A Long-Term Seagrass Monitoring Program for Corpus Christi Bay and Upper Laguna Madre

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Final Report to the Coastal Bend Bays and Estuaries Program
Seagrass Monitoring Project 1826

31 January 2019

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Texas Seagrass Monitoring CBBEP Contract No. 1826

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INTRODUCTION

In 1999, the Texas Parks and Wildlife Department (TPWD), along with the Texas General Land Office (TGLO) and the Texas Commission on Environmental Quality (TCEQ), drafted a Seagrass Conservation Plan that proposed, among other things, a seagrass habitat monitoring program (Pulich and Calnan, 1999). One of the main recommendations of this plan was to develop a coast wide monitoring program. In response, the Texas Seagrass Monitoring Plan (TSGMP) proposed a monitoring effort to detect changes in seagrass ecosystem conditions prior to actual seagrass mortality (Pulich et al., 2003). However, implementation of the plan required additional research to specifically identify the environmental parameters that elicit a seagrass stress response and the physiological or morphological variables that best reflect the impact of these environmental stressors.

Numerous researchers have related seagrass health to environmental stressors; however, these studies have not arrived at a consensus regarding the most effective habitat quality and seagrass condition indicators. Kirkman (1996) recommended biomass, productivity, and density for monitoring seagrass whereas other researchers focused on changes in seagrass distribution as a function of environmental stressors (Dennison et al., 1993, Livingston et al., 1998, Koch 2001, and Fourqurean et al., 2003). The consensus among these studies revealed that salinity, depth, light, nutrient concentrations, sediment characteristics, and temperature were among the most important variables that produced a response in a measured seagrass indicator. The relative influence of these environmental variables is likely a function of the seagrass species in question, the geographic location of the study, hydrography, methodology, and other factors specific to local climatology. Because no generalized approach can be extracted from previous research, careful analysis of regional seagrass ecosystems is necessary to develop an effective monitoring program for Texas.

Conservation efforts should seek to develop a conceptual model that outlines the linkages among seagrass ecosystem components and the role of indicators as predictive tools to assess the seagrass physiological response to stressors at various temporal and spatial scales. Tasks for this objective include the identification of stressors that arise from human-induced disturbances, which can result in seagrass loss or compromise plant physiological condition. For example, stressors that lead to higher water turbidity and light attenuation (e.g. dredging and shoreline erosion) are known to result in lower below-ground seagrass biomass and alterations to sediment nutrient concentrations. It is therefore necessary to evaluate long-term light measurements, the biomass of above- versus below-ground tissues and the concentrations of nutrients, sulfides, and dissolved oxygen in sediment porewater when examining the linkages between light attenuation and seagrass health.

This study is part of the Texas seagrass monitoring program, with specific focus on Corpus Christi Bay (CCB; Figure 1) and the Upper Laguna Madre (ULM; Figure 1), following protocols that evaluate seagrass condition based on landscape-scale dynamics. The program is based on a hierarchical strategy for seagrass monitoring outlined by Neckles et al. (2012) to establish the quantitative relationships between physical and biotic parameters that ultimately control seagrass condition, distribution, persistence, and overall health. This approach follows a broad template adopted by several federal and state agencies across the country, but which is uniquely designed for Texas (Dunton et al. 2011) and integrates plant condition indicators with landscape feature indicators to detect and interpret seagrass bed disturbances.

The objectives of this study were to (1) implement long-term monitoring to detect environmental changes with a focus on the ecological integrity of seagrass habitats, (2) provide insight to the ecological consequences of these changes, and (3) help decision makers (e.g. various state and federal agencies) determine if the observed change necessitates a revision of regulatory policy or management practices. We defined ecological integrity as the capacity of the seagrass system to support and maintain a balanced, integrated, and adaptive community of flora and fauna including its characteristic foundation seagrass species. Ecological integrity was assessed using a suite of condition indicators (physical, biological, hydrological, and chemical) measured annually on wide spatial scales.

The primary questions addressed in the 2018 annual Tier-2 surveys include:

1) What are the spatial and temporal patterns in the distribution of seagrasses over annual scales?
2) What are the characteristics of these plant communities, including their species composition and percent cover?
3) How are any changes in seagrass percent cover and species composition, related to measured characteristics of water quality?

METHODS

Sampling Summary

Tier-2 protocols, which are considered Rapid Assessment sampling methods, are adapted from Neckles et al. (2012). We conducted Tier-2 sampling from August to November 2018. Stations in Corpus Christi Bay were sampled on 28 August, 20, 24, and 26 September, and 3 October. Stations in Upper Laguna Madre were sampled on 3, 4, 9, and 11 October. The remaining stations were sampled on 7, 8 November. For statistical rigor, a repeated measures design with fixed sampling stations was implemented to maximize our ability to detect future change. Neckles et al. (2012) demonstrated that the Tier-2 approach, when all sampling stations are considered together within a regional system, results in > 99% probability that the bias in overall estimates will not interfere with detection of change.

Site Selection

The Tier-2 sampling program is intended to compliment ongoing remote sensing efforts. Sites were therefore selected from vegetation maps generated with aerial and satellite imagery during the 2004/2007 NOAA Benthic Habitat Assessment. The vegetation maps were then tessellated using polygons, and sample locations were randomly selected within each polygon (Figure 1). Only polygons containing > 50% seagrass cover were included in 2018 sampling efforts.

Water Quality

All sampling stations were located in the field using a handheld GPS device to within a 10 m radius of the pre-determined station coordinates. Upon arrival to a station, hydrographic measurements including water depth, conductivity, temperature, salinity, dissolved oxygen, chlorophyll fluorescence and pH were collected with a YSI 6920 data sonde. Water samples were obtained at each station for determination of Total Suspended Solid (TSS) concentration. Water transparency was derived from measurements of photosynthetically active radiation (PAR) using two LI-COR spherical quantum scalar sensors attached to a lowering frame. All sonde measurements and water samples were obtained prior to the deployment of benthic sampling equipment.

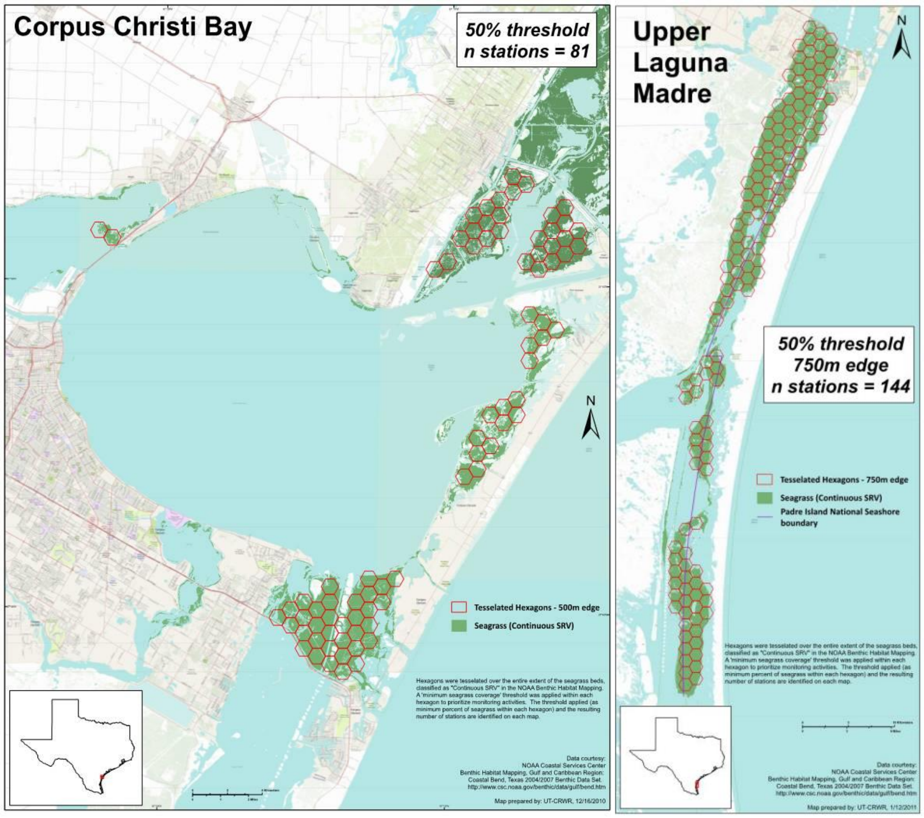

Figure 1. Tessellated boundaries of submerged vegetation delineated during the 2004/2007 NOAA Benthic Habitat Assessment where seagrass cover > 50%. Resulting stations (Upper Laguna Madre n = 144; Corpus Christi Bay n = 81) are identified in text on map. Stations outside the park boundary in Upper Laguna Madre are funded by CBBEP (n = 92) and are delineated by the light purple line on the map.

Seagrass Cover

Species composition and areal cover were obtained from four replicate quadrat samples per station at each of the four cardinal locations from the vessel. Percent cover of areal biomass was estimated by direct vertical observation of the seagrass canopy through the water using a 0.25 m^2 quadrat framer subdivided into 100 cells. Previous research has demonstrated that the probability of achieving a bias is less than 5% of the overall mean when using only four subsamples (Neckles, pers. comm.).

Spatial Data Analysis and Interpolation

ArcGIS software (Environmental Systems Research Institute) was used to manage, analyze, and display spatially referenced point samples and interpolate surfaces for all measured parameters. An inverse distance weighted method was used to assign a value to areas (cells) between sampling points. A total of 12 sampling stations were identified from a variable search radius to generate the value for a single unknown output cell (100 m^2). All data interpolation was spatially restricted to the geographic limits of the submerged vegetation map created during the 2004/2007 NOAA Benthic Habitat Assessment.

RESULTS

Water Quality

Corpus Christi Bay

The CCB region stations exhibited a depth of 77.5 ± 24.0 cm (mean ± standard deviation) and a mean water temperature of 30.00 ± 1.44 °C (Table 1). Salinity measurements were relatively variable among sampling stations in this region, with a mean of 31.2 ± 6.6 (Table 1). A tropical depression hit the Texas coast from 10-16 September, leading to lower than usual salinities in Redfish Bay (25-30). Stations located near the JFK Causeway displayed slightly hypersaline conditions (> 35). Dissolved oxygen concentrations in the CCB were 6.70 ± 1.79 mg L^{-1} with a saturation of 105.0 ± 29.2% (Table 1). No hypoxic (< 2 mg L^{-1}) or low oxygen (< 3 mg L^{-1}) concentrations were documented within the CCB region. Mean pH values for the CCB were 8.10 ± 0.24 (Table 1) with 24 stations that displayed values < 8. Thirteen of these stations were near the JFK Causeway, ten were in East Flats, and one was in Redfish Bay.

Upper Laguna Madre

Stations within the ULM region had a mean depth of 129.2 ± 40.5 cm and an average water temperature of 29.18 ± 1.90 °C (Table 1). Water levels were ~25 cm higher than previous years due to regular tidal cycles and the impact of Hurricane Michael on the western Gulf of Mexico. Salinity measurements were relatively consistent among sampling stations in this region, with a mean of 33.8 ± 1.6 (Table 1). Unlike previous years, this region did not experience hypersaline conditions during the sampling period. The ULM typically experiences hypersaline conditions because of its limited connection to Gulf waters and the lack of any significant freshwater source. Interestingly, salinities in Nine Mile Hole were at or below normal seawater salinity (35), which is relatively uncharacteristic of this area. The lower salinities within this region could be due in part to a particularly wet season. Mean dissolved oxygen concentration and saturation was 6.32 ± 1.17 mg L^{-1} (Table 1) and 99.8 ± 19.6% (Table 1), respectively. No hypoxic (< 2 mg L^{-1}) or low oxygen (< 3 mg L^{-1}) concentrations were documented within the ULM. The ULM region was characterized with a mean pH of 7.97 ± 0.15 (Table 1), with highest values near Bird Island Basin.

Table 1. Summary of water column hydrographic parameters by region.

		Depth (cm)	Temperature (°C)	Salinity	Dissolved Oxygen (mg L^{-1})	Dissolved Oxygen (%)	pH
CCB							
	Mean	77.5	30.00	31.2	6.70	105.0	8.10
	Std. Dev.	24.0	1.44	6.6	1.79	29.2	0.24
ULM							
	Mean	129.2	29.18	33.8	6.32	99.8	7.97
	Std. Dev.	40.5	1.90	1.6	1.17	19.6	0.15

Water Column Optical Properties

Corpus Christi Bay

The mean downward attenuation coefficient (K_d) was 1.24 ± 0.56 m^{-1} for the CCB region (Table 2). Light attenuation was greatest near Shamrock Cove, which coincided with higher TSS values in the area. Chlorophyll concentrations were less variable (3.4 ± 3.0 μg L^{-1}; Table 2) than TSS (8.0 ± 7.3 mg L^{-1}; Table 2) measurements for the CCB. Mean secchi depth varied among stations (72.0 ± 23.8 cm; Table 2) but overall, visibility at most stations was near the entire depth of the water column or within 5 cm of the vegetated or sediment surface, on average.

Upper Laguna Madre

The ULM stations were characterized by a mean K_d of 1.34 ± 0.59 m^{-1} (Table 2). The mean downward attenuation coefficient and variability were greater in ULM than in the CCB region. Higher light attenuation values were observed near the JFK Causeway. Water column chlorophyll (4.1 ± 1.8 μg L^{-1}; Table 2) was higher in the ULM than in the CCB region but TSS concentrations (6.5 ± 6.8 mg L^{-1}; Table 2) were lower and less variable. Highest water column chlorophyll and TSS concentrations were observed near the mouth of Baffin Bay. Mean secchi depth was variable (119.4 ± 35.7 cm; Table 2) and water transparency was relatively low. At most stations, visibility was within 10 cm of the vegetated or sediment surface, on average.

Table 2. Summary of water transparency property indicators by region.

		K_d (m^{-1})	Secchi (cm)	Chlorophyll *a* ($\mu g\ L^{-1}$)	Total Suspended Solids ($mg\ L^{-1}$)
CCB					
	Mean	1.24	72.0	3.4	8.0
	Std. Dev.	0.56	23.8	3.0	7.3
ULM					
	Mean	1.34	119.4	4.1	6.5
	Std. Dev.	0.59	35.7	1.8	6.8

Seagrass Cover and Species Distributions

Corpus Christi Bay

Mean total seagrass cover in the CCB region was 73.2%. The seagrass assemblage in the CCB was dominated by *Halodule wrightii* (44.0 ± 44.1%; Table 3, Figure 2), followed by *Thalassia testudinum* (16.9 ± 34.1%; Table 3, Figure 3) and *Syringodium filiforme* (10.5 ± 25.6%; Table 3, Figure 4), with minor contributions from *Ruppia maritima* (0.5 ± 4.1%; Table 3, Figure 5) and *Halophila engelmannii* (1.3 ± 7.2%; Table 3, Figure 6). Three stations (~ 4%) in the CCB did not have vegetation present. Low seagrass cover was observed in southern Redfish Bay near Ingleside and Aransas Pass, with a few patches north of JFK causeway (Figure 7). Hurricane Harvey explains some of the seagrass loss within Redfish Bay. *Thalassia testudinum* was most affected in this area in 2017 and coverage has yet to recover to pre-Harvey values. *Halodule wrightii* was most widely distributed within the CCB region relative to the other seagrass species. However, minimal cover was observed in the southwest portion of Redfish Bay, which was dominated by *Thalassia testudinum*. Established *Thalassia testudinum* populations are likely excluding *Halodule wrightii* from expanding into this area as *Thalassia testudinum* is a late successional species. It should be noted that it may be possible for *Halodule wrightii* populations to establish in beds that were previously colonized with *Thalassia testudinum*, specifically in areas that sustained severe damage following Hurricane Harvey. The poor recolonization abilities of *Thalassia testudinum* results in a significantly slower recovery than either *Halodule wrightii* or *Syringodium filiforme*. Therefore, the loss of *Thalassia testudinum* may create space for the colonization of these opportunistic species. Overall, *Thalassia testudinum* coverage in the CCB region decreased from 2017, while *Halodule wrightii* and *Syringodium filiforme* coverage increased. Canopy height was greatest in *Thalassia testudinum* (29.8 ± 11.7 cm; Table 4), followed by *Syringodium filiforme* (24.5 ± 23.0 cm; Table 4), *Halodule wrightii* (16.7 ± 5.6 cm; Table 4), *Ruppia maritima* (10.3 ± 3.8 cm; Table 4) and *Halophila engelmannii* (4.9 ± 1.6 cm; Table 4).

Upper Laguna Madre

The ULM mean seagrass cover for all species was approximately 65.8%. The seagrass assemblage was again dominated by *Halodule wrightii* (56.0 ± 39.1%; Table 3, Figure 2), followed by *Syringodium filiforme* (9.2 ± 23.1%; Table 3, Figure 4), and *Halophila engelmannii* (0.5 ± 4.7%; Table 3, Figure 6). The ULM region was devoid of *Thalassia testudinum* and *Ruppia maritima* (Table 3, Figures 3 and 5). Six sampling stations (~ 4%) were absent of vegetation. Typically, stations that were bare or had low seagrass cover corresponded with greater water depths (~2m) located near Bird Island

Basin. An exception, however, is the southeastern portion of Nine Mile Hole which appeared to have relatively low seagrass cover in 2018 but when compared to 2017, showed an increase in coverage. Nine Mile Hole is notorious for extremely hypersaline conditions during periods of low rainfall which ultimately causes high physiological stress on the plants, even for a tolerant species such as *Halodule wrightii*. Therefore, increased precipitation more than likely reduced salinities within this region and provided more suitable conditions for the growth and re-establishment of *Halodule wrightii*. *Syringodium filiforme* increased in cover near JFK Causeway and continued to expand south to Bird Island Basin. Highest canopy height values were observed in *Syringodium filiforme* (26.3 ± 9.2 cm; Table 4), followed by *Halodule wrightii* (23.8 ± 7.4 cm; Table 4) and *Halophila engelmannii* (7.5 ± 2.0 cm; Table 4). Mean canopy height was shorter in the ULM relative to the CCB region, which may be explained by the absence of *Thalassia testudinum* in the ULM.

Table 3. Summary of plant areal cover by species and region.

		H. wrightii (% cover)	*T. testudinum* (% cover)	*S. filiforme* (% cover)	*R. maritima* (% cover)	*H. engelmannii* (% cover)	Bare (% cover)
CCB							
	Mean	44.0	16.9	10.5	0.5	1.3	26.8
	Std. Dev.	44.1	34.1	25.6	4.1	7.2	32.4
ULM							
	Mean	56.0	0	9.2	0	0.5	34.2
	Std. Dev.	39.1	0	23.1	0	4.7	37.9

Table 4. Summary of plant canopy height by species and region.

		H. wrightii (cm)	*T. testudinum* (cm)	*S. filiforme* (cm)	*R. maritima* (cm)	*H. engelmannii* (cm)
CCB						
	Mean	16.7	29.8	24.5	10.3	4.9
	Std. Dev.	5.6	11.7	23.0	3.8	1.6
ULM						
	Mean	23.8	0	26.3	0	7.5
	Std. Dev.	7.4	0	9.2	0	2.0

CONCLUSIONS

Corpus Christi Bay

A tropical depression brought significant rain to the Texas coast a week before sampling the area, leading to a drop in salinity. In south Redfish Bay, we observed greater presence of *Thalassia testudinum* in the west portion while *Halodule wrightii* dominated the area to the east (Harbor Island). The average water depth is lower in east Redfish Bay than in the west portion and this difference may explain seagrass distribution within the CCB region. Overall, the mixed assemblage of seagrasses covers approximately 73% of the bay floor in the CCB which increased from 65% in 2017. The increase in seagrass cover is promising given the impact of Hurricane Harvey in 2017. However, *Thalassia testudinum* coverage and canopy height were both lower than in 2017, indicating a potential lingering impact of the storm. It is possible that the loss of *Thalassia testudinum* in Redfish Bay may create space for the colonization of the opportunistic species *Halodule wrightii* and *Syringodium filiforme*. Currently, the relative increase in cover of these species did not occur in the location of *Thalassia testudinum* loss. However, only future monitoring efforts will be able to determine if *Thalassia testudinum* will recover or it these areas will ultimately be colonized by these pioneer species or remain unvegetated. Spatial patterns suggest that *Syringodium filiforme* extended its range further north of JFK Causeway and *Halodule wrightii* increased in cover near Shamrock Cove.

Upper Laguna Madre

Overall, water quality in the ULM region was less amenable to seagrasses than the CCB region. Light attenuation was greater, likely due to elevated chlorophyll in the water column, particularly near the JFK Causeway. However, mean seagrass cover in the ULM was high, particularly from the JFK Causeway south to Baffin Bay. Low seagrass cover was observed near Bird Island Basin and Nine Mile Hole near the Land Cut. *Halodule wrightii* cover appears to have increased in the southwestern portion of Nine Mile Hole which may be linked to lower salinities as a result of increased precipitation. Nevertheless, due to minimal flushing and freshwater inflow, the ULM is susceptible to periods of hypersaline conditions during extended periods of aridity. Overall, seagrasses covered approximately 66% of the bay floor in the ULM, matching the coverage of 66% in 2017. This suggests that shifts in species composition and distribution occurred within the ULM. Specifically, there was a decrease in *Halodule wrightii* (outside Baffin Bay and Chapman Ranch) but an increase in *Syringodium filiforme* (outside Chapman Ranch). It is possible that lower salinities are supporting the re-establishment and re-expansion of *Syringodium filiforme* in the northern and central portions (outside Chapman Ranch) of the ULM since the massive die off in 2014 due to severe drought. Additionally, it appears that reduced salinities in Nine Mile Hole have also improved conditions for *Halodule wrightii* which has also re-established and expanded in this area. Future monitoring efforts will be able to document and identify the expansions and contractions of *Syringodium filiforme* and *Halodule wrightii* within the ULM that are largely driven by changes in salinity and species competition.

FIGURES

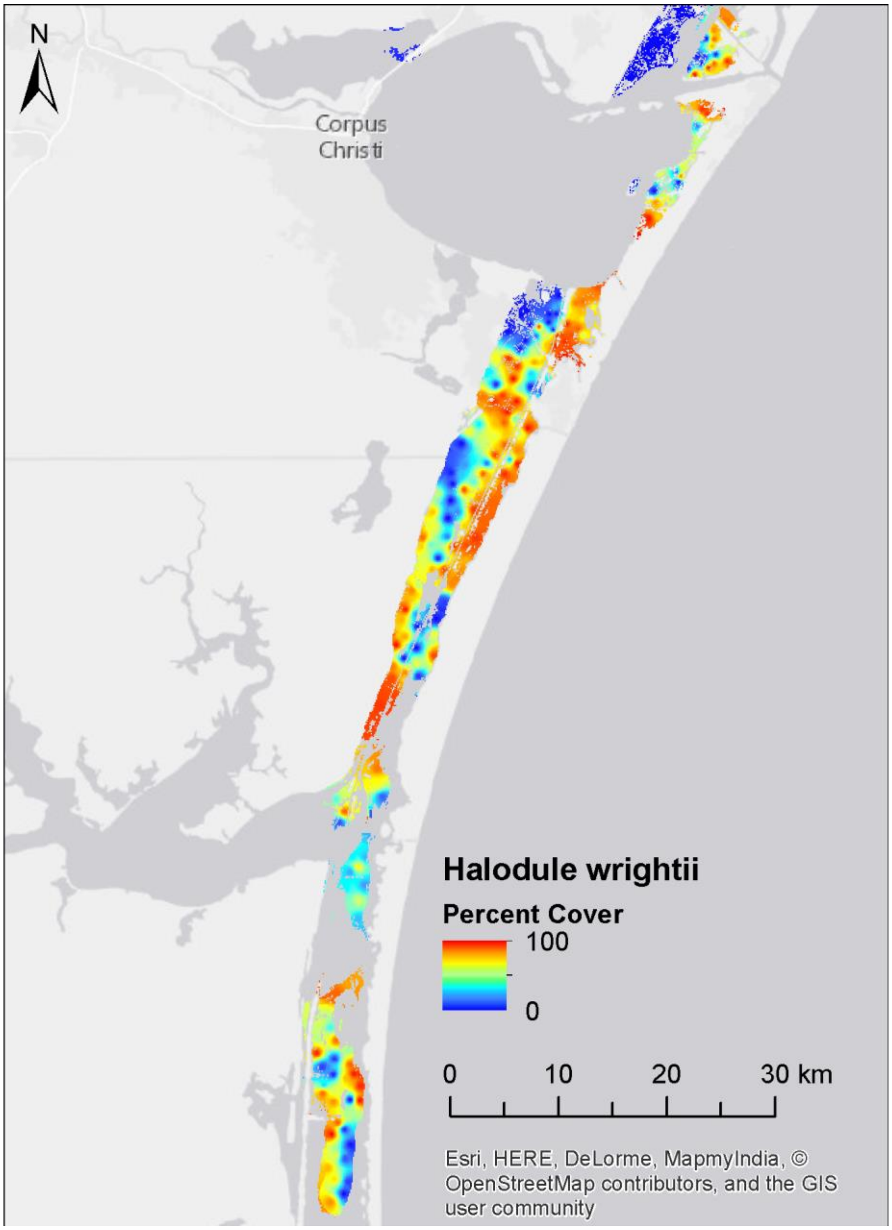

Figure 2. Spatial representations of percent cover for *Halodule wrightii* for 2018. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated during the 2004/2007 NOAA Benthic Habitat Assessment.

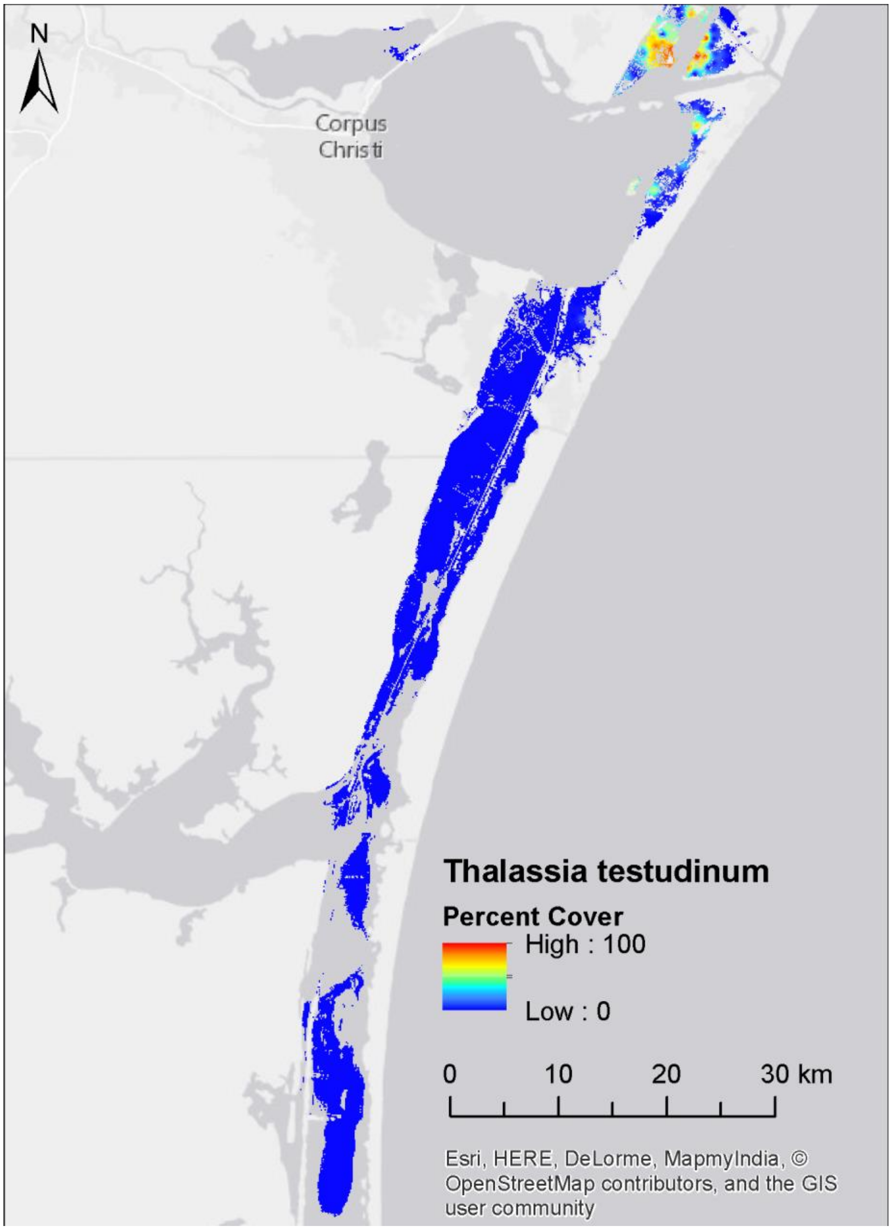

Figure 3. Spatial representations of percent cover for *Thalassia testudinum* for 2018. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated during the 2004/2007 NOAA Benthic Habitat Assessment.

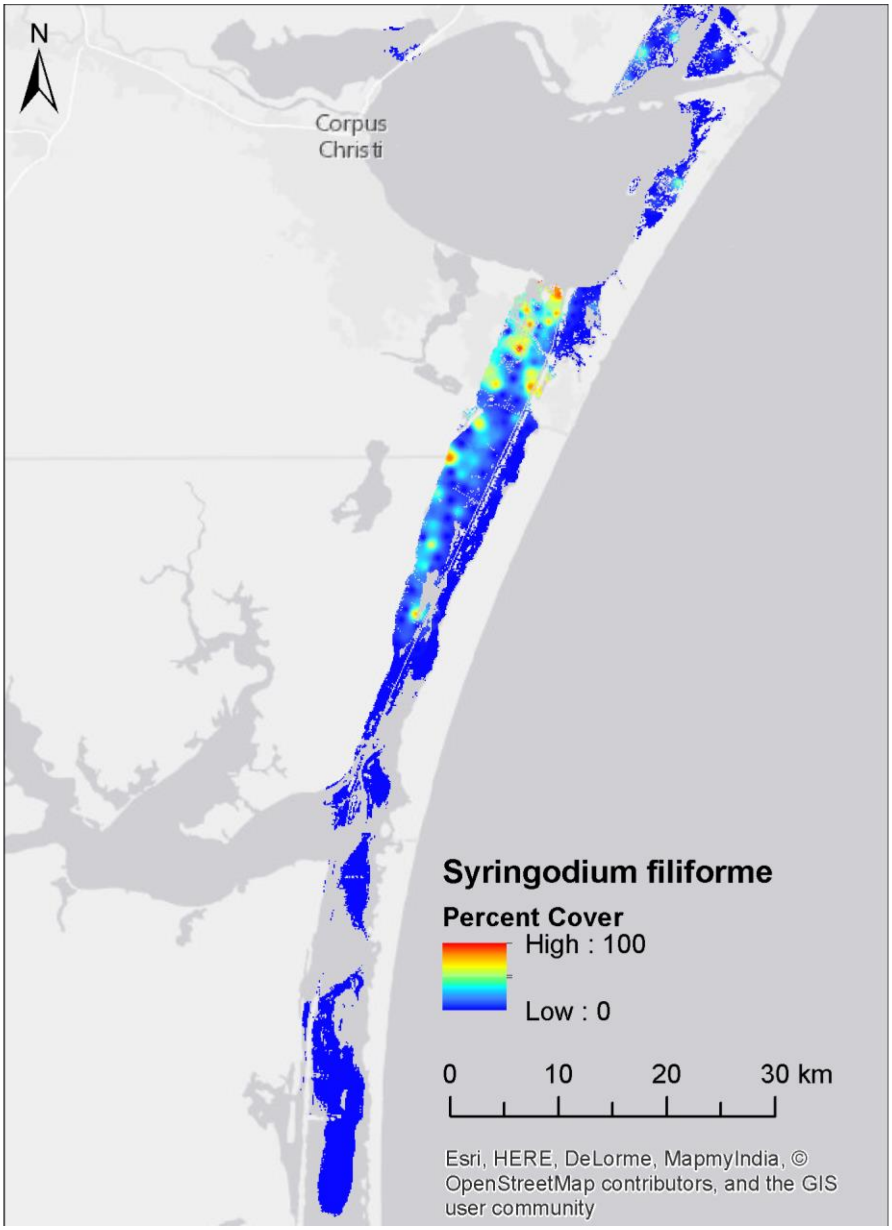

Figure 4. Spatial representations of percent cover for *Syringodium filiforme* for 2018. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated during the 2004/2007 NOAA Benthic Habitat Assessment.

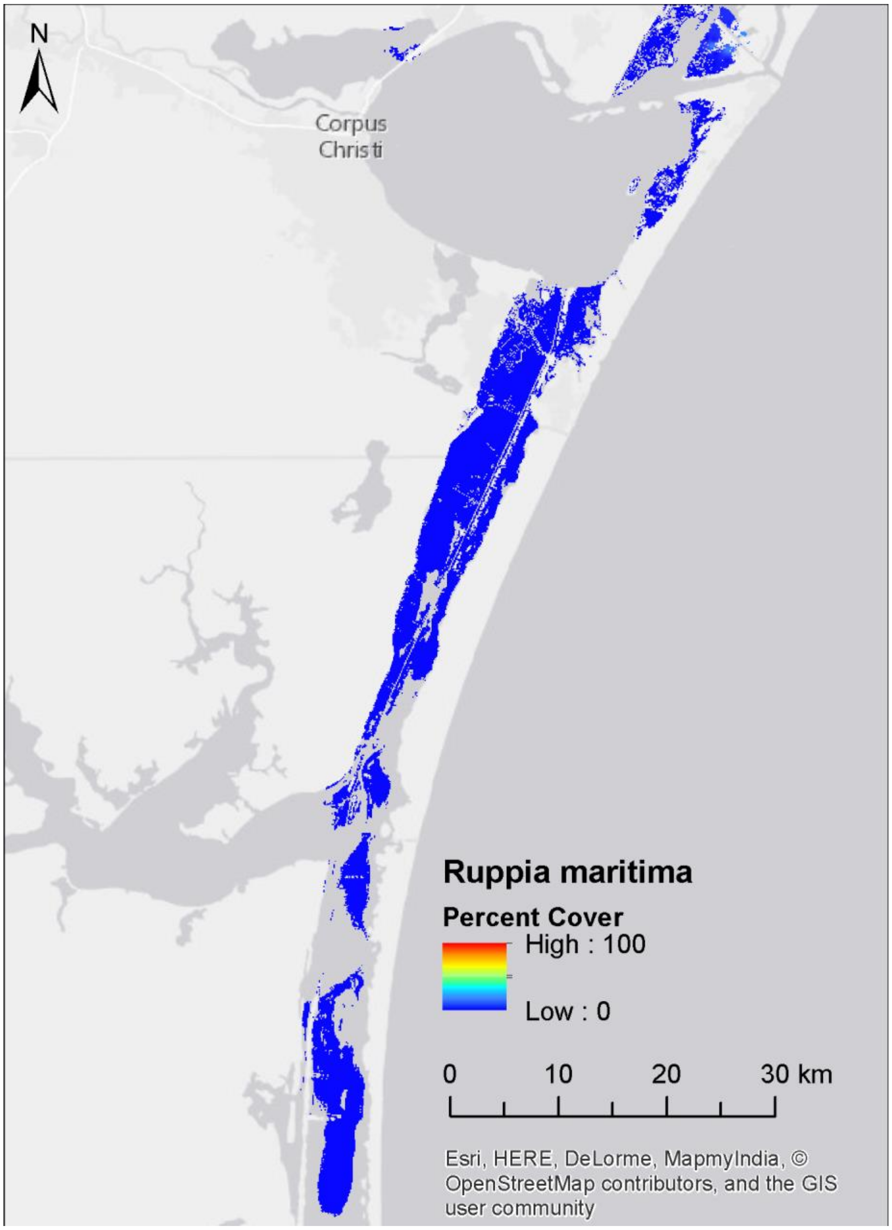

Figure 5. Spatial representations of percent cover for *Ruppia maritima* for 2018. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated during the 2004/2007 NOAA Benthic Habitat Assessment.

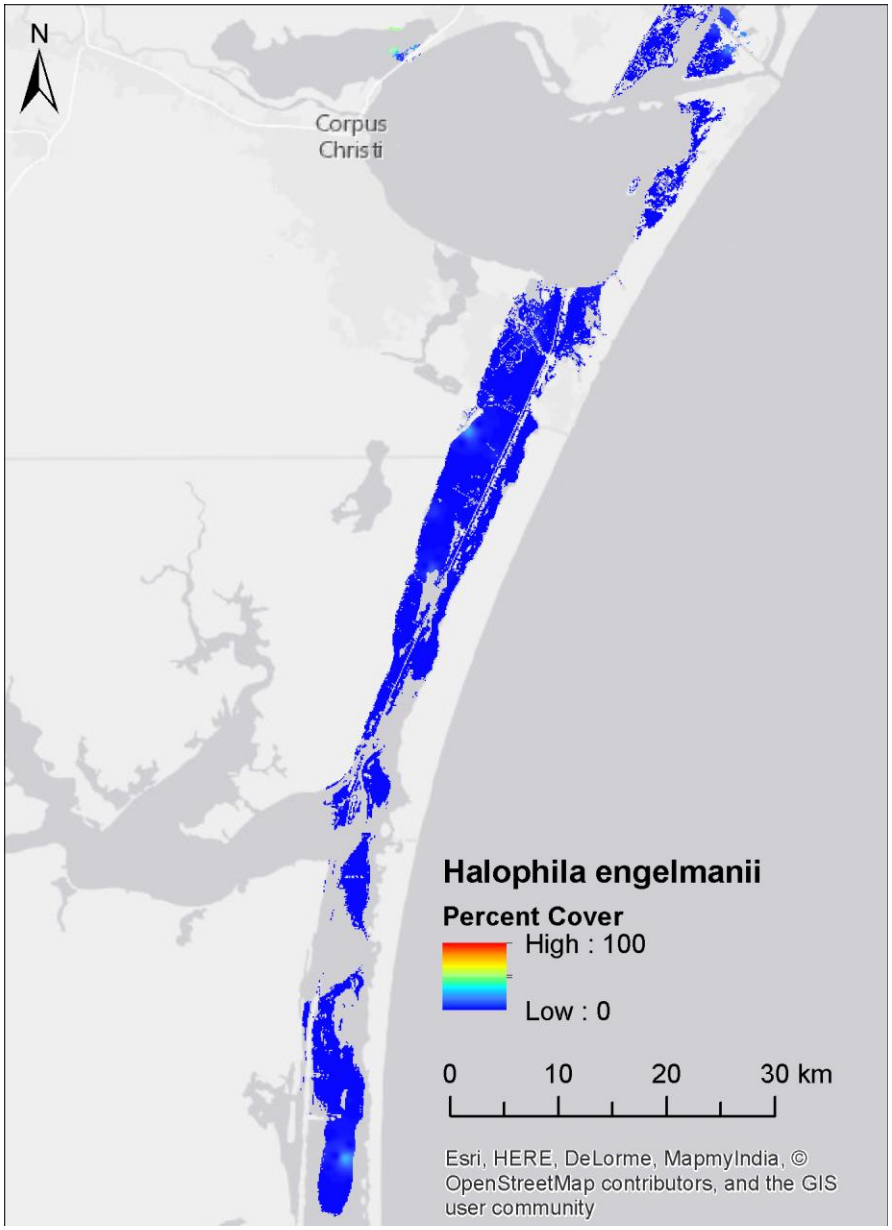

Figure 6. Spatial representations of percent cover for *Halophila engelmannii* for 2018. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated during the 2004/2007 NOAA Benthic Habitat Assessment.

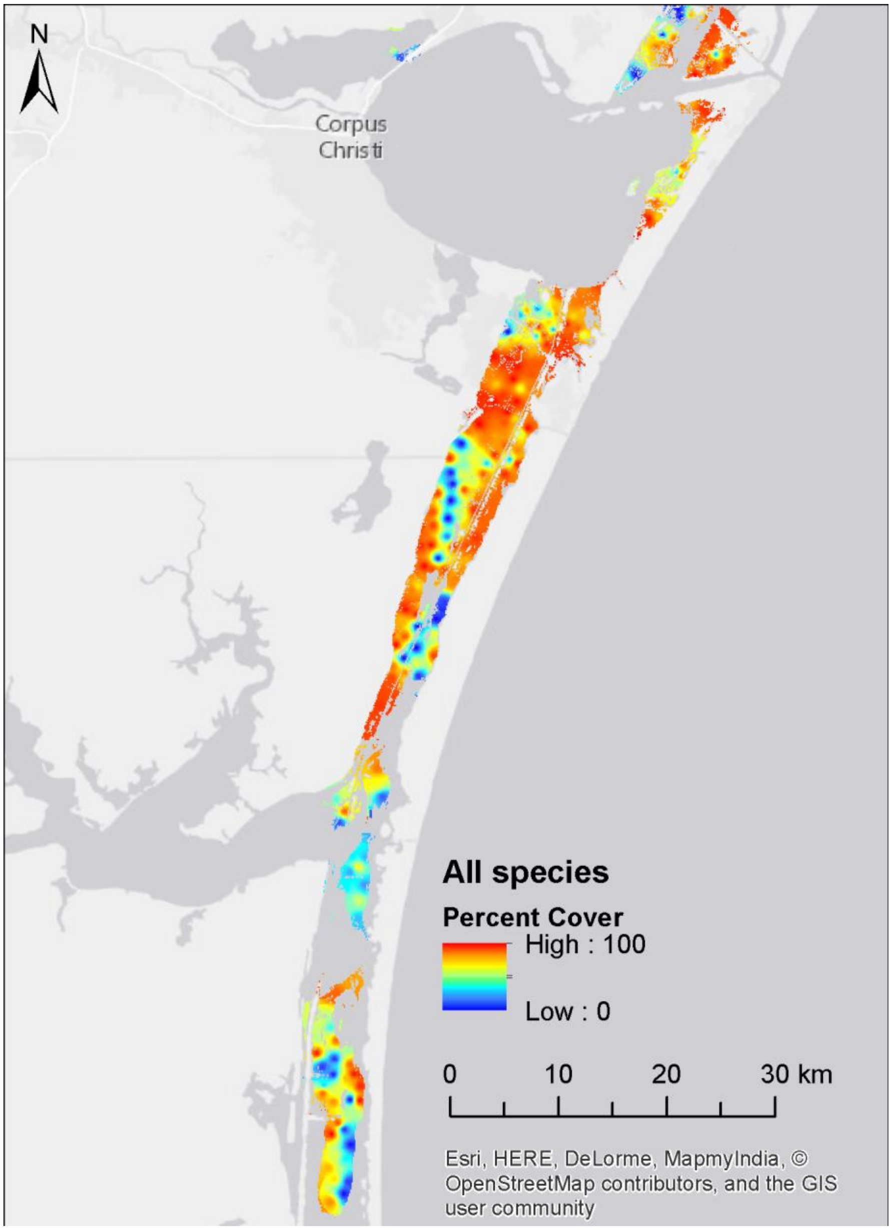

Figure 7. Spatial representations of percent cover for all seagrass species for 2018. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated during the 2004/2007 NOAA Benthic Habitat Assessment.

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