# A LONG-TERM SEAGRASS MONITORING PROGRAM FOR CORPUS CHRISTI BAY and UPPER LAGUNA MADRE

Final Report

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Submitted to:
**Coastal Bend Bays & Estuaries Program**
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Corpus Christi, TX 78401

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**Final Report to the Coastal Bend Bays and Estuaries Program**
**Seagrass Monitoring Project 2230**

**July 2022**

# Kyle A. Capistrant-Fossa and Kenneth H. Dunton

Texas Seagrass Monitoring CBBEP Contract No. 2230

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## EXECUTIVE SUMMARY


This study is part of the Texas seagrass monitoring program, with specific focus on Corpus Christi Bay (CCB) and the Upper Laguna Madre (ULM), following protocols that evaluate seagrass condition based on landscape-scale dynamics. This work is a continuation of the efforts set forth by Dunton et al., 2011 to implement long-term monitoring to detect environmental changes with a focus on the ecological integrity of seagrass habitats. 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 purpose of this study is to provide insight regarding the ecological consequences of environmental changes, and help decision makers (e.g., various state and federal agencies) determine if the observed change necessitates a revision of regulatory policy or management practices. The primary questions addressed in the 2021 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?", and 3) "How are any changes in seagrass percent cover and species composition related to measured characteristics of water quality?".

Seagrasses covered a significant portion of sampled Tier-2 sites with greater average cover in Corpus Christi Bay (66.3%) than Upper Laguna Madre (53.4%). Seagrass coverage in CCB significantly decreased from 2018 (73%), and current coverage is near post-Hurricane Harvey cover (63.3%). Seagrass canopy height has increased in some subregions after Harvey, indicating recovery. Many sites in ULM were deep (>2 m), which is near the light limit for seagrasses in the region, but light attenuation is lower in ULM compared to CCB. Average salinity was lowest in both bay systems during the sampling period since we began collecting data in 2011. *Halodule wrightii* and *Syringodium filiforme* were the most widely distributed seagrasses in both regions, *Thalassia testudinum* and *Ruppia maritima* were absent from ULM, and *Halophila engelmannii* was rarely found. High proportions of wrack (dead seagrass) and drift macroalgae were found in subregions of both ULM (Nine Mile Hole, Baffin Bay) and CCB (JFK Causeway). Fouling from drift seaweeds can significantly reduce the light available for seagrass photosynthesis.

# 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 coast-wide seagrass habitat monitoring program (Pulich and Calnan, 1999). 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 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. For the purposes of this study, ecological integrity is defined 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 2021 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). Tier-2 sampling was conducted from September to December 2021. Stations in Corpus Christi Bay were sampled in September (22, 27, 29), October (4, 6, 22), and November (3, 11). Stations in Upper Laguna Madre were sampled in October (7, 11, 18, 19), November (30), and December (2, 21). 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 2021 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.

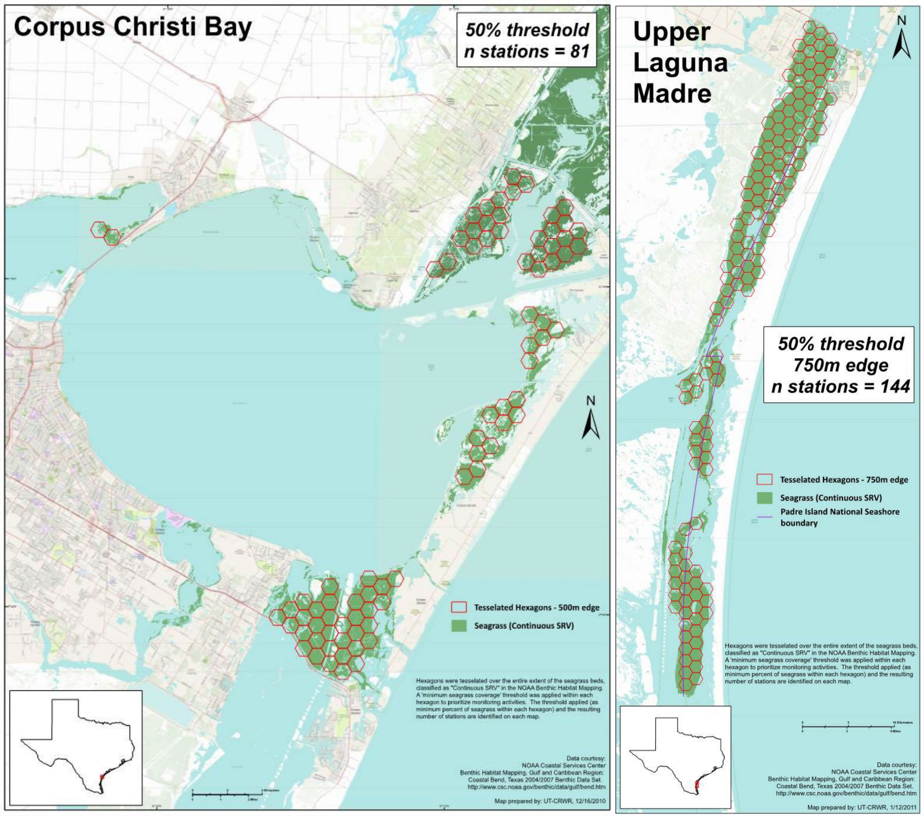


**Figure 1.** Tessellated boundaries of submerged vegetation delineated during the 2004/2007 NOAA Benthic Habitat Assessment where seagrass cover > 50%. Resulting stations (Upper Laguna Madre n = 144; Corpus Christi Bay n = 81) are identified in text on map. Stations outside the park boundary in Upper 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 2022 NOAA USA seagrass distribution database.

## RESULTS

### Water Quality

*Corpus Christi Bay*

The CCB region stations exhibited a depth of 81.1 ± 22.4 cm (mean ± standard deviation) and a mean water temperature of 27.1 ± 2.1°C (Table 1). Salinity measurements were relatively stable among sampling stations in this region, with a mean of 27.8 ± 2.7 (Table 1). Unusually low salinities for the region were recorded compared to our last synoptic sampling in 2017 (Figure 2). Also, no hypersaline conditions (>35) were recorded in the region in 2021. Dissolved oxygen concentrations in the CCB were 7.5 ± 2.7 mg $L^{-1}$ with a saturation of 111.5 ± 41.7% (Table 1). No hypoxic (≤ 2 mg $L^{-1}$) or low oxygen (≤ 3 mg $L^{-1}$) conditions were documented. Mean pH values for the CCB were 8.3 ± 0.2 (Table 1) and only two stations near the JFK Causeway that displayed values < 8.

*Upper Laguna Madre*

Stations within the ULM region had a mean depth of 112.3 ± 45.4 cm and an average water temperature of 21.8 ± 4.5 °C (Table 1). Salinity measurements were fresher and more variable than 2018 in this region, with a mean of 26.5 ± 3.0 (Table 1). Unlike previous years, this region did not experience hypersaline conditions during the sampling period (Figure 2). 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 8.7 ± 2.1 mg $L^{-1}$ (Table 1) and 114.9 ± 26.1% (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 8.3 ± 0.1 (Table 1), with highest values within Nine Mile Hole.

**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** | 81.1 | 27.1 | 27.8 | 7.5 | 111.5 | 8.3 |
| | **Std. Dev.** | 22.4 | 2.1 | 2.7 | 2.7 | 41.7 | 0.2 |
| **ULM** | | | | | | | |
| | **Mean** | 112.3 | 21.8 | 26.5 | 8.7 | 114.9 | 8.3 |
| | **Std. Dev.** | 45.4 | 4.5 | 3 | 2.1 | 26.1 | 0.1 |

**Water Column Optical Properties**

*Corpus Christi Bay*

The mean downward attenuation coefficient ($K_d$) was 1.2 ± 0.6 $m^{-1}$ for the CCB region (Table 2). Light attenuation was greatest near Redfish Bay, which coincided with higher TSS values in the area. Chlorophyll concentrations were less variable (4.5 ± 3.8 µg $L^{-1}$; Table 2) than TSS (11.1 ± 9.8 mg $L^{-1}$; Table 2) measurements for the CCB. Mean Secchi depth varied among stations (65.6 ± 17.0 cm; Table 2) but overall, visibility at most stations was near the entire depth of the water column or within 15 cm of the vegetated or sediment surface.

*Upper Laguna Madre*

The ULM stations were characterized by a mean $K_d$ of 1.1 ± 0.5 $m^{-1}$ (Table 2). The mean downward attenuation coefficient and variability were lesser in ULM than in the CCB region. Higher light attenuation values were observed near the JFK Causeway and Nine Mile Hole. Water column chlorophyll (5.1 ± 3.0 µg $L^{-1}$; Table 2) was higher in the ULM than in the CCB region but TSS concentrations (7.9 ± 8.0 mg $L^{-1}$; Table 2) were lower and less variable. Highest water column chlorophyll and TSS concentrations were observed near the JFK Causeway. Mean Secchi depth was variable (90.1 ± 29.1 cm; Table 2) and water transparency was low. At most stations, visibility was within 30 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** | 1.2 | 65.6 | 4.5 | 11.1 |
| | **Std. Dev.** | 0.6 | 17.0 | 3.8 | 9.8 |
| **ULM** | | | | | |
| | **Mean** | 1.1 | 90.1 | 5.1 | 9.5 |
| | **Std. Dev.** | 0.5 | 29.1 | 3 | 8.0 |

**Seagrass Cover and Species Distributions**

*Corpus Christi Bay*

Mean total seagrass cover in the CCB region was 66.3%. The seagrass assemblage in the CCB was dominated by *Halodule wrightii* (36.1 ± 38.6%; Table 3, Figure 3), followed by *Thalassia testudinum* (14.9 ± 26.9%; Table 3, Figure 4) and *Syringodium filiforme* (11.5 ± 23.5%; Table 3, Figure 5), with minor contributions from *Ruppia maritima* (1.1 ± 4.3%; Table 3, Figure 6) and *Halophila engelmannii* (2.7 ± 10.2%; Table 3, Figure 7). *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*. Six stations (~ 7%) in the CCB did not have vegetation present. Low seagrass cover was observed in southern Redfish Bay near Ingleside and Aransas Pass, and northwest of the JFK causeway (Figure 8). Some of these regions coincide with higher proportions of drift macroalgae ("other"; Figure 9) that would limit the light available to seagrass thereby hindering their growth. High proportions of wrack (dead seagrass) were present at a few stations near the JFK Causeway and would have a similar affect to drift macroalgae (Figure 10). Furthermore, seagrasses within Redfish Bay were particularly affected by Hurricane Harvey and have yet to recover to pre-Harvey values. Established *Thalassia testudinum* populations are probably 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* and *Halodule wrightii* coverage in the CCB region decreased from 2018, while *Syringodium filiforme* coverage increased. Canopy height was greatest in *Syringodium filiforme* (34.2 ± 9.1 cm; Table 4) followed by *Thalassia testudinum* (30.9 ± 10.1 cm; Table 4), *Halodule wrightii* (22.2 ± 5.3 cm; Table 4), *Ruppia maritima* (6.3 ± 1.2 cm; Table 4) and *Halophila engelmannii* (6 ± 1.7 cm; Table 4).

*Upper Laguna Madre*

The ULM mean seagrass cover for all species was approximately 53.4%. The seagrass assemblage was again dominated by *Halodule wrightii* (42.4 ± 37.0%; Table 3, Figure 3), followed by and *Syringodium filiforme* (7.8 ± 21.4%; Table 3, Figure 5), and *Halophila engelmannii* (3.2 ± 8.9%; Table 3, Figure 7). The ULM region was devoid of

*Thalassia testudinum* and *Ruppia maritima* (Table 3, Figures 4 and 6). Twenty-five sampling stations (~ 17%) were absent of vegetation. Typically, stations that were bare or had low seagrass cover corresponded with greater water depths (~2 m) especially those located along the western shore of Laguna Madre. An exception, however, is the mouth of Baffin Bay and the northern part of Nine Mile Hole which had substantial amounts of drift wrack (i.e., mats of dead seagrass). This seagrass was completely bleached indicating it had died much earlier in the season. Nine Mile Hole is notorious for extremely hypersaline conditions during periods of low rainfall which causes high physiological stress on the plants, even for a tolerant species such as *Halodule wrightii*. If meteorological conditions permit, this drift wrack can be released back into the seagrass meadows to limit light availability and severely stress the living plants. *Syringodium filiforme* has maintained high cover near the JFK Causeway but percent cover along the western shore of Laguna Madre has remained exceptionally low (at water depths ~2 m). Highest canopy height values were observed in *Syringodium filiforme* (32.2 ± 9.9 cm; Table 4), followed by *Halodule wrightii* (22.3 ± 7.9 cm; Table 4) and *Halophila engelmannii* (5.5 ± 1.8 cm; Table 4). Mean canopy height was similar between the ULM and CCB regions.

**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) | Wrack (% cover) | Other (% cover) |
|---|---|---|---|---|---|---|---|---|---|
| **CCB** | | | | | | | | | |
| | **Mean** | 36.1 | 14.9 | 11.5 | 1.1 | 2.7 | 21.9 | 3.8 | 8.0 |
| | **Std. Dev.** | 38.6 | 26.9 | 23.5 | 4.3 | 10.2 | 29.5 | 12.7 | 15.0 |
| **ULM** | | | | | | | | | |
| | **Mean** | 42.4 | 0 | 7.8 | 0 | 3.2 | 30.9 | 11.8 | 3.9 |
| | **Std. Dev.** | 37.0 | 0 | 21.4 | 0 | 8.9 | 40.2 | 20.1 | 8.0 |

**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** | 22.2 | 30.9 | 34.2 | 6.3 | 6 |
| | **Std. Dev.** | 5.3 | 10.1 | 9.1 | 1.2 | 1.7 |
| **ULM** | | | | | | |
| | **Mean** | 22.3 | 0 | 32.2 | 0 | 5.5 |
| | **Std. Dev.** | 7.9 | 0 | 9.9 | 0 | 1.8 |

## CONCLUSIONS

*Corpus Christi Bay*

The average salinity during our sampling period was the lowest recorded during Tier-2 sampling, due to 2021 being one of the rainiest years on record for the CCB region. In south Redfish Bay, a greater presence of *Thalassia testudinum* was observed 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 66% of the seabed in CCB which decreased from 73% in 2018 to the post Hurricane Harvey (2017) value of 65%. The decrease in seagrass cover to near post-Harvey levels warrants attention given the significant decrease in seagrass coverage following Harvey (79% to 65%). (Congdon et al., 2019). *Thalassia testudinum* and *Halodule wrightii* cover has decreased since 2018, but the average canopy height for both has increased. This suggests that seagrass canopies were recovering from the effects of Hurricane Harvey, but an unexpected event may have caused a reduction in meadow coverage. A historically large freeze affected the ULM and CCB regions in 2021 and could have killed less cold-tolerant blades to cause a reduction in seagrass meadow cover (Hicks et al., 1998). Additionally, high proportions of drift macroalgae may smother seagrasses, compete for nutrients, and decrease available light for photosynthesis (Kopecky and Dunton, 2006). Future monitoring is needed to determine if *Thalassia testudinum* will recover, be replaced by pioneer species, or remain unvegetated. Spatial patterns suggest that *Syringodium filiforme* extended its range further north into Shamrock Cove and *Halodule wrightii* decreased in cover near Shamrock Cove and East Flats.

*Upper Laguna Madre*

Overall, water quality in the ULM region was more amenable to seagrass growth than the CCB region. Lower light attenuation coefficients in ULM are likely in response to reduced concentrations of TSS in the water. Despite the favorable water transparency in ULM, mean seagrass cover in the ULM was lower than CCB. Seagrass cover was lower along the western shore of Laguna Madre, likely because of diminished light availability in deeper waters, but seagrasses were particularly prevalent along the eastern shore of Laguna Madre into Nine Mile Hole. *Halodule wrightii* cover appears to have increased in Nine Mile Hole which can be attributed to lower salinities caused by 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 53.4% of the seabed in the ULM, significantly less than the coverage of 66% in 2018. This significant decrease in seagrass coverage suggests a largescale seagrass die-off occurred within the ULM, possibly from regional climatic drivers (such as the February 2021 freeze event)

Much of the western shoreline of ULM was barren. Nine Mile Hole and the mouth of Baffin Bay had large proportions of drift *Halodule* wrack that covered live seagrass beds. This wrack appeared to be heavily degraded indicating that it spent months on the shore. Given the quantity of wrack and shallow water in the ULM, it is possible the seagrasses here were less protected from the 2021 freeze event. However, reduced salinities in Nine Mile Hole have improved conditions for *Halodule wrightii* which has 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 driven by changes in salinity and species competition (Wilson and Dunton, 2018).

**FIGURES**

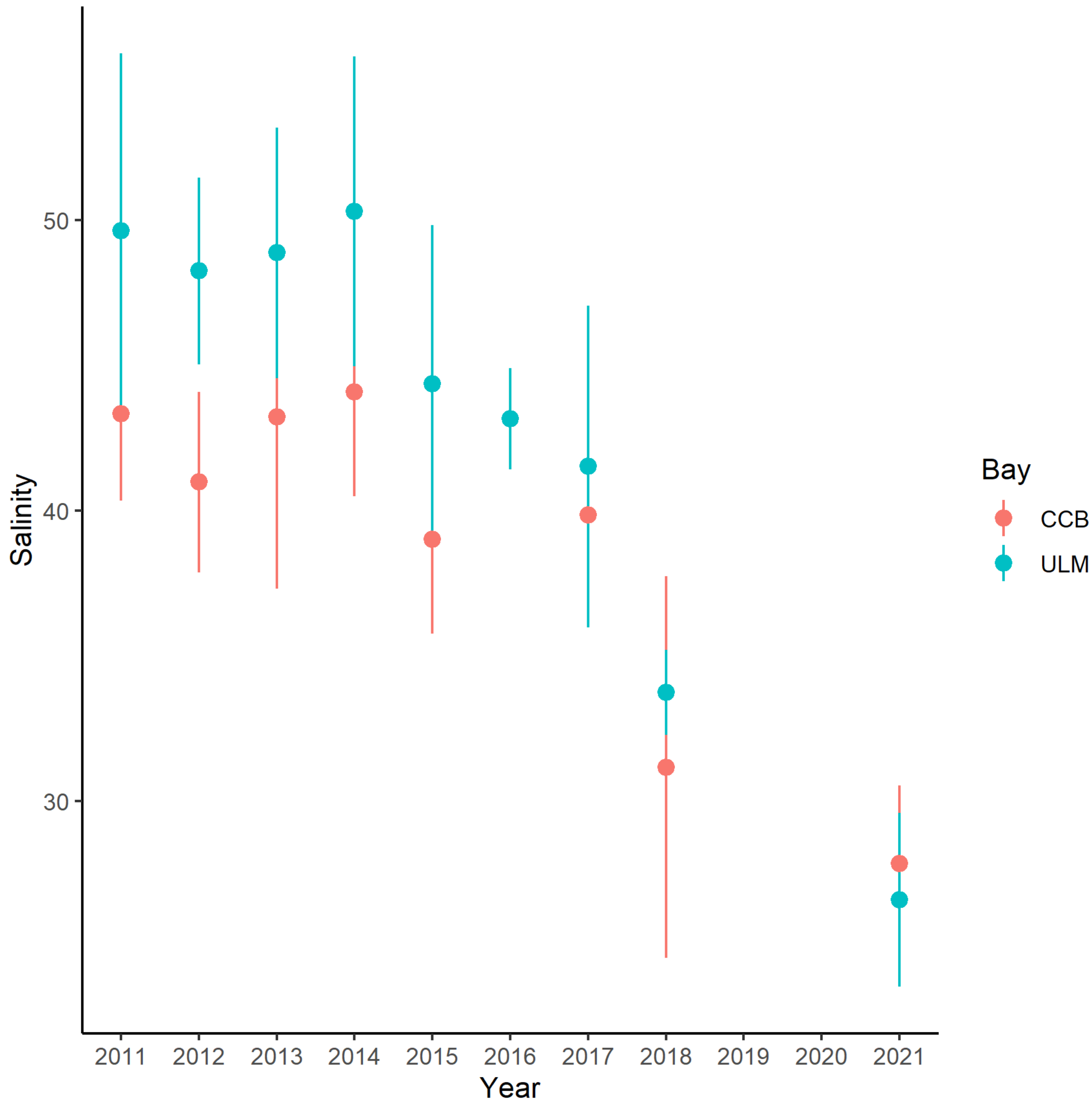


**Figure 2.** Average (±SD) salinity collected from Corpus Christi Bay (CCB) and Upper Laguna Madre (ULM) during Tier-2 sampling from 2011 – 2021. Note: CCB was not sampled in 2016 and neither bay was sampled in 2019 or 2020.

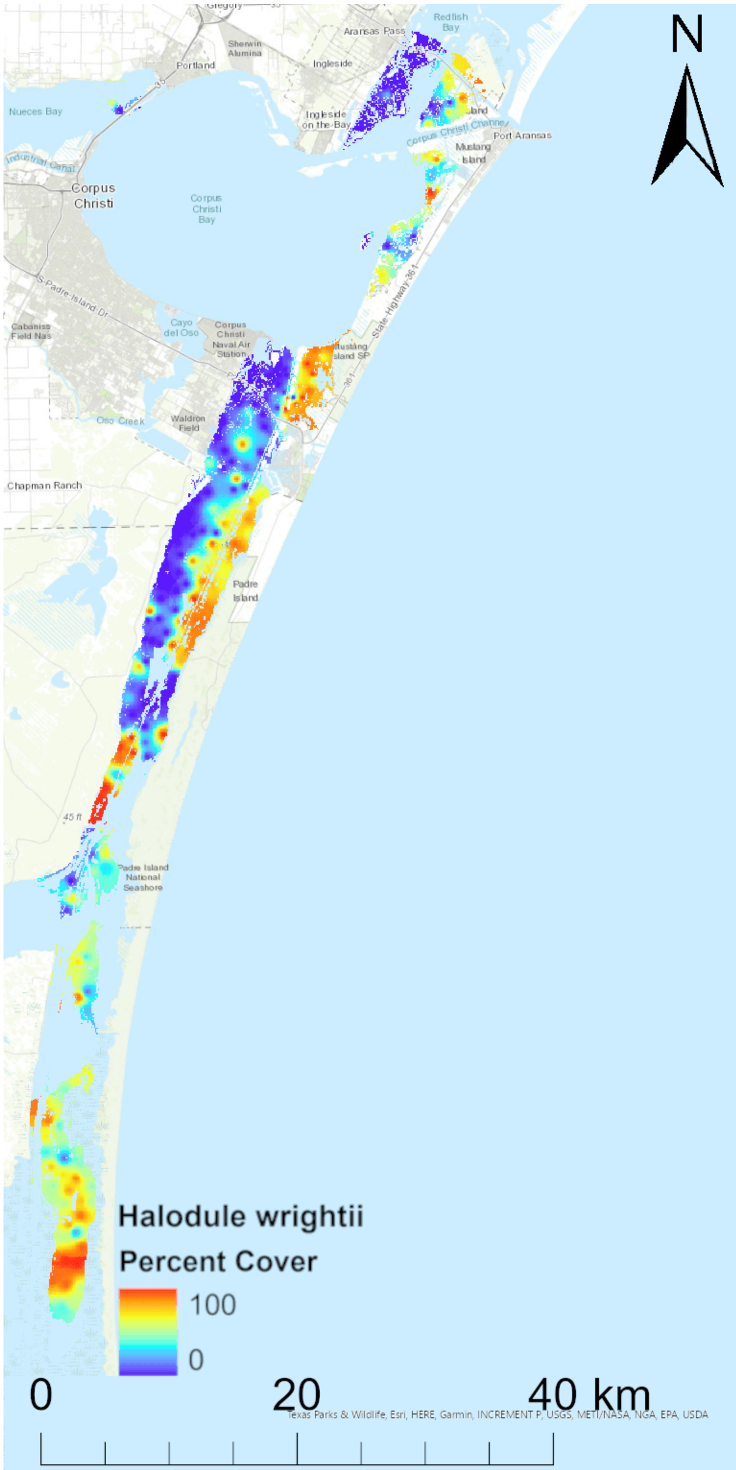


**Figure 3.** Spatial representations of percent cover for *Halodule wrightii* for 2021. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database. The map was prepared by UT-CWE.

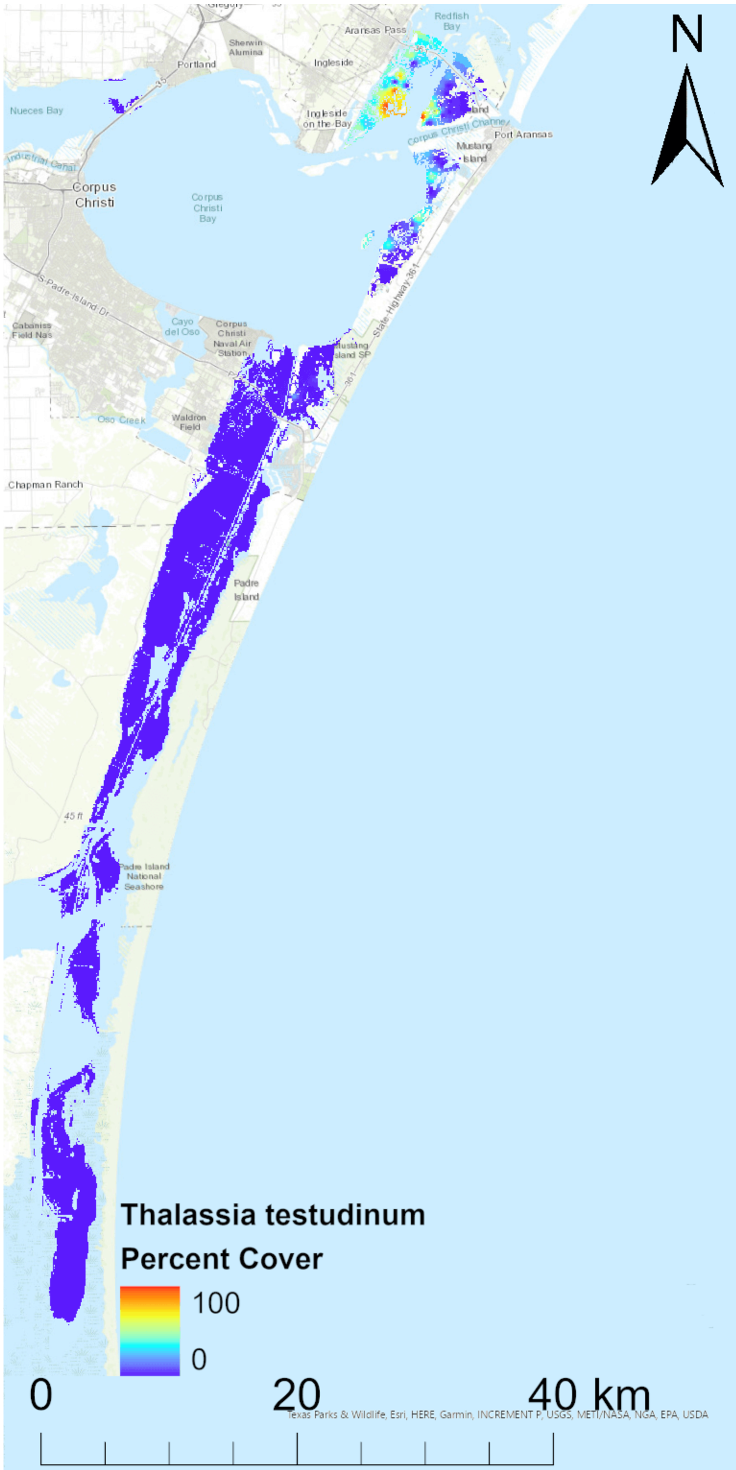


**Figure 4.** Spatial representations of percent cover for *Thalassia testudinum* for 2021. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database. The map was prepared by UT-CWE.

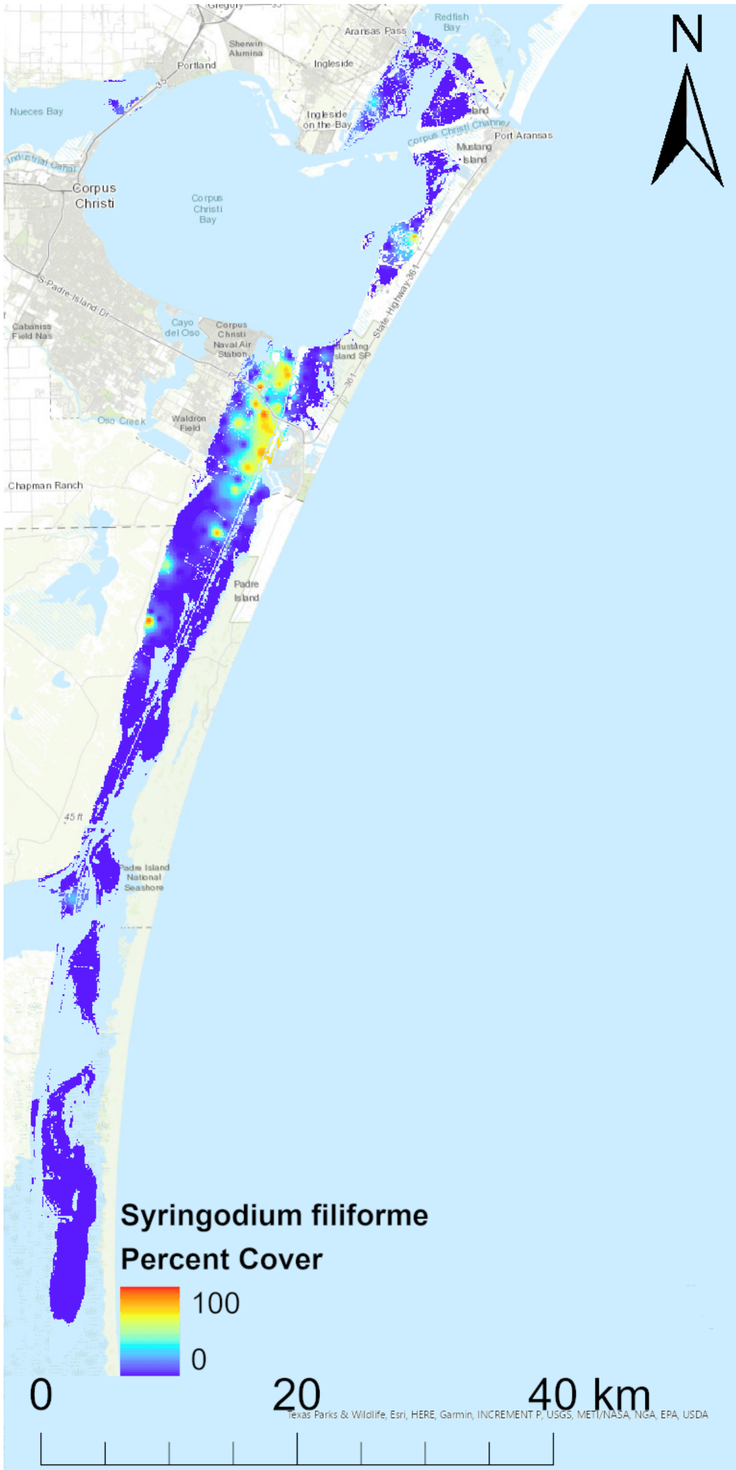


**Figure 5.** Spatial representations of percent cover for *Syringodium filiforme* for 2021. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database. The map was prepared by UT-CWE.

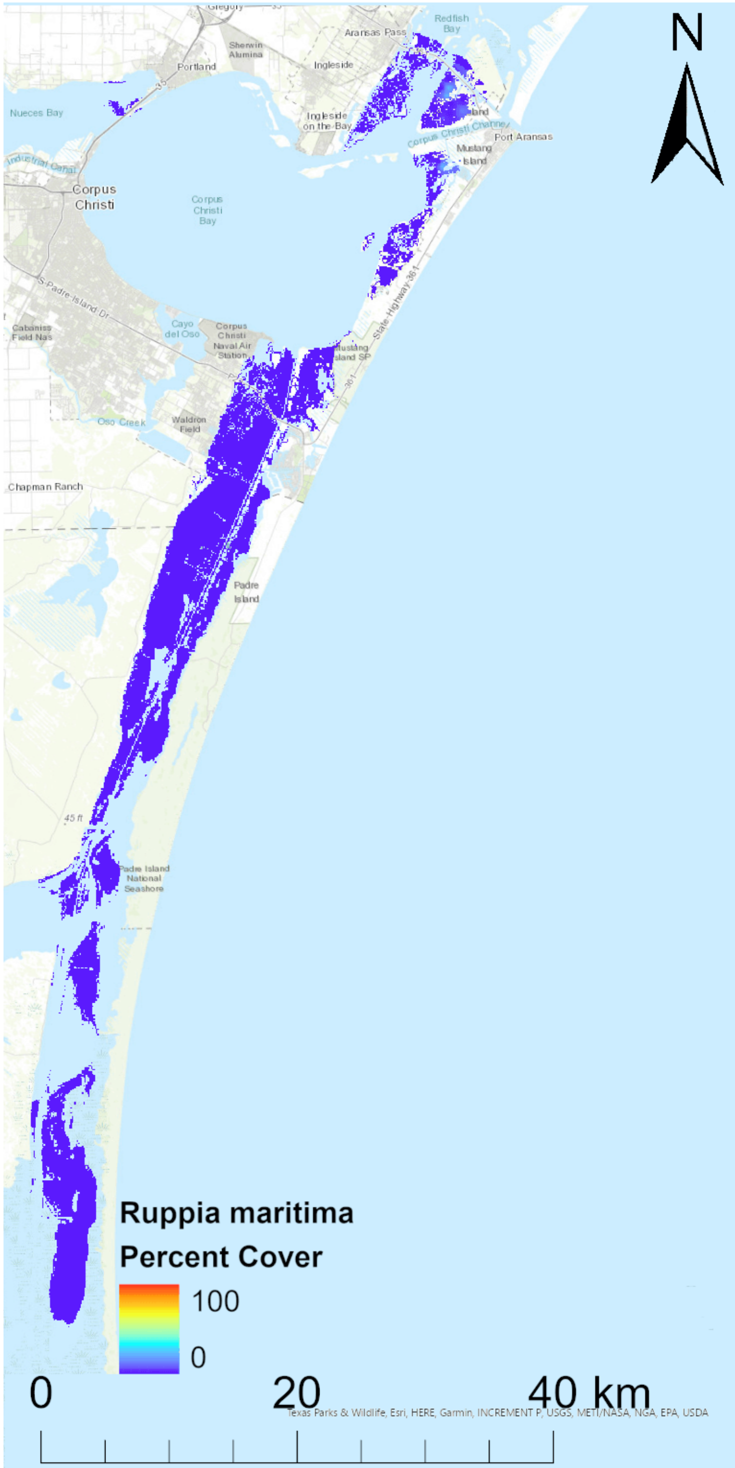


**Figure 6.** Spatial representations of percent cover for *Ruppia maritima* for 2021. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database. The map was prepared by UT-CWE.

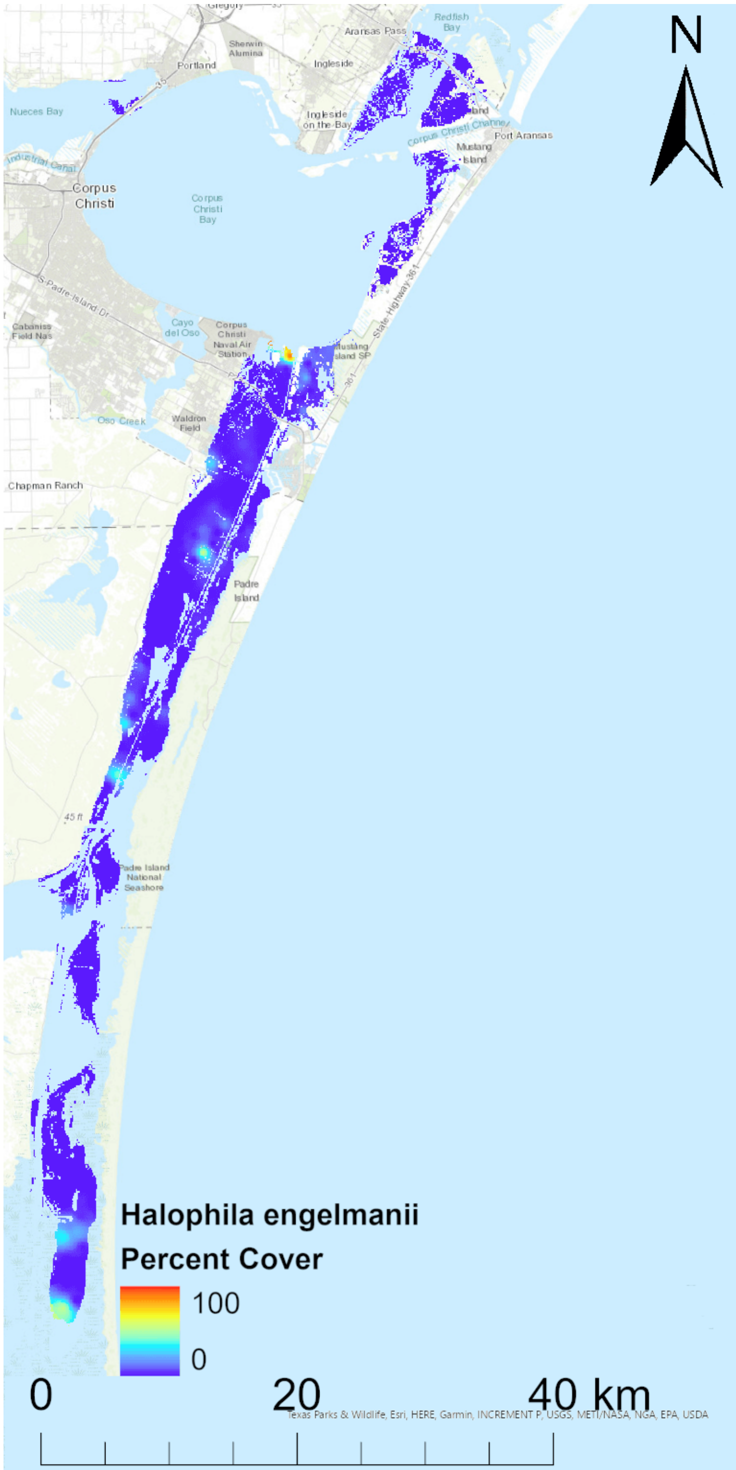


**Figure 7.** Spatial representations of percent cover for *Halophila engelmannii* for 2021. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database. The map was prepared by UT-CWE.

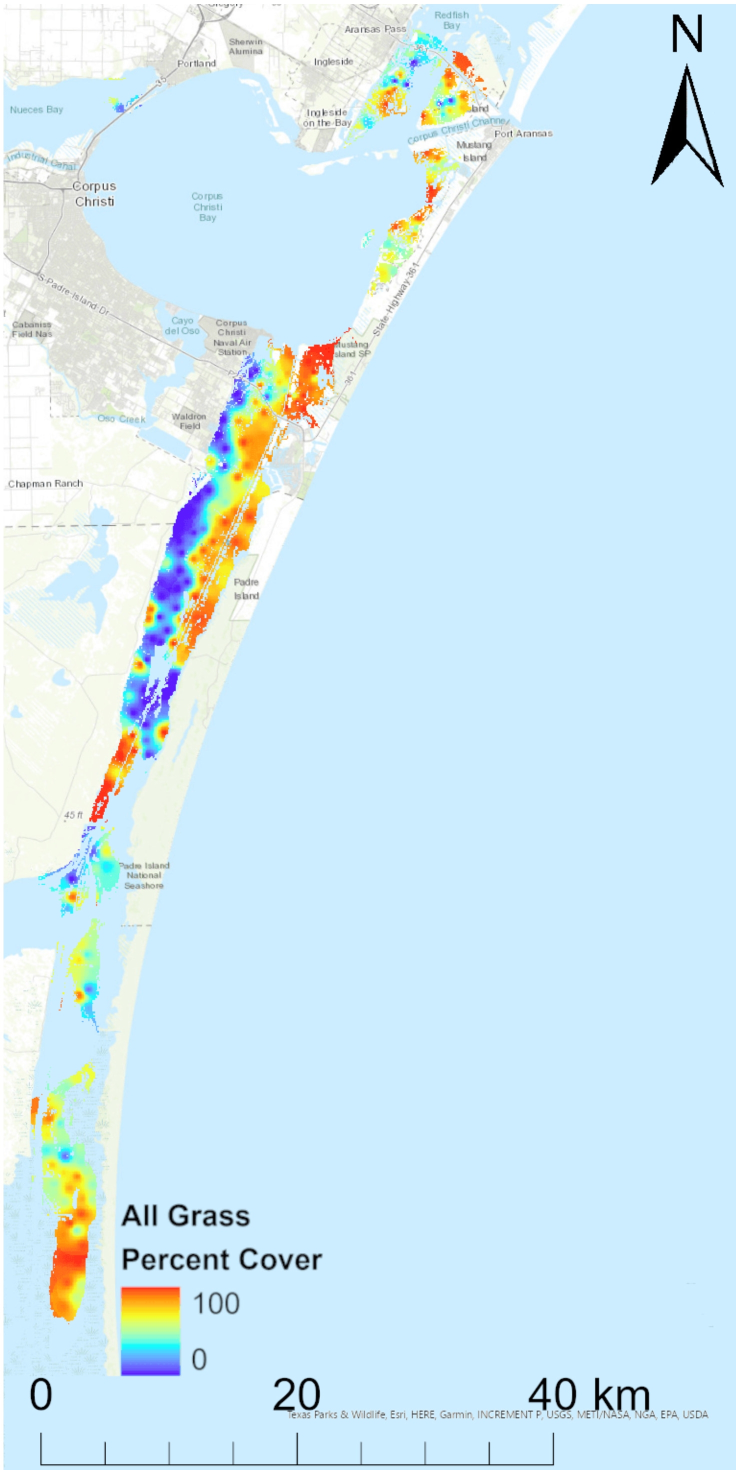


**Figure 8.** Spatial representations of percent cover for all seagrass species for 2021. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database. The map was prepared by UT-CWE.

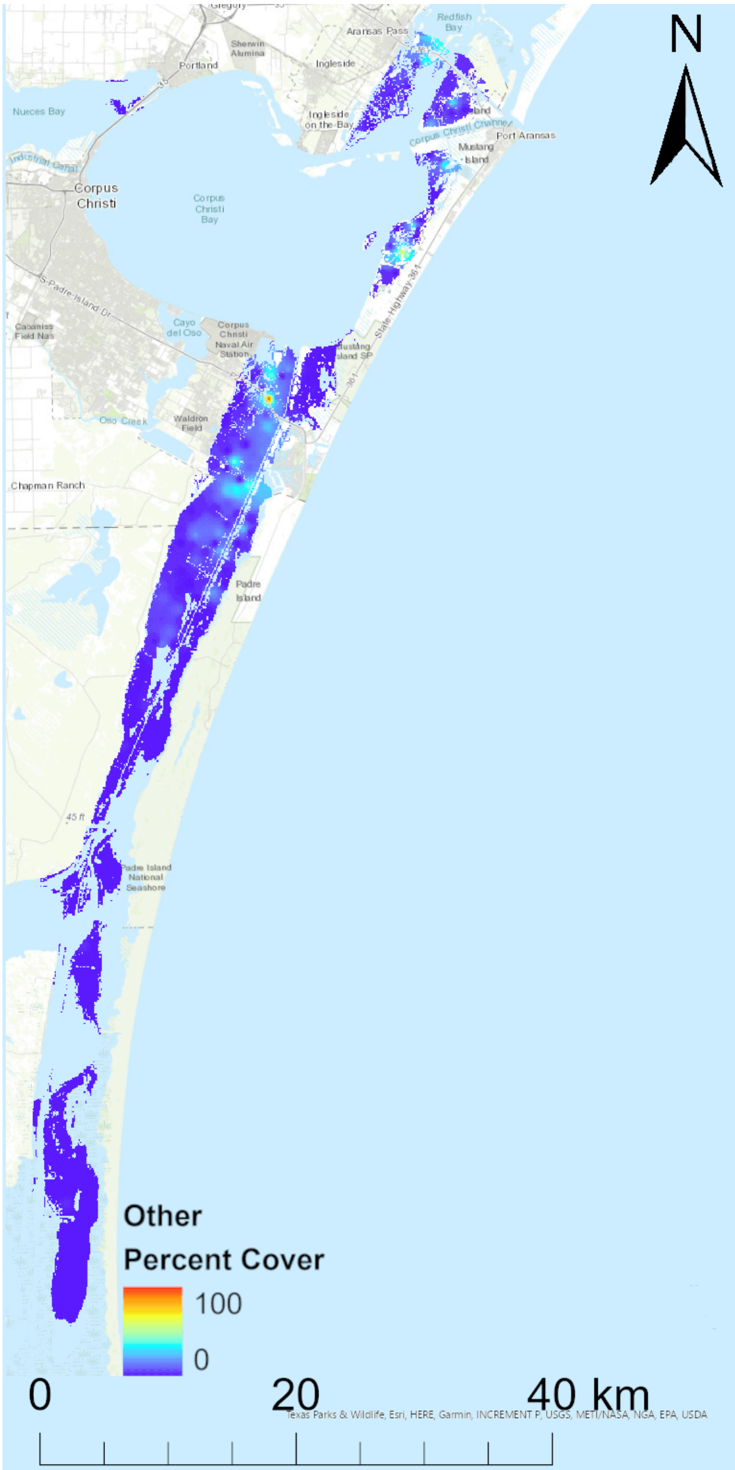


**Figure 9.** Spatial representations of percent cover for living, non-seagrass, ecosystem components (e.g., drift macroalgae) for 2021. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database. The map was prepared by UT-CWE.

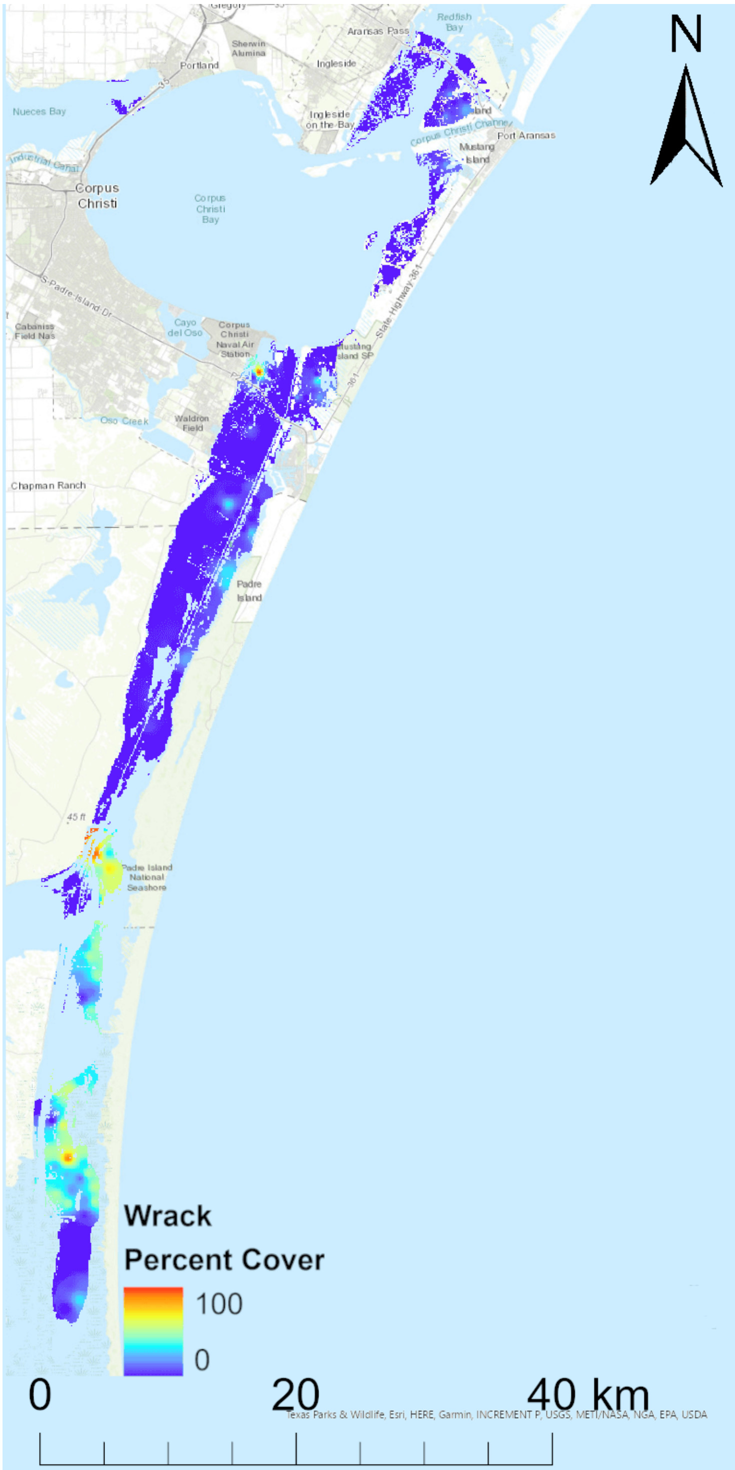


**Figure 10.** Spatial representations of percent cover for seagrass wrack for 2021. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database. The map was prepared by UT-CWE.

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