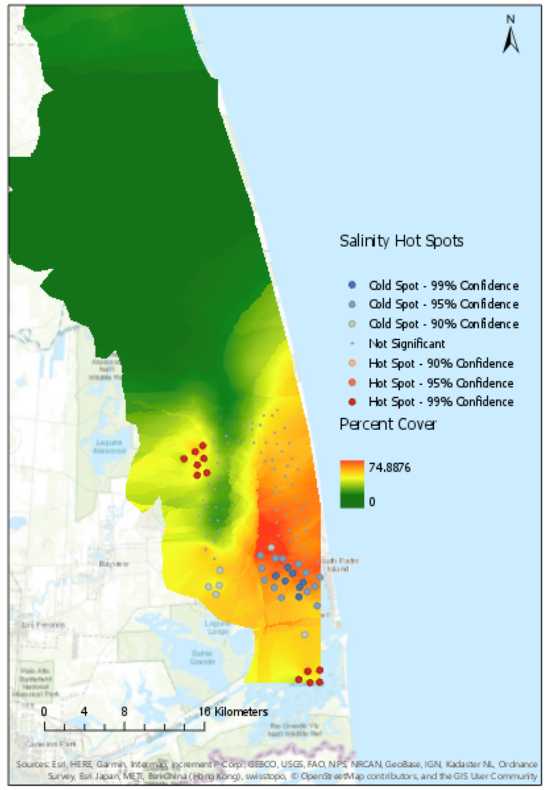

Fig 9: *Thalassia* Salinity Hotspots values over Percent Cover

Light attenuation was plotted over *Halodule* percent cover with a range from 0.13 to 2.33 and a mean of 1.07 (SD ± 0.41) (Figure 10). The hotspot analysis shows an area of significantly low values over areas of lower percent cover and high salinity on areas of high salinity (Figure 11). This is the expected correlation between high salinity and higher percent cover. The light attenuation for *Thalassia* ranges from 0.55 to 3.19 with a mean of 1.21 (SD ± 0.54) (Figure 12). Running hotspot analysis shows a clustering of significantly lower light attenuation values correlating to areas of higher *Thalassia* percent cover the opposite of the expected results (Figure 13).

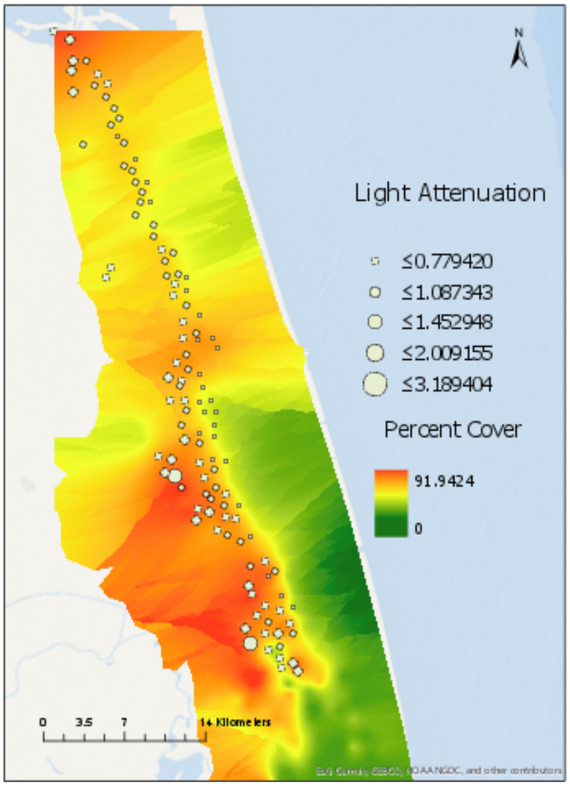

Fig 10: ***Halodule*** **Light Attenuation over Percent Cover**

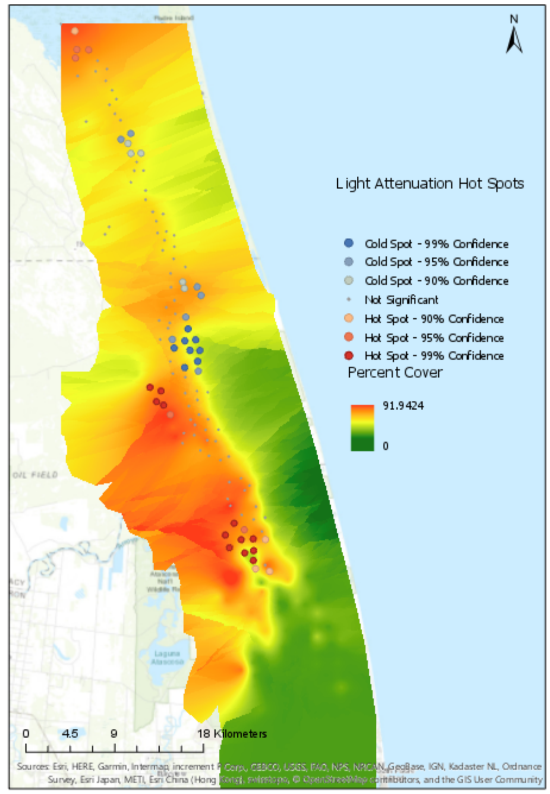

Fig 11: ***Thalassia*** **Light Attenuation Hotspots over Percent Cover**

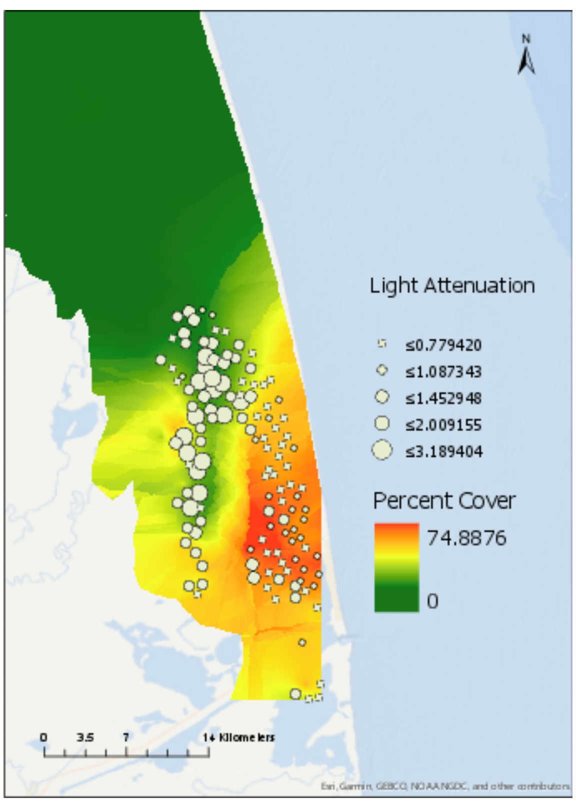

Fig 12: ***Thalassia*** **Light Attenuation over Percent Cover**

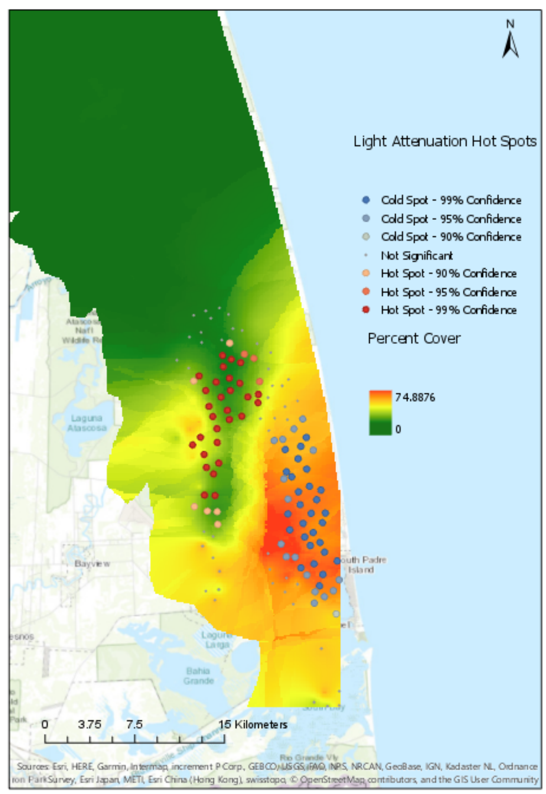

Fig 13: ***Thalassia*** **Light Attenuation Hotspots over Percent Cover**

The three variables of light attenuation, N:P Ratios, and salinity were put into a linear model explaining the seagrass percent cover for either *Halodule wrightii* or *Thalassia testudinum* (Table 1). Nitrogen to Phosphorous ratios are statistically significant in predicting seagrass cover and light attenuation was significant for *Thalassia* cover. The *Thalassia* linear model explained more variation in the seagrass cover (Adj R-Square=.3509) than the *Halodule* model (Adj R-Square=.1605).

Halodule		*Thalassia*	
Beta	P-value	Beta	P-value
NP Ratio*	.0436	NP Ratio*	.0000040
Light Attenuation	.1188	Light Attenuation*	.00521
Salinity	.3210	Salinity	.640
Adj R-Square	.1605	Adj R-Square	.3509

Table 1: Statistical Summary of Linear Models to predict Seagrass Cover

Discussion

The results of this project indicate that the variables that affect seagrass cover vary based on location and seagrass species. In *Thalassia* beds, low salinity, light attenuation and N:P rations correlated to high percent cover. Within *Halodule* beds, the relationships are not as strongly correlated with both statistically high and low values of each variable on top of increased percent cover. This is possibly due to differences in the seagrass species and their distribution at different latitudes within the lower Laguna Madre. The two species may have differing requirements for light and salinity. *Thalassia* has a more southern distribution while *Halodule* is dominant in the northern part of the study area. The two areas could have different environmental conditions that create differing growth requirements. Finally, the sampling points for *Halodule* variables are in a straight line, making it difficult to interpolate over broad areas and could account for the differences between trends seen in *Halodule* versus *Thalassia* beds.

Visually, the variables had a more direct relationship with *Thalassia* seagrass beds than with *Halodule* beds. This was confirmed statistically as the linear model for *Thalassia* had a higher Adjusted R-Square value and therefore is able to account for more variation based on the given parameters. The N:P ratios were significant for both models, however they had the strongest correlation for *Thalassia* highlighting the importance of nutrient ratios for predicting percent cover. Additionally, light attenuation was significant for the *Thalassia* model, a fact that may be explained by its more southern distribution. Overall, the variables evaluated help predict *Thalassia* percent cover the most and other variables need to be explored in order to increase the Adjusted R-Squared value of either models.

The discoveries of this project point to the possibility of a successful predictive modeling in the future for difference seagrass species along the Texas coast. Due to the time intensive nature of isotope analysis, nutrient data from 2011-2015 were recently added to the public website and available for analysis. This delay between sampling and data availability limits the ability to do significant temporal analyses until more data is added in the future therefore this project focused upon spatial analysis and statistical relationships. As the collected samples are processed, it will be a future topic of interest to evaluate all the measured variables over time to go into future models for seagrass cover. This could assist future efforts to conserve seagrass cover to preserve coastal ecosystems and support fisheries and diving duck populations along the coast of Texas.

References

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