Characterization of seagrass on the Texas coast

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INTRODUCTION

Seagrasses are vascular, submerged marine angiosperms that create vast meadows within coastal regions worldwide via sexual reproduction and propagation by rhizomal extension. Seagrass presence alters fluid velocity within and around beds due to the structural complexity created by the aboveground shoots and leaves (Gacia et al. 1999), which impede flow velocity into and throughout the canopy (Fonseca et al. 1982). Reduced flow into and within the canopy, coupled with increasing turbulence, promotes the accretion of sediments therefore providing stability and nutrient accumulation (Gacia et al. 1999). Sediments near the bottom of the bed can become resuspended during tidal motion generating a flux of organic matter and nutrients from within the sediments and redistributing it into the water column (Wainright 1990). Seagrasses can remineralize resuspended nutrients therefore reducing the potential for algal blooms and decreased light penetration (McGlathery et al. 2007). However, excessive disturbances and resuspension of total suspended solids (TSS) may result in a decrease in light attenuation to benthic seagrasses (Ward et al. 1984). Seagrasses have a high light requirement, at least 18-20% incident light (Duarte 1991); therefore, increased light attenuation results in decreased productivity and potentially decreased biomass. Thus, water quality can determine seagrass presence and sustainment of seagrasses.

Seagrass canopies are productive habitats that generate and sustain diverse ecosystems (Jackson et al. 2001); they function as nurseries for many commercially fished species and are major exporters of nutrients to coastal food webs (Beck et al. 2001). Seagrasses provide many important ecosystem services (Costanza et al. 1997) and therefore require time and attention in understanding their pivotal role within the biological community. Dynamic interactions occurring between potential stressors such as light attenuation and TSS, and seagrass canopies are not yet fully understood along the Texas coast signifying the importance of pursuing greater knowledge of these ecological interactions. This research will attempt to explore the affects of light attenuation and TSS on seagrass abundance. Characterization of water quality parameters is an important first step in understanding the complex functions and ecological processes associated with seagrass habitats.

I predict that there should be a decrease in seagrass percent cover with 1) greater light attenuation, 2) greater TSS, 3) lower surface irradiance (SI), and 3) light attenuation and TSS are positively correlated.

BACKGROUND

Study Area

The Texas coast can be characterized as an extensive linked lagoon system that is comprised of beds of *Thalassia testudinum* (turtle grass), *Halodule wrightii* (shoal grass), *Syringodium filiforme* (manatee grass), *Ruppia maritima* (widgeon grass), and *Halophila engelmanni* (clover grass). In Texas alone, seagrasses cover 235,000 acres with approximately 28,000 acres residing within Aransas, Copano, Redfish, and Corpus Christi bays (TPWD 2004). This study will focus on assessing the impact of light attenuation on seagrass abundance along the Texas coast: specifically, if light attenuation can be used as a predictor of seagrass presence utilizing ArcGIS.

The Texas Seagrass Monitoring Program (2011-present) is a collaborative effort involving numerous organizations, where the University of Texas Marine Science Institute is largely responsible for data acquisition. The goal of the program is to determine the affects of physical and biotic parameters influencing seagrass distribution, condition, and persistence. There are 567 sampling sites along the Texas coast, which are divided into four systems relative to site location: National Estuarine Research Reserve (NERR), Corpus Christi Bay (CCBAY), Upper Laguna Madre (ULM) and Lower Laguna Madre (LLM) (Fig. 1). Many biological and physiochemical parameters are collected, however, I am specifically interested in variables light attenuation, total suspended solids (TSS) and seagrass percent cover (all species). It is well documented that light attenuation and total suspended solids influence water transparency, where greater light attenuation occurs due to resuspended sediments and organic material. TSS is organic and inorganic material resuspended within the water column and can increase light attenuation by absorbing light, therefore decreasing water quality.

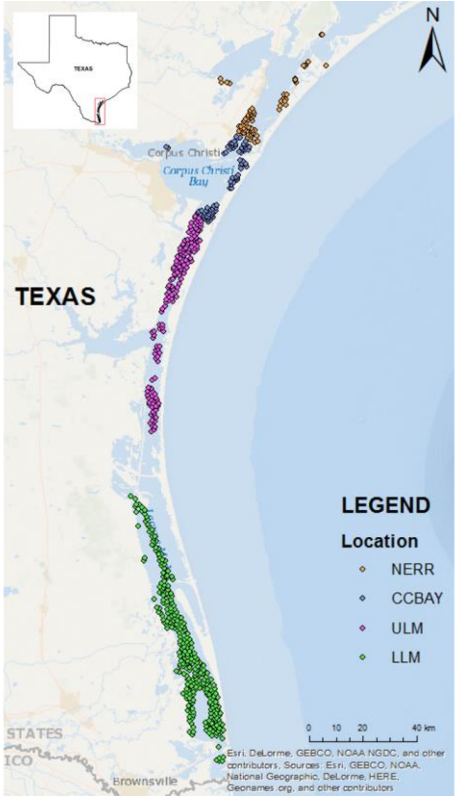


Fig. 1. Four systems comprising the Texas coast utilizing site location data from the Texas Seagrass Monitoring Program, July-October of 2011-present. NERR (n=57), CCBAY (n=81), ULM (n=144), and LLM (n=285).

METHODS

ArcMap 10.2.2 was utilized to display spatial and temporal distributions of total species seagrass percent cover (%) as a function of 1] light attenuation (k_d), 2] TSS (mg/L), and 3] surface irradiance (SI %) at site locations within systems NERR, CCBAY, ULM, and LLM.

Seagrass monitoring excel data obtained from the field were added and exported into ArcMap. Light attenuation and seagrass percent cover were characterized using graduated symbology within all four systems and analyzed. Empirical Bayesian Kriging (EBK) was used for interpolating between neighboring site sampling locations. EBK methodology was selected for operational simplicity and the likelihood that the model captured small scale effects, thus identifying any spatial patterns. EBK was executed using the 'Geostatistical Analyst Tools' within ArcToolbox, where 'Interpolation' was selected and

EBK run. The 'Editor' function was used to create a polygon shapefile of the LLM where seagrass is present (polygon shaped to aerial photography by NOAA). 'Extract by Mask' allowed parameters to be constrained within this boundary region. Hotspot Analysis was run by selecting 'Spatial Statistics Tools' within ArcToolbox and 'Mapping Clusters'. Definition query was utilized to illustrate sampled site data that were statistically significant ($p < 0.001$) within Hot Spot Analysis. Clustered phenomena assumes these aggregations are strong and indicate either low (blue) or high (red) parameter data values. These analyses were performed for all four variables of interest only within the LLM due to preliminary results indicating greater spatial variability and logistical time constraints. SI was calculated using the equation SI % = (I_z/I_o) x 100, where I_z and Io are irradiance (µmol photons $m^{-2}sec^{-1}$) at depth z (meters) and at the surface, respectively.

RESULTS

Graduated Symbology Technique

Composite NERR, CCBAY, ULM, and LLM light attenuation (m^{-1}) were 0.760 ± 0.1885, 0.787 ± 0.131, 0.774 ± 0.105 and 0.748 ± 0.165 (mean ± standard deviation) respectively. Mean ± standard deviation seagrass percent cover for NERR, CCBAY, ULM, and LLM were 62.62 ± 32.71, 60.99 ± 32.27, 74.45 ± 34.04, and 42.27 ± 39.10 respectively. Therefore, NERR, CCBAY, and ULM exhibited relatively greater light attenuation and seagrass percent cover than LLM (Fig. 2a, b). When seagrass percent cover was superimposed onto light attenuation for each system, substantial spatial variability was characteristic of LLM compared to the other systems. NERR showed minor variation along the west side of Aransas Bay (Fig. 3a). CCBAY also showed minor derivation, with a few sites in near the causeway (Fig. 3b). ULM had some sites within northern-middle portion of the bay near the Intracoastal Waterway (Fig. 3c). LLM showed greater attenuation with reduced percent cover in the middle and southern part of the bay (Fig. 3d). It should be noted that although the differences within NERR, CCBAY, and ULM appear subtle, I posit that further research will indicate otherwise. For this study I will focus on investigating differences between light attenuation and seagrass percent cover within the patchy variation of LLM.

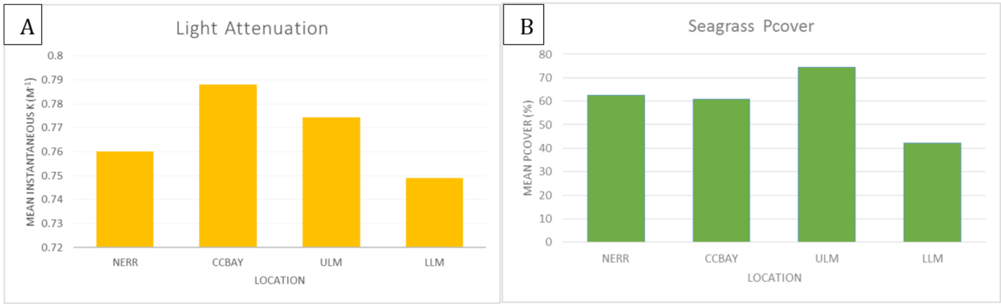
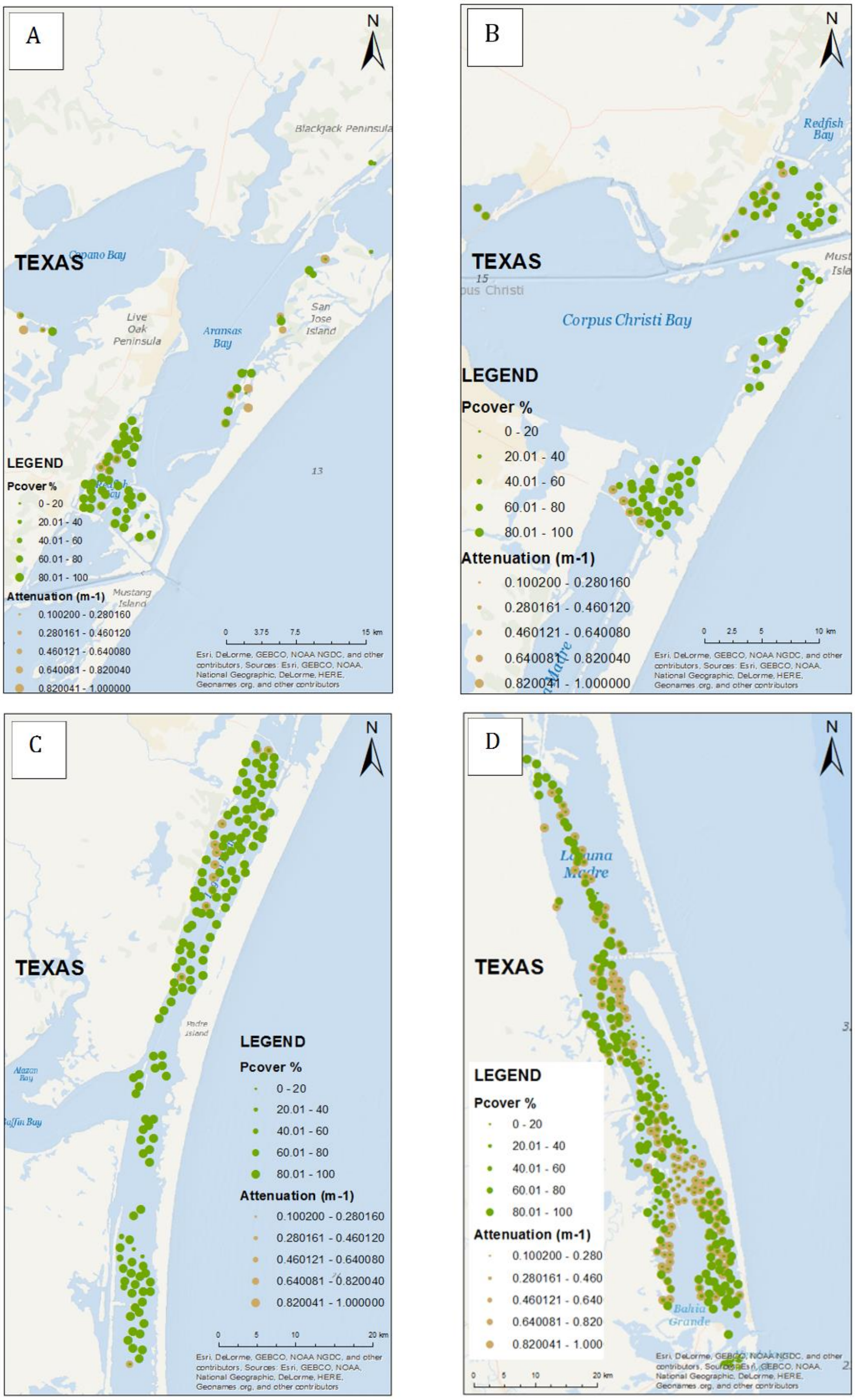


Fig. 2a. 2011-2013 mean instantaneous light attenuation (k_d).
Fig. 2b. 2011-2013 mean seagrass percent cover (denoted Pcover).
Both parameters were characterized at four locations along the Texas coast: NERR, CCBAY, ULM, and LLM. Values were populated from the seagrass monitoring dataset using ArcMap Statistics function.



Figures 3 a, b, c, d. 2001-2013 light attenuation and seagrass percent cover for four systems along the Texas coast: NERR, CCBAY, ULM, and LLM, respectively.

EBK Technique

Light attenuation (k_d) within the LLM ranged from 0.462 to 0.896 m^{-1}, with a mean ± standard deviation where $k_d < 0.5$ was 0.367 ± 0.110 and $k_d > 0.5$ was 0.783 ± 0.119. However, light attenuation was not uniform and displayed spatial variation, particularly within the southern middle part of the bay (Fig. 4a). Lower values of light attenuation were present within this area surrounded by mid to high levels of light attenuation throughout the bay. Hot spot analysis revealed a pronounced clustering of low values (- z-scores with $p < 0.001$) within this southern middle part of the bay (Fig. 4b).

Seagrass percent cover ranged from 0 to 82.90 %, where mean ± standard deviation where % < 0.5 was 11.23 ± 14.93 and % > 0.5 was 83.63 ± 16.98. Percent cover varied spatially, where reduced percent cover is evident within the southern middle part of the bay and some areas along the western side where greater percent cover is seen near the southern-most part of the bay and along the eastern side (Fig. 5a). Hot spot analysis revealed a pronounced clustering of low values (- z-scores with $p < 0.001$) within the same location of the southern middle part of the bay as seen with light attenuation (Fig. 5b). Additionally, there is some positive clustering occurring within the southern part of LLM (+ z-scores with $p < 0.001$) (Fig. 5b).

TSS ranged from 4.76 to 102.59 mg/L, where mean ± standard deviation where TSS < 17 was 9.21 ± 3.55 and TSS >17 was 34.21 ± 24.44. TSS were relatively low, with the exception of a few locations such as the southern middle part of the bay and some areas along the western and eastern sides closest to the coastline (Fig. 6a). Hot spot analysis revealed a pronounced clustering of high values (+ z-scores with $p < 0.001$) within the same location, southern middle, as seen with light attenuation and seagrass percent cover (Fig. 6b). A clustering of low values (- z-scores with $p < 0.001$) is visible within the vicinity of southern LLM seen with seagrass percent cover (Fig. 6b).

SI ranged from 50.55 to 93.62 %, where mean ± standard deviation where SI < 50 was 36.145 ± 10.644 and SI > 50 was 76.506 ± 11.157. Most noticeable SI spatial variation occurred within the southern middle part of the bay, indicated with relatively low SI values (Fig. 7a). Greatest SI values were located along the eastern edge of the bay. Hot spot analysis revealed a pronounced clustering of low values (- z-scores with $p < 0.001$) within this southern middle part of the bay (Fig. 7b). This pattern is identical to what was seen with light attenuation (Fig. 4b) which emphasizes the relationship dependency (instantaneous light attenuation correlated with independent calculation of SI in methods).

Light attenuation and TSS graduated symbology were overlaid on the seagrass percent cover EBK layer. These results indicate that both light attenuation and TSS negatively impact percent cover (Figs. 8, 9). However, hot spot analysis revealed that this southern middle region was characterized with relatively low light attenuation; results indicate that TSS may exert stronger influence in comparison with light attenuation (Fig. 10).

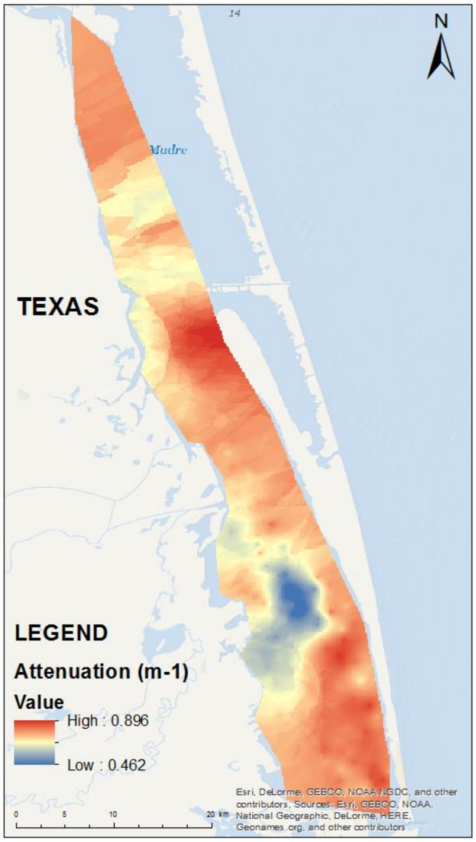


Fig. 4a. LLM light attenuation 2011-2013.

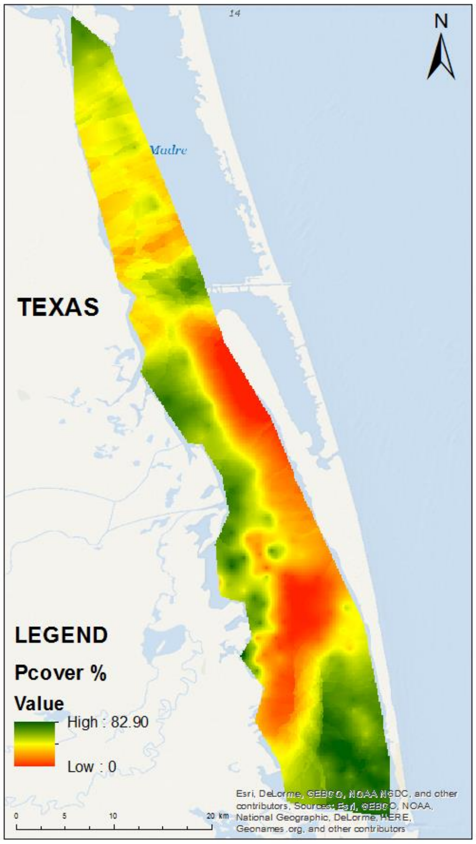


Fig. 5a. LLM seagrass percent cover 2011-2013.

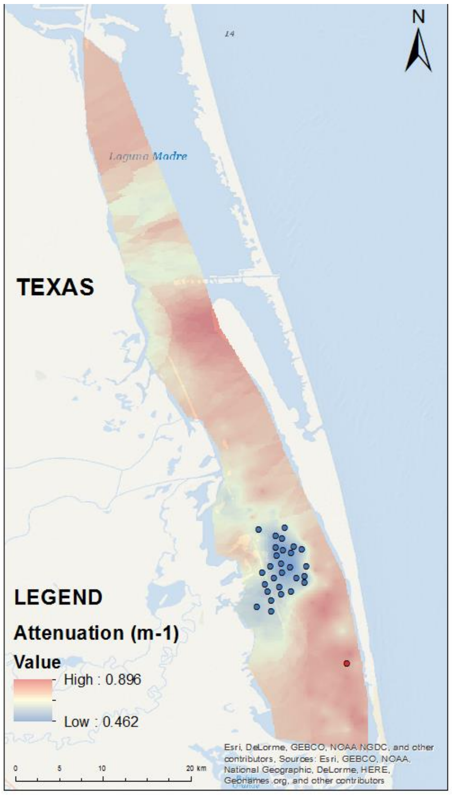


Fig. 4b. LLM light attenuation (p<0.001).

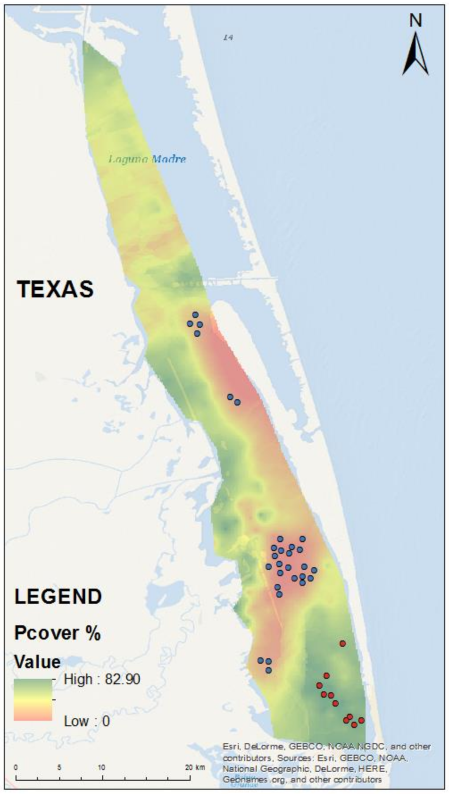


Fig. 5b. LLM seagrass percent cover (p<0.001).

Fig. 6a. LLM TSS 2011-2013.

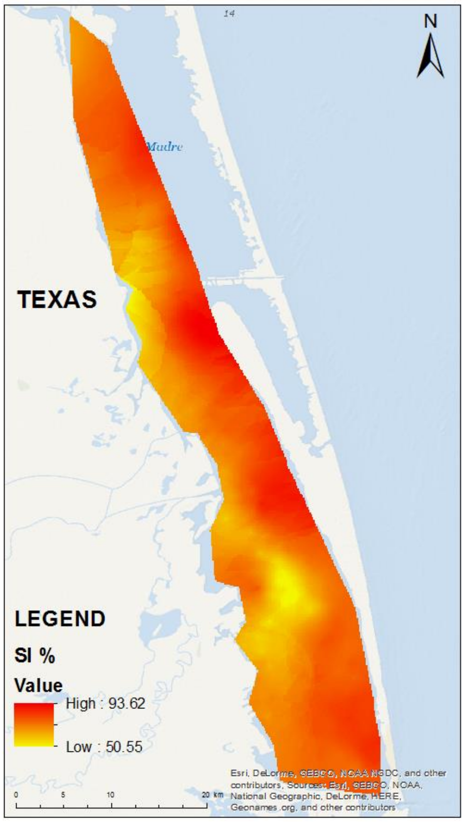


Fig. 7a. LLM SI 2011-2013.

Fig. 6b. LLM TSS (p<0.001).

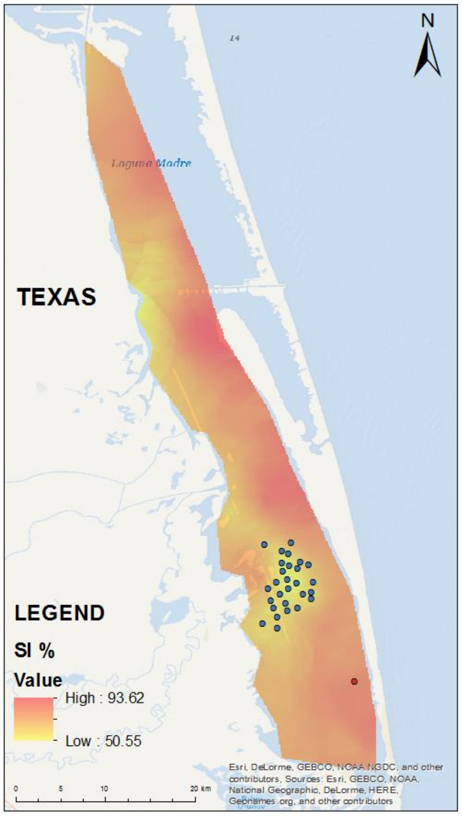


Fig. 7b. LLM SI (p<0.001).

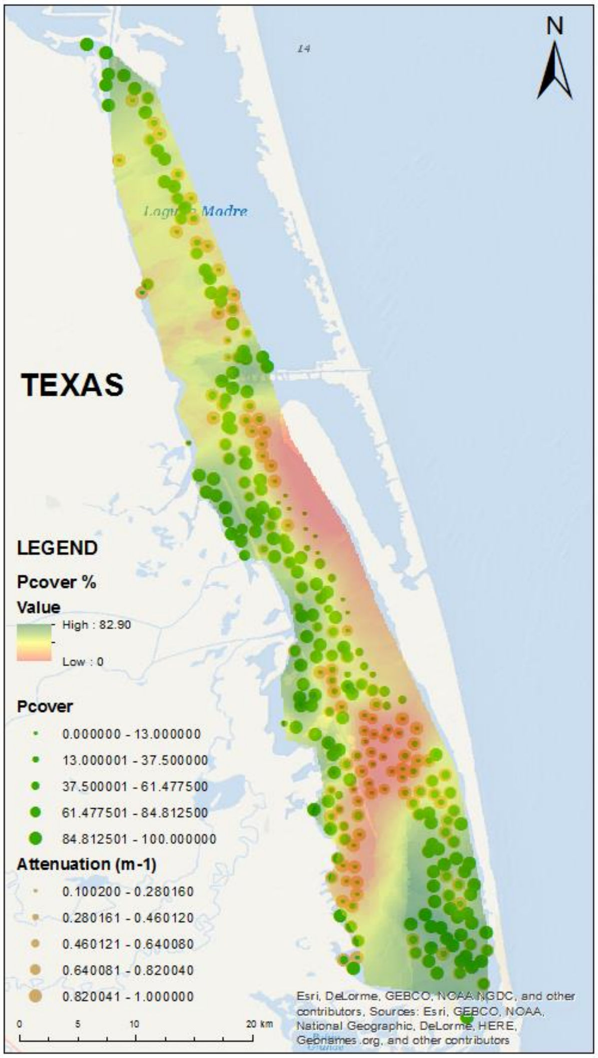


Fig 8. LLM light attenuation and seagrass percent cover 2011-2013.

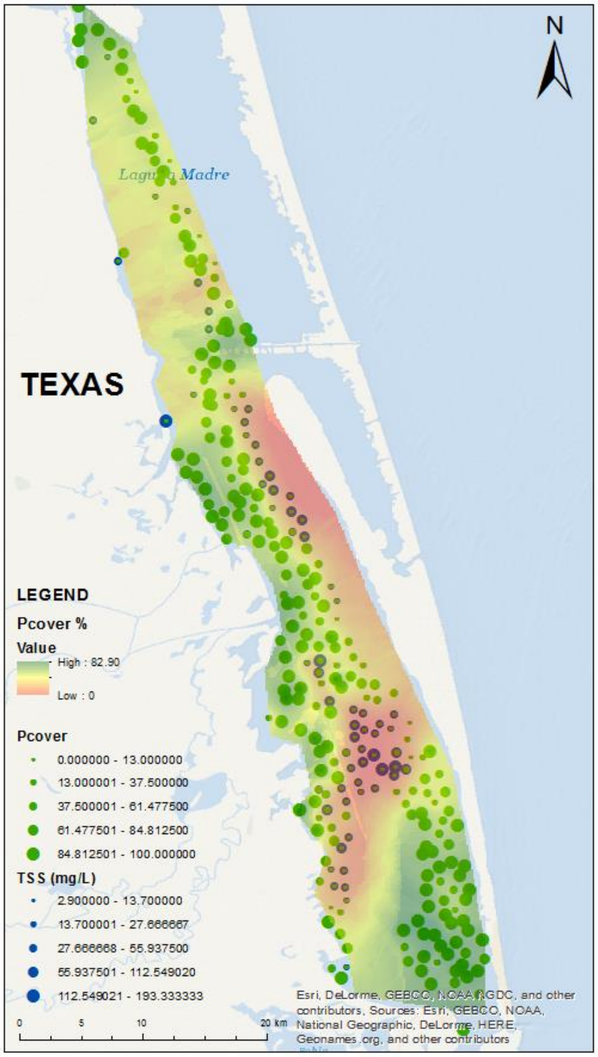


Fig 9. LLM TSS and seagrass percent cover 2011-2013.

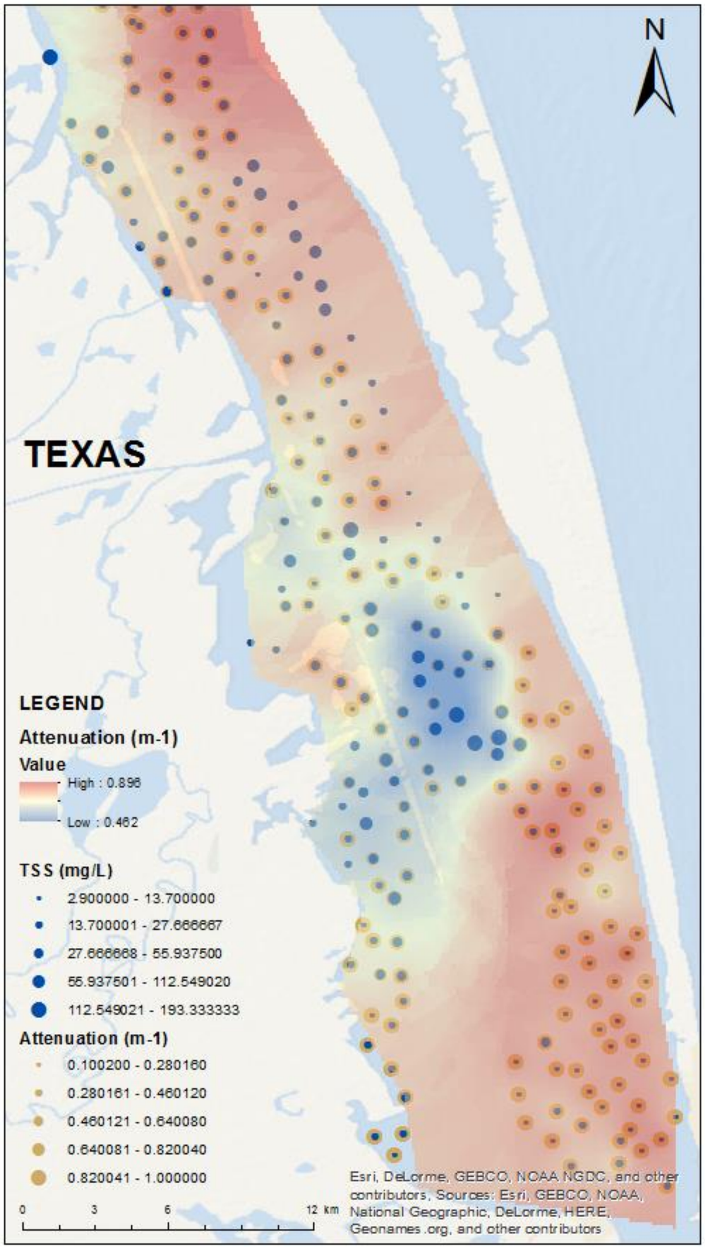


Fig 10. LLM light attenuation and TSS 2011-2013.

CONCLUSIONS

GIS is a powerful tool and is critical in analyzing spatial and temporal variation, proving particularly useful in this study. GIS provides exceptional resolution, which is essential when assessing water quality impacts (as well as additional variables) on seagrasses. I initially hypothesized that greater light attenuation would correspond with higher TSS and thus a reduction in both SI and seagrass percent cover. These analyses supported and refuted my initial hypotheses.

Some locations within LLM, specifically the eastern side of the bay, had increased light attenuation resulting in reduced percent cover as expected. However, this was not the case in the southern middle part of the bay. This finding is counterintuitive as one would speculate that lower attenuation seen in this area would promote seagrass growth. Despite this relationship, the opposite was shown where low light attenuation resulted in decreased percent cover. This similar pattern, but opposite in nature, is apparent within the southern LLM; greater attenuation yielded greater percent cover. These findings were confounding as they do not fall within the predicted outcome. One can surmise that other variables must be involved and are therefore creating these unexpected spatial distributions. Other factors that may explain how good-fair water quality (transparency) results in the absence of seagrass include excessive nutrient input, destructive physical disturbances, or climatic conditions such as reduced precipitation or increased evaporation resulting in greater salinities.

Although I did not see the patterns as initially predicted, it was interesting to see that these physiological factors change on spatial scales. Comparing these variables on a temporal scale may allow us to better predict seagrass absence and presence. These new findings prompt further research into looking at what other factors may be driving these changes. This would involve utilizing GIS to generate current and future data on a temporal scale so comparison can be made on a year-to-year basis. I did not try other methods to display these data, thus, it is possible that other methods could provide different results. These are things that I plan to further investigate in order to develop more refined deductions and results.

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