A LONG-TERM SEAGRASS MONITORING PROGRAM FOR CORPUS CHRISTI BAY, UPPER LAGUNA MADRE, AND BAFFIN BAY

Final Report

Publication CBBEP – 162
Project Number – 2330

1 August 2023

Prepared by:

Kyle A. Capistrant-Fossa, M.S.
Sofia Armada Tapia, B.S.
and
Kenneth H. Dunton, Ph.D.
University of Texas at Austin Marine Science Institute
750 Channel View Drive, Port Aransas, TX 78373
Phone: (361) 749-6744
Fax: (361) 749-6777
E-mail: ken.dunton@utexas.edu

Submitted to:
Coastal Bend Bays & Estuaries Program
1305 N. Shoreline Blvd., Suite 205
Corpus Christi, TX 78401

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Seagrass Monitoring Project 2330

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Kyle A. Capistrant-Fossa, Sofia Armada Tapia, and Kenneth H. Dunton

EXECUTIVE SUMMARY

This study is part of the Texas seagrass monitoring program, with specific focus on Corpus Christi Bay (CCB), Baffin Bay (BB), 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 2022 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%) or Baffin Bay (30.2 %). Seagrass coverage in CCB increased from 2021 (66.3%). Seagrass canopy height has increased in some subregions indicating continued recovery after Hurricane Harvey and Winter Storm Uri. Many sites in ULM were deep (>1.5 m), which is near the light limit for seagrasses in the region. Only 5% of sites were barren in ULM when Tier-2 sampling began in 2011 compared to 24% in 2022. Waters in BAF were the worst optically because of the high attenuation rates, suspended solids, and Chlorophyll a concentrations. *Halodule wrightii* and *Syringodium filiforme* were the most widely distributed seagrasses in all regions. *Thalassia testudinum* was only found in CCB while *Ruppia maritima* and *Halophila engelmannii* were rarely found in all systems.

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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), Upper Laguna Madre (ULM), and Baffin Bay (BAF) following protocols that evaluate seagrass condition based on landscape-scale dynamics (Figure 1). Secondary bays within each system that have high seagrass coverage were also included (e.g., Nueces Bay, Alazan Bay). 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 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 2022 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 (rapid assessment sampling methods) are adapted from Neckles et al. (2012). We conducted Tier-2 sampling from August to December 2022. Stations in Corpus Christi Bay were sampled in September (8, 22, 26, 30) and October (3). Stations in the Upper Laguna Madre were sampled in August (10, 18), September (19), October (3, 5, 12, 13), November (15), and December (2). Stations in Baffin Bay were sampled in October (26), November (23, 28), and December (2). 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 compliments ongoing remote sensing efforts. Therefore, we selected sites from vegetation maps generated with aerial and satellite imagery during the 2004/2007 NOAA Benthic Habitat Assessment (ULM/CCB) and the 2022 NOAA Seagrass Database (BAF). The vegetation maps were then tessellated using hexagons, and sample locations were randomly selected within each hexagon (Figure 1). Only hexagons containing > 50% seagrass cover were included in 2022 sampling efforts for ULM and CCB. Additional stations with < 50% cover were included in Baffin Bay to fully sample the extent of seagrasses in the system.

Water Quality

All sampling stations were located using a handheld GPS device to be 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.

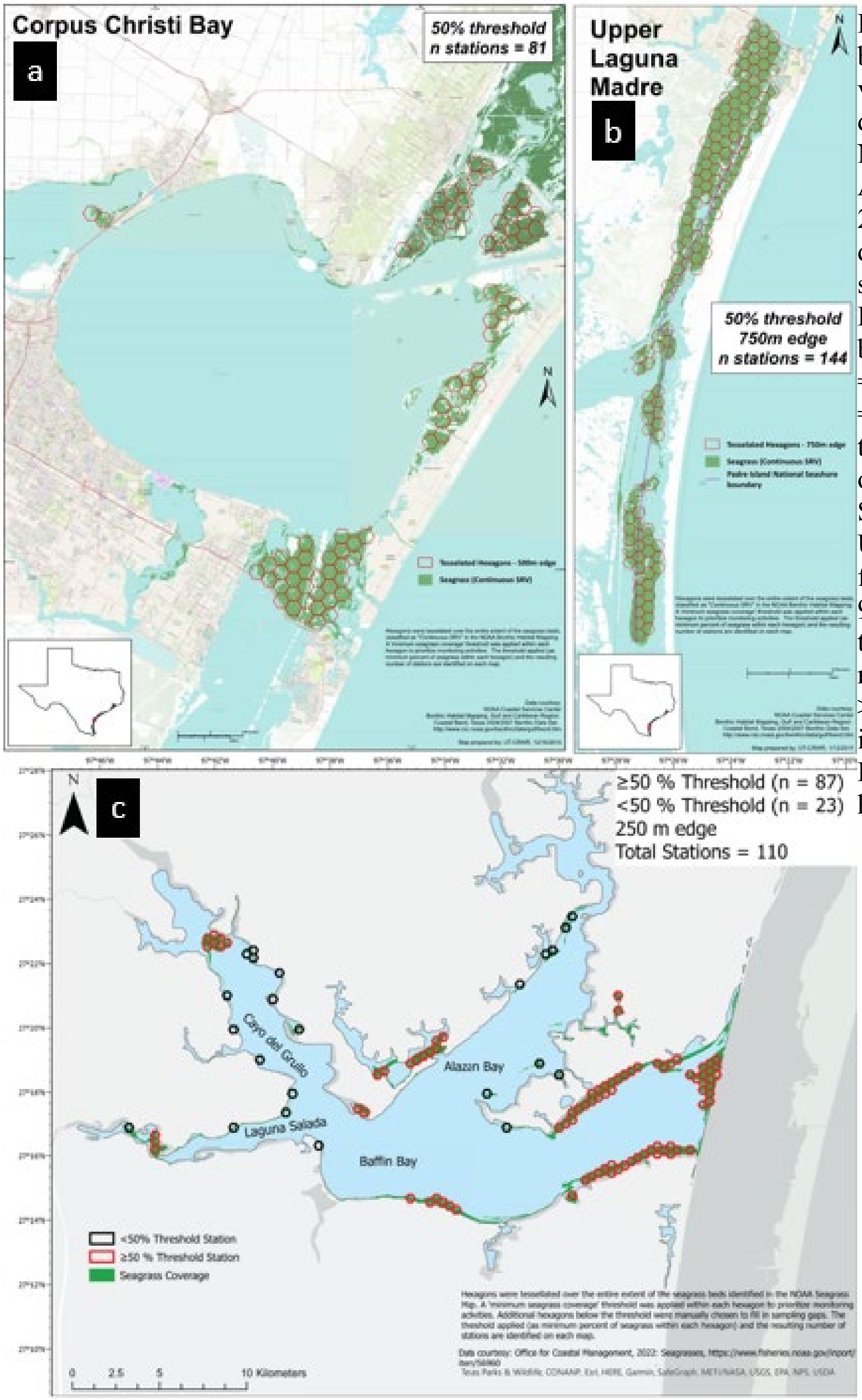


Figure 1. Tessellated boundaries of submerged vegetation delineated during the 2004/2007 NOAA Benthic Habitat Assessment (a, b) or the 2022 NOAA seagrass dataset (c). Resulting stations in a) Upper Laguna Madre (n = 144), b) Corpus Christi Bay (n = 81), or c) Baffin Bay (n = 110) are identified in text on map. Stations outside the National Park Service boundary in Upper Laguna Madre are funded by CBBEP (n = 92) and are delineated by the light purple line on the map. Stations must have >50% seagrass coverage in CCB and ULM, but BAF stations in black have less <50%.

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

Corpus Christi Bay stations had a mean water depth of 84.6 ± 21.3 cm (mean ± standard deviation), water temperature of 28.9 ± 2.2°C, and salinity of 35.9 ± 1.7 (Table 1). Overall, stations were warmer, deeper, and saltier in 2022 than 2021 (Capistrant-Fossa & Dunton, 2022). Dissolved oxygen concentrations were 7.4 ± 1.9 mg L^{-1} with an oxygen saturation of 117.6 ± 32.4% (Table 1). No hypoxic ($\leq$ 2 mg L^{-1}) or low oxygen ($\leq$ 3 mg L^{-1}) conditions were documented. The mean pH value for CCB was 8.1 ± 0.2 (Table 1). Many stations had pH < 8 including East Flats, Shamrock Bay, Redfish Bay, and the Nueces Bay Causeway.

Upper Laguna Madre

Stations had a mean water depth of 110 ± 43.2 cm and temperature of 26.7 ± 4.8°C (Table 1). This system was hypersaline because mean salinity (39.3 ± 3.7) was greater than typical oceanic conditions (Table 1). Overall, waters were deeper, saltier, and warmer than 2021 (Capistrant-Fossa & Dunton, 2022). Interestingly, the salinity increased by >12 to typical hypersaline conditions in Nine Mile Hole. This area 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.* The ULM typically experiences hypersaline conditions because of its limited connection to Gulf waters and the lack of any significant freshwater source. However, salinity has been relatively low in the past few years due to high precipitation rates. The mean dissolved oxygen concentration and saturation was 6.6 ± 1.6 mg L^{-1} (Table 1) and 102.1 ± 21.2% (Table 1), respectively. No monitoring sites were hypoxic (< 2 mg L^{-1}), but three had low oxygen (< 3 mg L^{-1}). The mean pH was 8.1 ± 0.1 (Table 1), with the highest values within Nine Mile Hole.

Baffin Bay

Stations in Baffin Bay had a mean water depth of 91 ± 39.5 cm (Table 1). BAF was the coolest (15.8 ± 3.2°C) and most saline (41.6 ± 3.6) estuary sampled during 2022 (Table 1). Hypersaline conditions are common in this area due to the low freshwater inflow and high evaporation rates, with a high residency time (An & Gardner, 2002). The mean dissolved oxygen concentration was 8.6 ± 1.5 mg L^{-1} with a saturation of 111.6 ± 16% (Table 1). No hypoxic ($\leq$ 2 mg L^{-1}) sites were documented in the region. The mean pH was 8.3 ± 0.1.

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	84.6	28.9	35.9	7.4	117.6	8.1
	Std. Dev.	21.3	2.2	1.7	1.9	32.4	0.2
ULM							
	Mean	110	26.7	39.3	6.6	102.1	8.1
	Std. Dev.	43.2	4.8	3.7	1.6	21.2	0.1
BAF							
	Mean	91	15.8	41.6	8.6	111.6	8.3
	Std. Dev.	39.5	3.2	3.6	1.5	16	0.1

Water Column Optical Properties

Corpus Christi Bay

The mean downward light attenuation coefficient (K_d) was 1.0 ± 0.5 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 (4.4 ± 2.8 µg L^{-1}) than TSS (11.1 ± 8.9 mg L^{-1}) measurements (Table 2). Mean Secchi depth varied among stations (77.7 ± 17.9 cm) but overall, visibility at most stations was near the entire depth of the water column or within 10 cm of the vegetated or sediment surface (Table 2). Overall, water quality conditions were better in 2022 than 2021 for CCB (Capistrant-Fossa & Dunton, 2022).

Upper Laguna Madre

Monitoring in 2022 revealed a higher and more variable mean downward light attenuation coefficient (K_d 1.4 ± 0.7 m^{-1}) than in 2021 (Table 2; Capistrant-Fossa & Dunton, 2022). Higher light attenuation coefficients were observed near the JFK Causeway, Baffin Bay, and Nine Mile Hole. Additionally, water column chlorophyll (6.5 ± 4.1 µg L^{-1}; Table 2) and TSS (12.7 ± 10.3 mg L^{-1}; Table 2) were higher in 2022 compared to 2021. The mean Secchi depth was variable (83.5 ± 27.8 cm; Table 2) and water transparency was relatively low. At most stations, visibility was within 30 cm of the vegetated or sediment surface, on average.

Baffin Bay

The downward light attenuation coefficient (K_d) had a mean value of 1.9 ± 1.2 m^{-1} (Table 2) although the number of samples (n=9) was low in comparison to the other regions. TSS concentrations (mean 23.2 ± 15.4 mg L^{-1}; Table 2) had the highest values near Kingsville. Furthermore, mean chlorophyll values were 9.9 ± 8.5 µg L^{-1} (Table 2). Mean Secchi depth (59.9 ± 25.1 cm; Table 2) was variable among stations, nonetheless, visibility was within 30 cm of the vegetated or sediment surface, on average.

Table 2. Summary of water transparency property indicators by region. *Low number of samples.

		K_d **(m^{-1})**	**Secchi** **(cm)**	**Chlorophyll *a*** **($\mu g\ L^{-1}$)**	**Total Suspended Solids** **($mg\ L^{-1}$)**
CCB					
	Mean	1.0	77.7	4.4	11
	Std. Dev.	0.5	17.9	2.8	8.9
ULM					
	Mean	1.4	83.5	6.5	12.7
	Std. Dev.	0.7	27.8	4.1	10.3
BAF					
	Mean	1.9*	59.9	9.9	23.2
	Std. Dev.	1.2*	25.1	8.5	15.4

Seagrass Cover and Species Distributions

Corpus Christi Bay

The mean seagrass coverage for sites sampled in the CCB region was 68.5%. The seagrass assemblage (Table 3) in CCB was dominated by *Halodule wrightii* (35.6 ± 42.1%; Figure 2), followed by *Thalassia testudinum* (15.3 ± 28.9%; Figure 3) and *Syringodium filiforme* (17.2 ± 31.3%; Figure 4), with minor contributions from *Ruppia maritima* (0.2 ± 1%; Figure 5) and *Halophila engelmannii* (0.2 ± 0.8%; Figure 6). *Halodule wrightii* was most widely distributed within the CCB region relative to the other seagrass species (Figure 2). However, minimal cover was observed in the southwest portion of Redfish Bay, which was dominated by *Thalassia testudinum*. Four stations (~ 5%) 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 7). Overall, *Thalassia testudinum* and *Halodule wrightii* coverage in the CCB remained stable between 2021 and 2022 (Capistrant-Fossa & Dunton, 2023), while *Syringodium filiforme* coverage increased by ~6%. Canopy height (Table 4) was greatest in *Thalassia testudinum* (33.9 ± 8.8 cm), followed by *Syringodium filiforme* (29.9 ± 9.7 cm), *Halodule wrightii* (23 ± 5.5 cm), *Ruppia maritima* (4.6 ± 0.7 cm) and *Halophila engelmannii* (4 ± 0.9 cm).

Upper Laguna Madre

The mean seagrass cover for sites within the ULM for all species was 54.3%, a 1.1% decrease from 2021 because of *Syringodium filiforme* (-3.1%) and *Halophila engelmannii* (-2.6%) losses (Capistrant-Fossa & Dunton, 2023). However, the coverage of the dominant seagrass, *Halodule wrightii,* increased (+4.8%; Table 3; Figure 2). Interestingly, *Ruppia maritima* was found in Nine Mile Hole, whereas it was absent from ULM in 2021 (Figure 5). No *Thalassia testudinum* was present during sampling. Thirty-five sampling stations (24%) were devoid of vegetation compared to only twenty-five sampling stations in 2021. Typically, stations that were bare or had low seagrass cover corresponded with greater water depths (>1.5 m) especially those located along the northwestern shore of Laguna Madre (Figure 7). Seagrass coverage was also low in Nine Mile Hole where some sites had substantial amounts of drift wrack (i.e., mats of dead seagrass). *Syringodium filiforme* has maintained high cover near the JFK Causeway and the mouth of Baffin Bay (Figure 4). *Halophila* was rarely found in northern ULM (Figure 6). Little rooted wrack (dead seagrass) or attached macroalgae was found in ULM (Figures 8, 9). The highest canopy height values were observed in *Syringodium filiforme* (23.7 ± 9.1 cm; Table 4), followed by *Halodule wrightii* (20.9 ± 8.4 cm), *Halophila engelmannii* (8.2 ± 5 cm), and *Ruppia maritima* (5.1 ± 2.5 cm). Mean canopy height was significantly lower in 2022 than 2021 (Capistrant-Fossa & Dunton, 2023).

Baffin Bay

The mean seagrass cover for sites in Baffin Bay was 30.2% for all species. The seagrass meadow was mainly composed of *Halodule wrightii* (28.7 ± 37.5%; Table 3, Figure 2) with a higher abundance along the southwest shore near Upper Laguna Madre and Cayo del Infiernillo. Other species like *Syringodium filiforme* (0.7 ± 6.5%; Table 3, Figure 4), *Ruppia maritima* (0.7 ± 7.4%; Table 3, Figure 5) and *Halophila engelmannii* (0.1 ± 0.9%; Table 3, Figure 6) had minor contributions with small patches in specific areas. *Syringodium filiforme* was found in the mouth of the bay near Upper Laguna Madre, whereas *Ruppia maritima* was mostly in the northern part of Cayo del Grullo. *Thalassia testudinum* was not found in any of the stations. Furthermore, seagrass was not found in forty-five stations (40%) located near Laguna Salada, Alazan Bay and Cayo del Grullo (Figure 7). Canopy height was highest in *Syringodium filiforme* with a mean of 17.9 ± 0.4 cm (Table 4), followed by *Halodule wrightii* (13.8 ± 5.2 cm; Table 4), *Ruppia maritima* (6 ± 1.5 cm; Table 4) and *Halophila engelmannii* (5 ± 1.5 cm; Table 4).

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	35.6	15.3	17.2	0.2	0.2	31.6	0	0.1
	Std. Dev.	42.1	28.9	31.3	1	0.8	34.3	0	0.3
ULM									
	Mean	47.6	0	6	0	0.7	45.3	0.4	0.0
	Std. Dev.	44.3	0	17.8	0.2	3.7	43.1	3.9	0.4
BAF									
	Mean	28.7	0	0.7	0.7	0.1	69.8	0	0
	Std. Dev.	37.5	0	6.5	7.4	0.9	37.8	0.1	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	23.0	33.9	29.9	4.6	4.0
	Std. Dev.	5.5	8.8	9.7	0.7	0.9
ULM						
	Mean	20.9	0	23.71	5.1	8.2
	Std. Dev.	8.4	0	9.1	2.5	5
BAF						
	Mean	13.8	0	17.9	6	5
	Std. Dev.	5.2	0	0.4	1.5	1.5

CONCLUSIONS

Corpus Christi Bay

In south Redfish Bay, we observed a 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 68.5% of the seabed in CCB which increased from post Hurricane Harvey (2017) value of 65%. The increase in seagrass cover is promising given the impact of Hurricane Harvey in 2017 (Congdon et al., 2019). *Thalassia testudinum* and *Halodule wrightii* cover has decreased since 2018, but the average canopy height for both has increased. Additionally, seagrass coverage was low in 2021 probably because of the damage from Winter Storm Uri, and large amounts of drift macroalgae. Large amounts of drift macroalgae may smother seagrasses, compete for nutrients, and decrease available light for photosynthesis (Kopecky and Dunton, 2006). However, canopy cover increased in 2022 suggesting that seagrass canopies have recovered from the effects of both storms. Future monitoring is needed to determine if historical *Thalassia testudinum* beds 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 across the ULM region was worse for seagrass growth in 2022 than 2021. Increased chlorophyll-*a* and suspended solid concentrations likely elevated the light attenuation coefficients. Together, these changes resulted in an ~29% decrease in light available for seagrasses to perform photosynthesis across the ULM. Decreases in light availability are one of the major drivers of seagrass loss worldwide, and likely contributed to the decreased canopy cover and height. Increased phytoplankton (determined via chlorophyll a) could potentially compensate for lost seagrass production for the ecosystem but decreases in pH and dissolved oxygen suggest a depressed net ecosystem metabolism. Additionally, the number of completely barren locations has reached ~25% of all monitoring sites within ULM. Seagrass cover was lower along the western shore of Laguna Madre, likely because of diminished light availability in deeper waters. In contrast, seagrasses were particularly prevalent in shallower areas along the eastern shore of Laguna Madre into Nine Mile Hole. *Halodule wrightii* cover decreased in Nine Mile Hole which we attribute to higher salinities because of decreased precipitation. 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 54.3% of the seabed in the ULM, significantly less than the coverage of 66% in 2018 (Reyna & Dunton, 2019). This significant decrease in seagrass coverage suggests large-scale seagrass declines are occurring within the ULM, likely from increased water depth (Capistrant-Fossa & Dunton, 2023). Future monitoring efforts are needed to document and identify the expansions and contractions of *Syringodium filiforme* and *Halodule wrightii* within the ULM that are largely driven by changes in water quality, climate, and species competition (Wilson and Dunton, 2018).

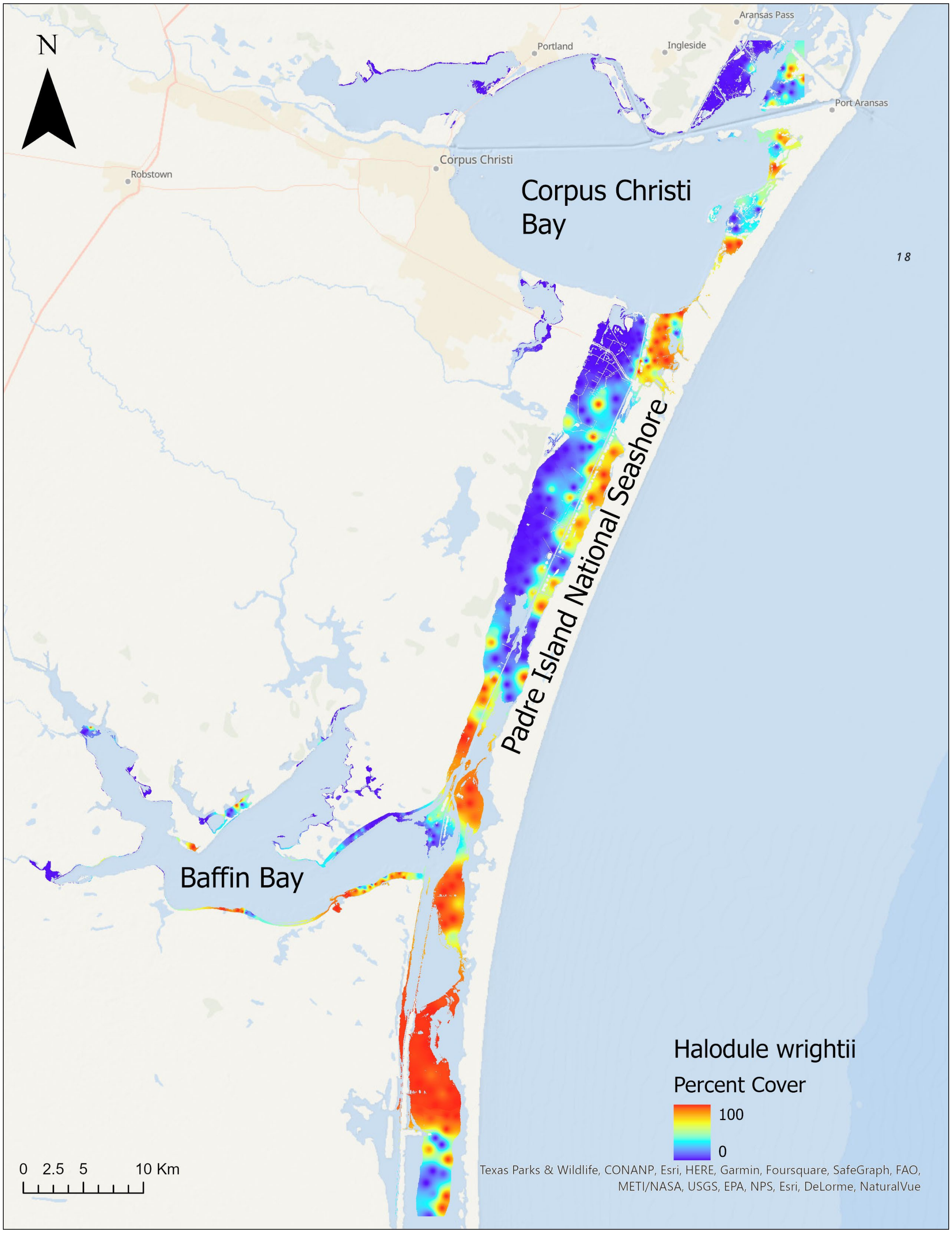
Baffin Bay

The water quality of BAF was suboptimal for seagrass growth because of decreased light availability. This is reflected in the sparse distribution of seagrass across the region, where percent cover and total suspended solids were inversely related. Furthermore, chlorophyll concentrations were highest in this area, contributing to the low availability of light that would limit seagrass photosynthesis. Combined, these factors could potentially drive this area to have the lowest seagrass meadow coverage during Tier-2 sampling. The number of barren sites in BAF identified where almost half of the sites sampled (40%). Overall, *Halodule wrightii* dominated meadows and was especially prevalent along the southwest shore of BAF. Although the physical conditions of the environment play an important role in the distribution and abundance of seagrass, the seagrass cover recorded could be underestimating the actual percentage cover due to seasonality. Earlier in the season, seagrass presence was recorded in barren areas, so the area likely has strong seasonal biomass cycles.

Summary

Differences in water quality trends help explain the significant variation in seagrass meadow coverage between bay systems. Waters in BAF were optically poor because of high chlorophyll and suspended solid concentrations leading to low light penetration. Although sampling in BAF typically took place later in the growing season than CCB or ULM, these patterns are likely robust. Chlorophyll a was significantly higher in BAF than CCB or ULM, despite it not being near peak biomass in any system (Tominack & Wetz, 2022; Beecraft & Wetz, 2022). Likewise, TSS concentrations are relatively low in Nov-Feb compared to other parts of the year in CCB and ULM because of frontal passages (Reisinger et al., 2017). Consequently, seagrasses meadows were sparser and more barren in Baffin Bay compared to other systems. However, seasonality likely also contributed to this decrease because of plant senescence in cooler temperatures. Earlier in the season, preliminary site visits noted seagrass presence at sites that were subsequently barren. Therefore, our measurements likely underestimate the amount of seagrass in Baffin Bay but truly reflect a lesser meadow coverage and stature within the system. Furthermore, this positive relationship between optical properties and meadow coverage is highlighted when comparing CCB and ULM because the more suitable environment within CCB during 2022 promoted more seagrass growth than in ULM. Unfortunately, environmental conditions within ULM appear to be degrading. Only 5% of sites were barren in ULM when Tier-2 sampling began in 2011 compared to 24% in 2022 (Capistrant-Fossa & Dunton, 2023). Preliminary research suggests this is related to rising sea levels in the Upper Laguna Madre (Capistrant-Fossa & Dunton, 2023).

FIGURES



Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, Foursquare, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS, Esri, DeLorme, NaturalVue

Figure 2. Spatial representations of percent cover for *Halodule wrightii* for 2022. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database.

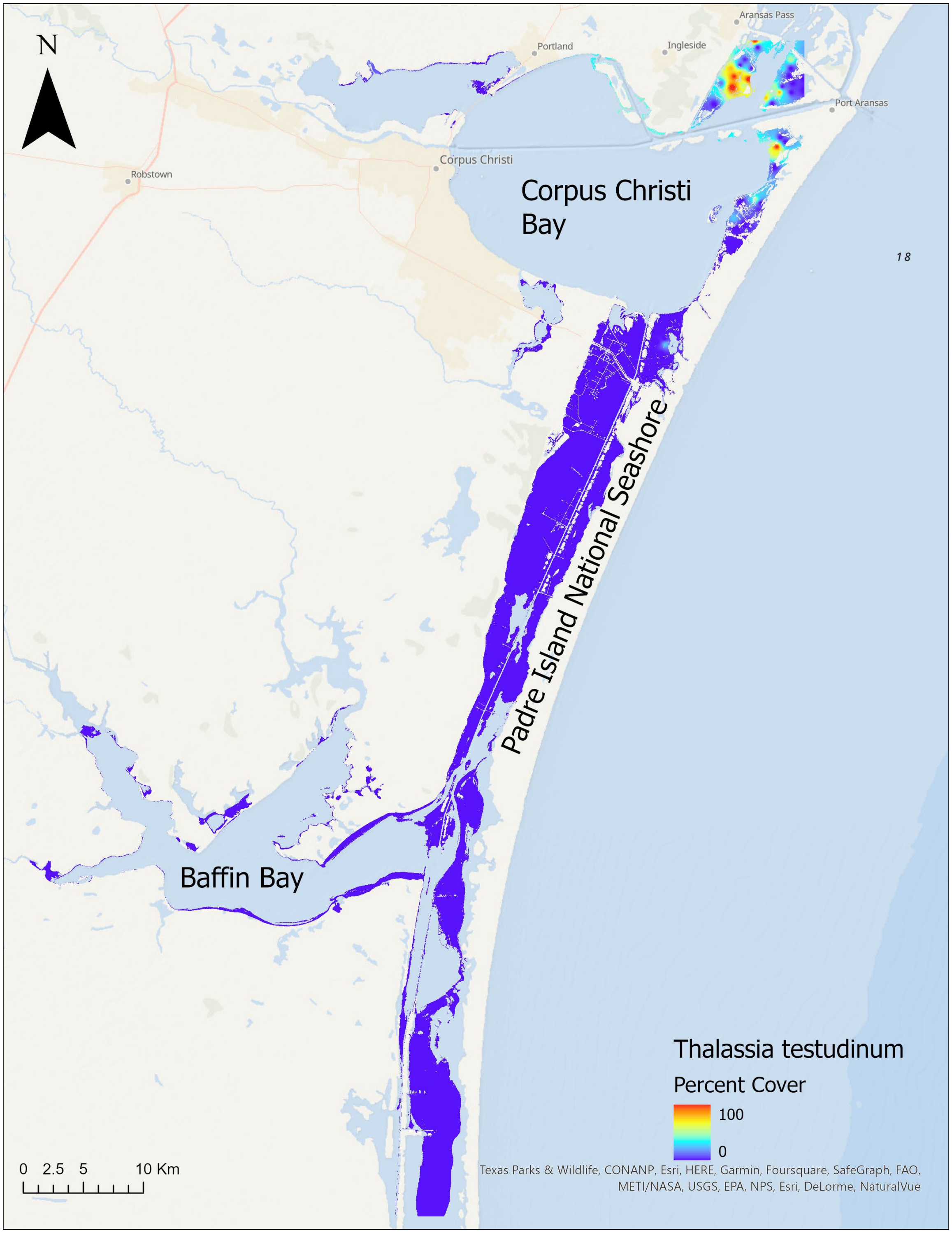


Figure 3. Spatial representations of percent cover for *Thalassia testudinum* for 2022. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database.

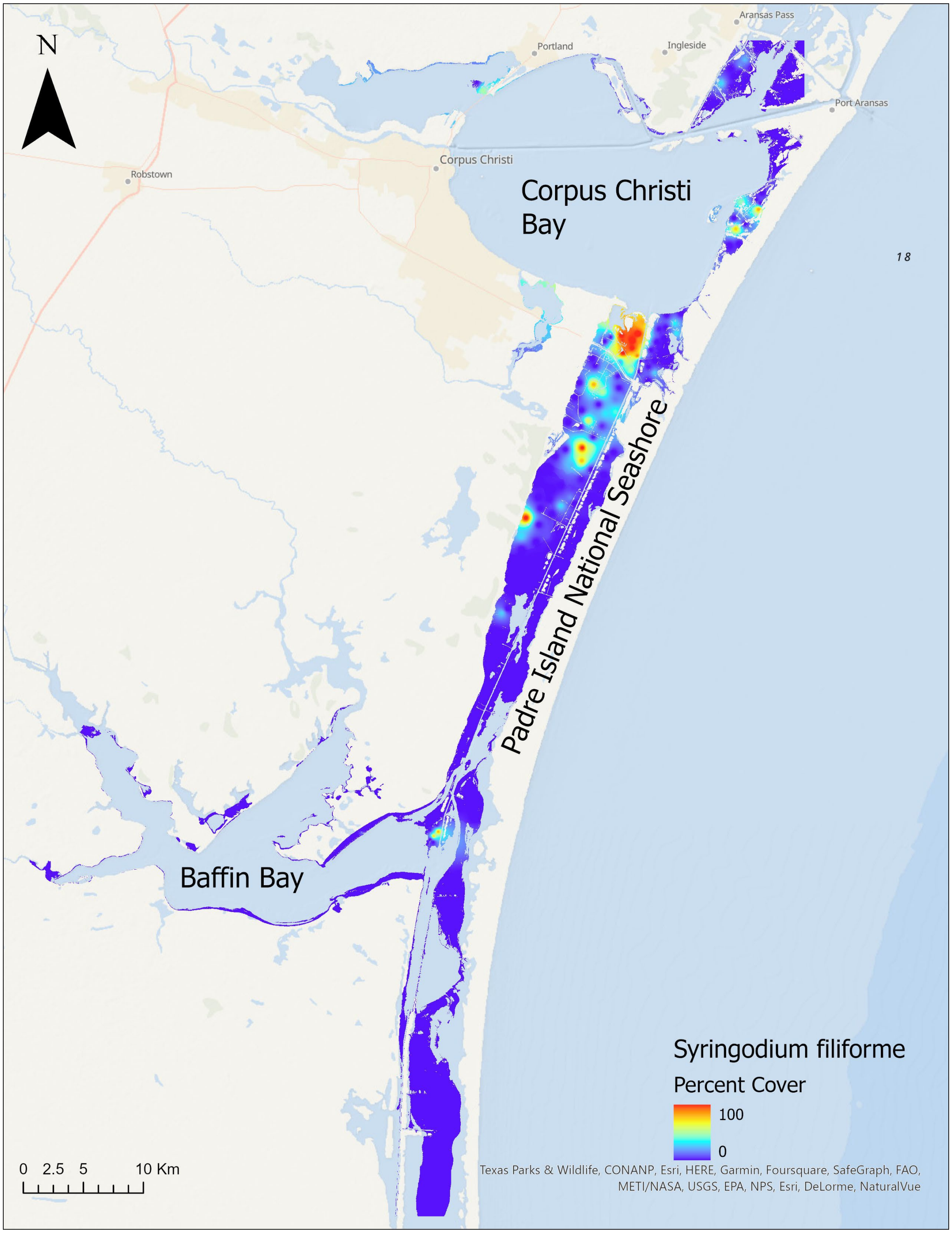


Figure 4. Spatial representations of percent cover for *Syringodium filiforme* for 2022. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database.

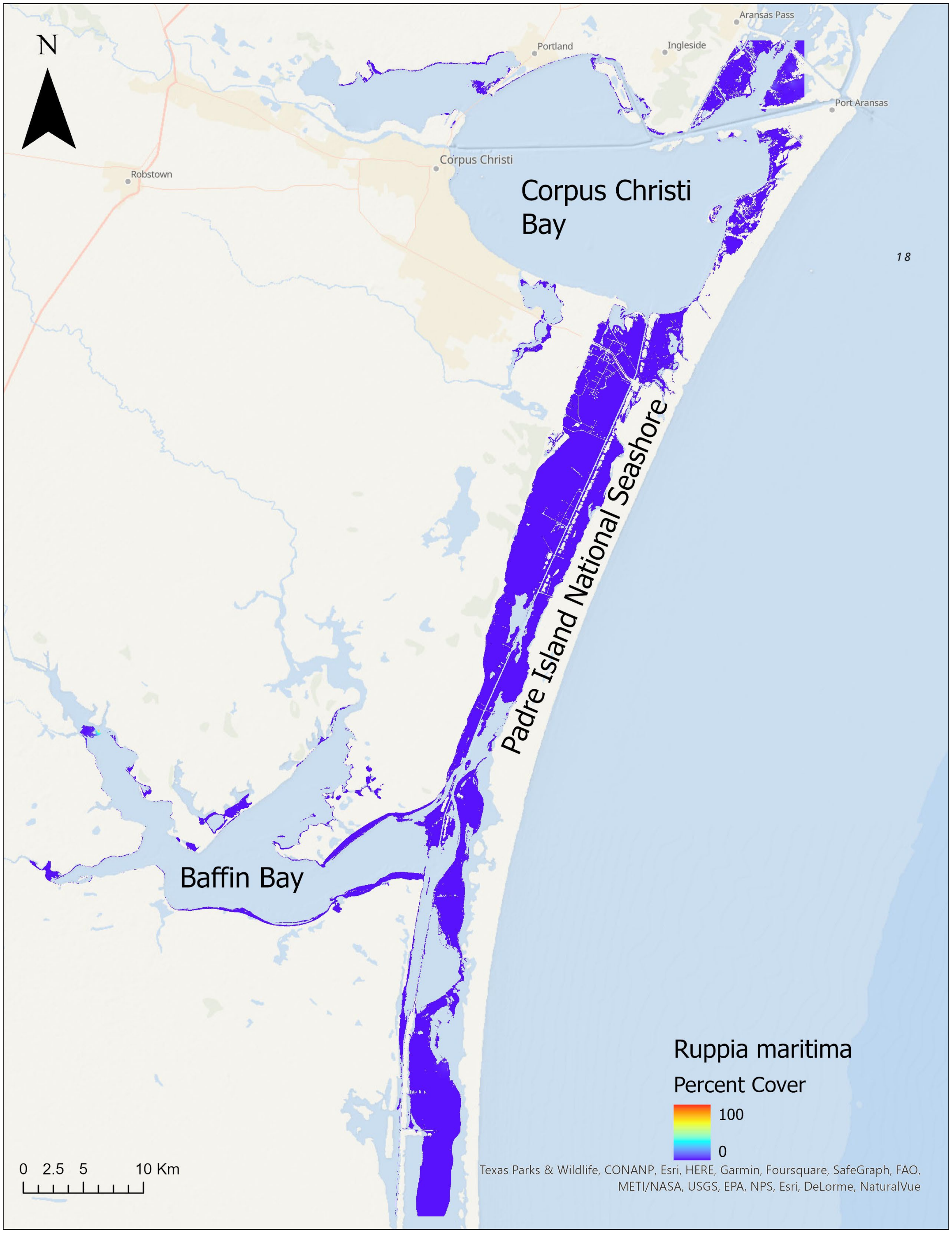


Figure 5. Spatial representations of percent cover for *Ruppia maritima* for 2022. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database.

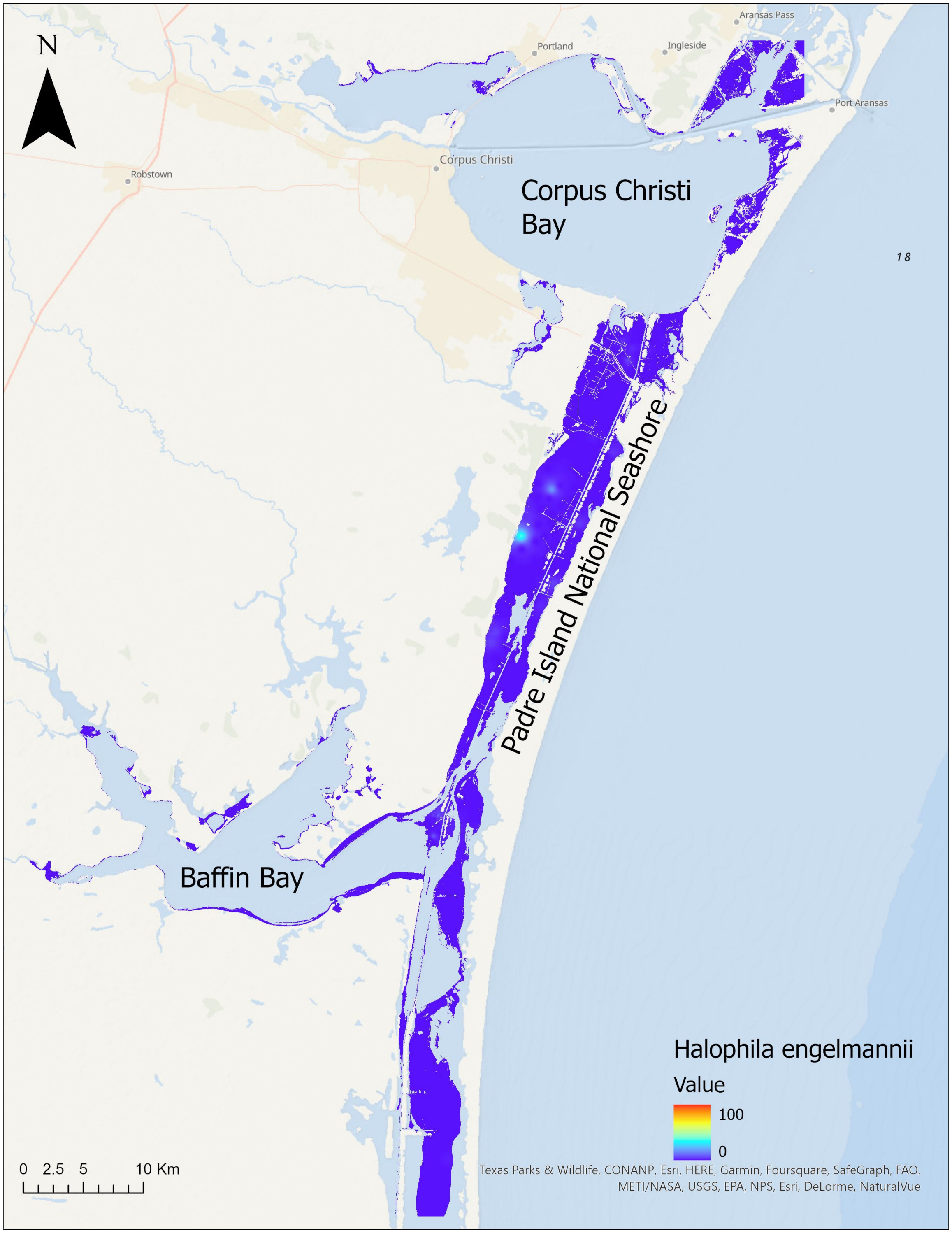


Figure 6. Spatial representations of percent cover for *Halophila engelmannii* for 2022. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database.

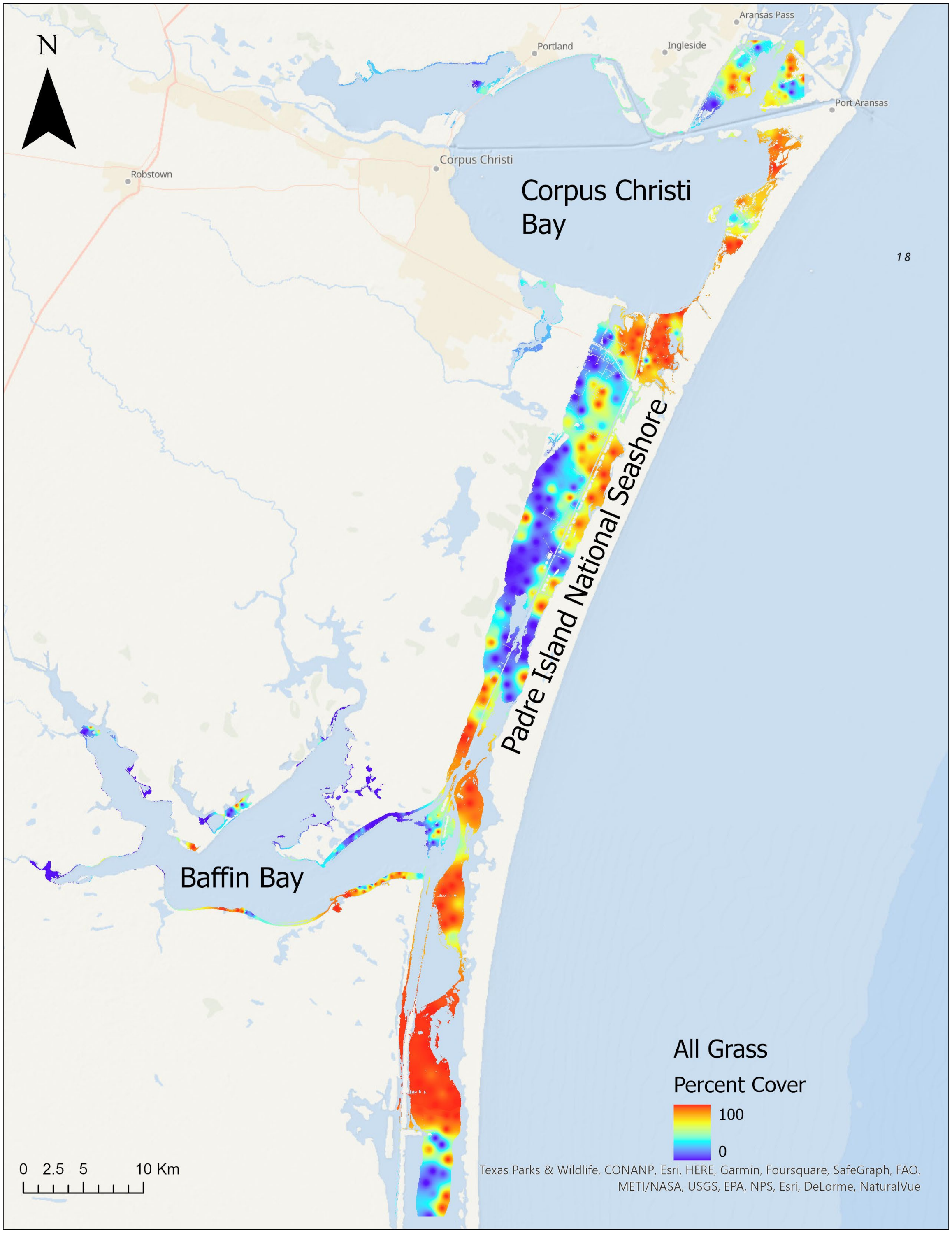


Figure 7. Spatial representations of percent cover for all seagrass species for 2022. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database.

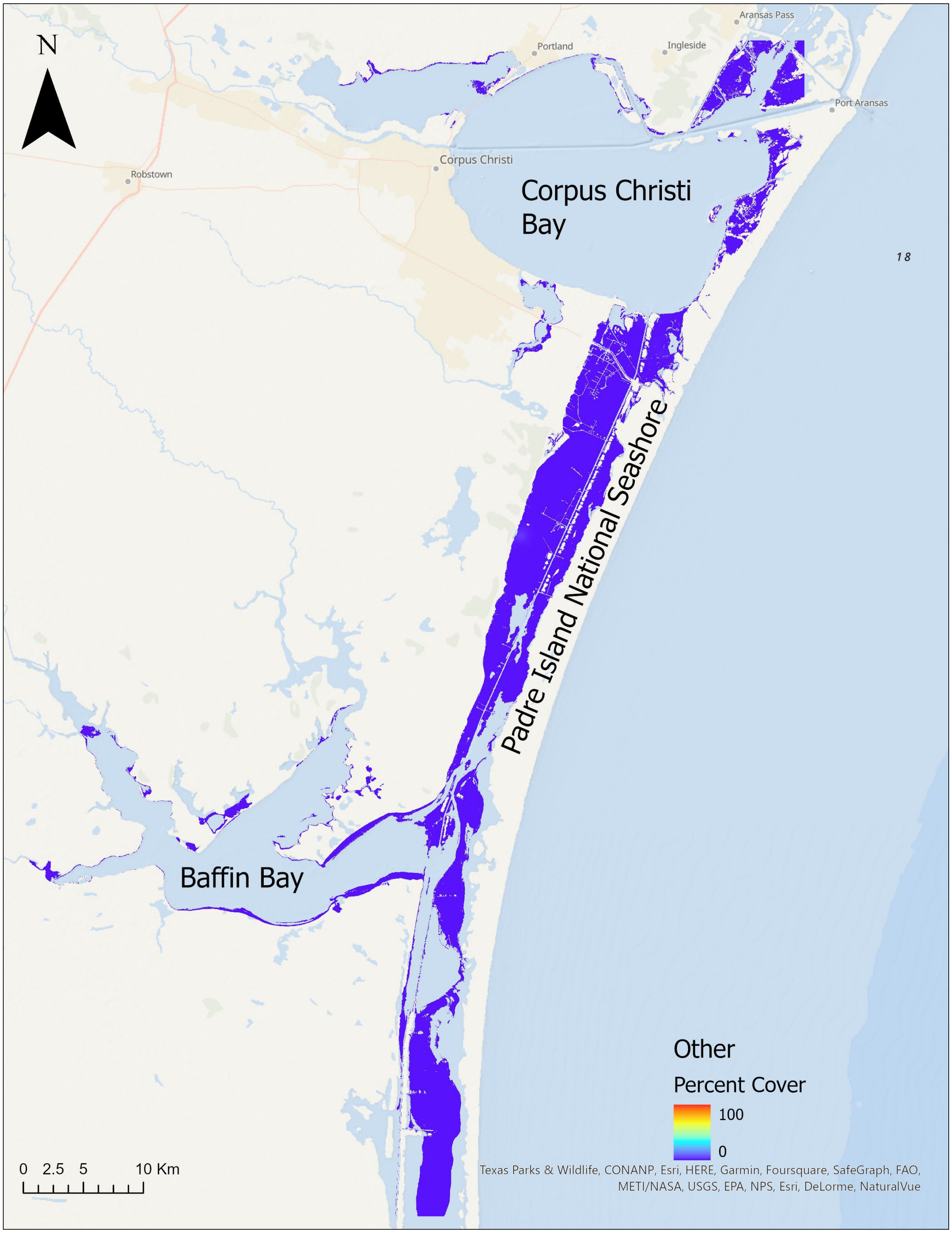


Figure 8. Spatial representations of percent cover for living, non-seagrass, ecosystem components (e.g., macroalgae) for 2022. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database.

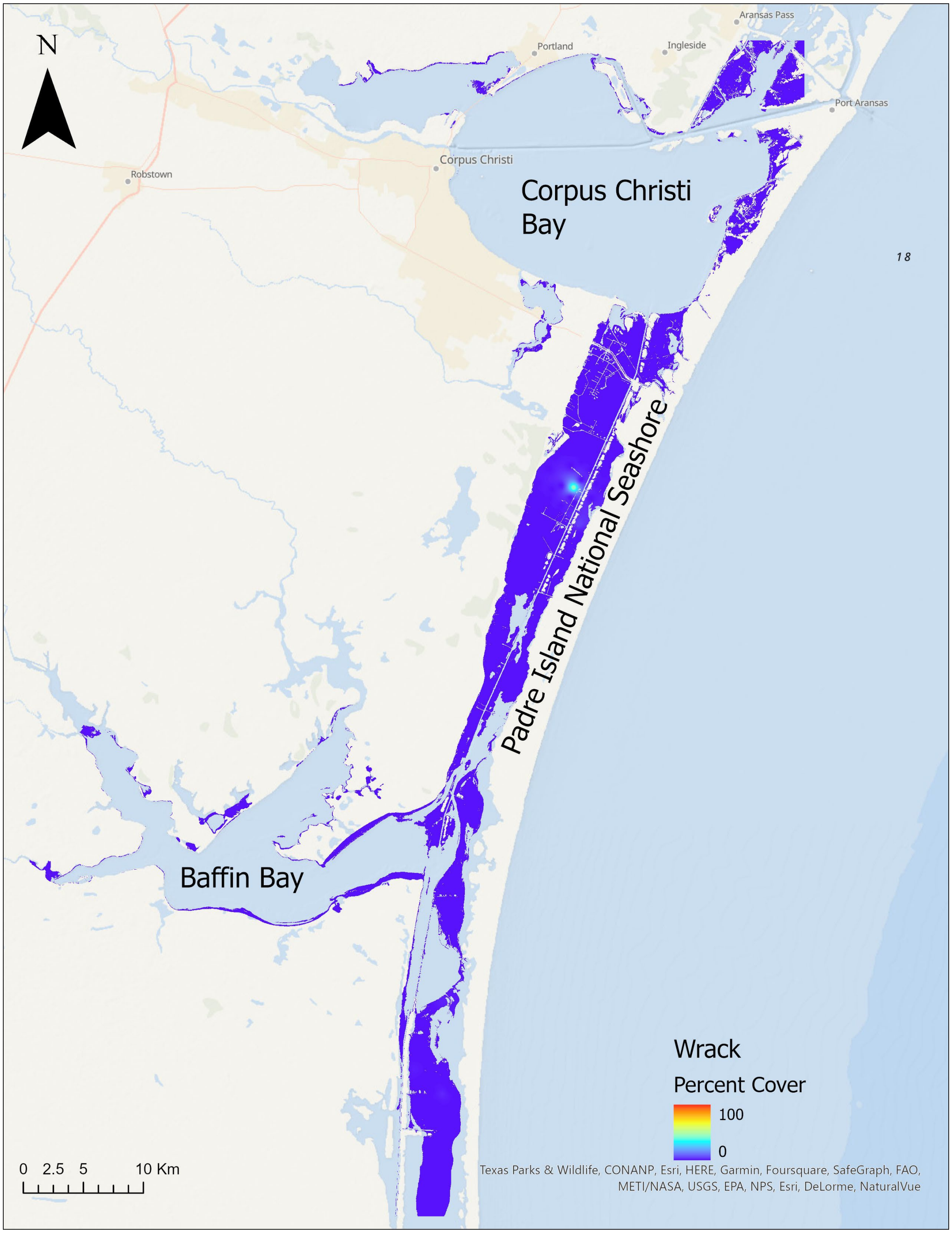


Figure 9. Spatial representations of percent cover for seagrass wrack for 2022. The spatial data interpolation is limited to the boundaries of seagrass habitat delineated by the 2022 NOAA USA seagrass distribution database.

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