

Assessment of seagrass habitat and stability in Texas coastal waters

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Final Report

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Project Background:

Seagrass meadows provide numerous ecosystem services that benefit coastal communities including: (1) protection from erosion through sediment stabilization, (2) wave attenuation that protects coastal habitats, and (3) habitat creation and nursery support for commercially and recreationally important fisheries. Texas has the second-largest coverage of seagrass meadows in the United States, with over 950 km² along its 600 km coastline. The State of Texas remains committed to preserving the health of these ecosystems through legislation, management efforts, and collaboration with academic institutions and nonprofit organizations. In 1999, Texas Parks & Wildlife, Texas General Land Office, and Texas Commission on Environmental Quality (then Texas Natural Resource Conservation Commission), drafted the Seagrass Conservation Plan for Texas that identified research gaps and proposed a management program (Pulich and Calnan, 1999). This Project of Special Merit addressed two objectives of the plan: (1) to facilitate the collection of seagrass distribution data, and (2) promote research on seagrass productivity through the development of new technology.

In accordance with the Seagrass Conservation Plan for Texas, Dunton et al. (2011) proposed the implementation of a three-tiered, field-based monitoring program for seagrass in Texas coastal waters. Tier-1 involves aerial mapping every 3-5 years (has not happened in ~20 years), Tier-2 includes periodic rapid assessment monitoring, and Tier-3 is intensive site-based targeted research. In 2011, UTMSI launched the Tier-2 component with funding support from the TGLO Coastal Management Program, National Park Service, Coastal Bend Bays & Estuaries Program, and Mission-Aransas National Estuarine Research Reserve.

The main goal of this project is to maintain the ecological integrity of seagrass ecosystems along the entire Texas coast through enhanced monitoring. We define ecological integrity as the capacity of the seagrass system to support/maintain a balanced, integrated, and adaptive community of flora and fauna, including its historically characteristic seagrass species. Findings from this research will (1) inform coastal managers through a coast-wide survey of the current condition of Texas seagrass beds, (2) provide data for an overdue seagrass mapping effort, and (3) utilize recent technological advances in remote monitoring to rapidly assess seagrass health and productivity on site.

This project allowed us to (1) implement coast-wide Tier-2 monitoring (last sampling was 2018) from Port Isabel to Galveston, (2) utilize newly developed acoustic technology to enable remote monitoring of environmental seagrass condition under an experimental Tier-3 effort, (3) improve capabilities for data sharing, and (4) interface with the public on the importance of these meadows.

Task 1: Coast-wide seagrass sampling (Tier – 2), seagrass condition assessment, and ground-truthing of seagrass coverage maps (Tier – 1)

Seagrasses cover approximately 950 km² of seafloor within 14 coastal counties (Figure 1). Each of Texas' eight major estuarine systems is hydrographically unique and therefore must be monitored individually. This project, the largest effort since 2018, allowed us to monitor 677 sites (Upper and Lower Laguna Madre, Baffin Bay, Corpus Christi Bay, Mission-Aransas Bay) and provide support to TPWD and TCEQ on the upper coast during 2022 and 2023 (Matagorda Bay & Galveston Bay; Figure 2). We measured optical (total suspended solids, light attenuation, Secchi depth), hydrographic (temperature, salinity, pH, water depth), morphometric (species composition, canopy height), physiological (leaf tissue carbon, nitrogen, and stable isotopes), and sedimentary (carbon, nitrogen, and stable isotopes) conditions at sites.

With over a decade of monitoring data, we are now able to begin assessing the long-term health of Texas' seagrass meadows. We used Upper Laguna Madre as a case study because it had the most complete data coverage and had records going back over thirty years. We noted substantial seagrass losses from some locations especially over the past decade (Capistrant-Fossa and Dunton, 2024). There were no shifts in any environmental conditions during this period, except a significant increase in water depth (Figure 3). We determined that when water depth reaches ~1.5m a site there is not enough sunlight reaching the meadow to sustain seagrasses (Capistrant-Fossa and Dunton, 2024). This threshold allowed us to predict future distributions of seagrass in Upper Laguna Madre if water depths continued to increase (Figure 3). Notably, newly flooded land in the southern Laguna may offset losses if all available habitat is colonized (Figure 4).

Monitoring efforts in other systems revealed little deviation from long-term mean percent cover in Corpus Christi Bay and the Mission-Aransas Estuary (also known as the "NERR" because it is a federally recognized National Estuarine Research Reserve; Figure 5). In contrast, substantial losses of seagrass were observed in Galveston Bay, though there is currently insufficient evidence to determine the cause. Conversely, seagrass coverage appeared to increase in the Lower Laguna Madre (Figure 5). Analyses of the seagrass leaf nutrient and isotopic composition did not reveal any large-scale shifts overtime in any system (Figure 6). Short-term changes may reflect stochastic events (e.g., hurricanes, droughts), but there does not appear to be any long-term alterations in seagrass nutrient processes.

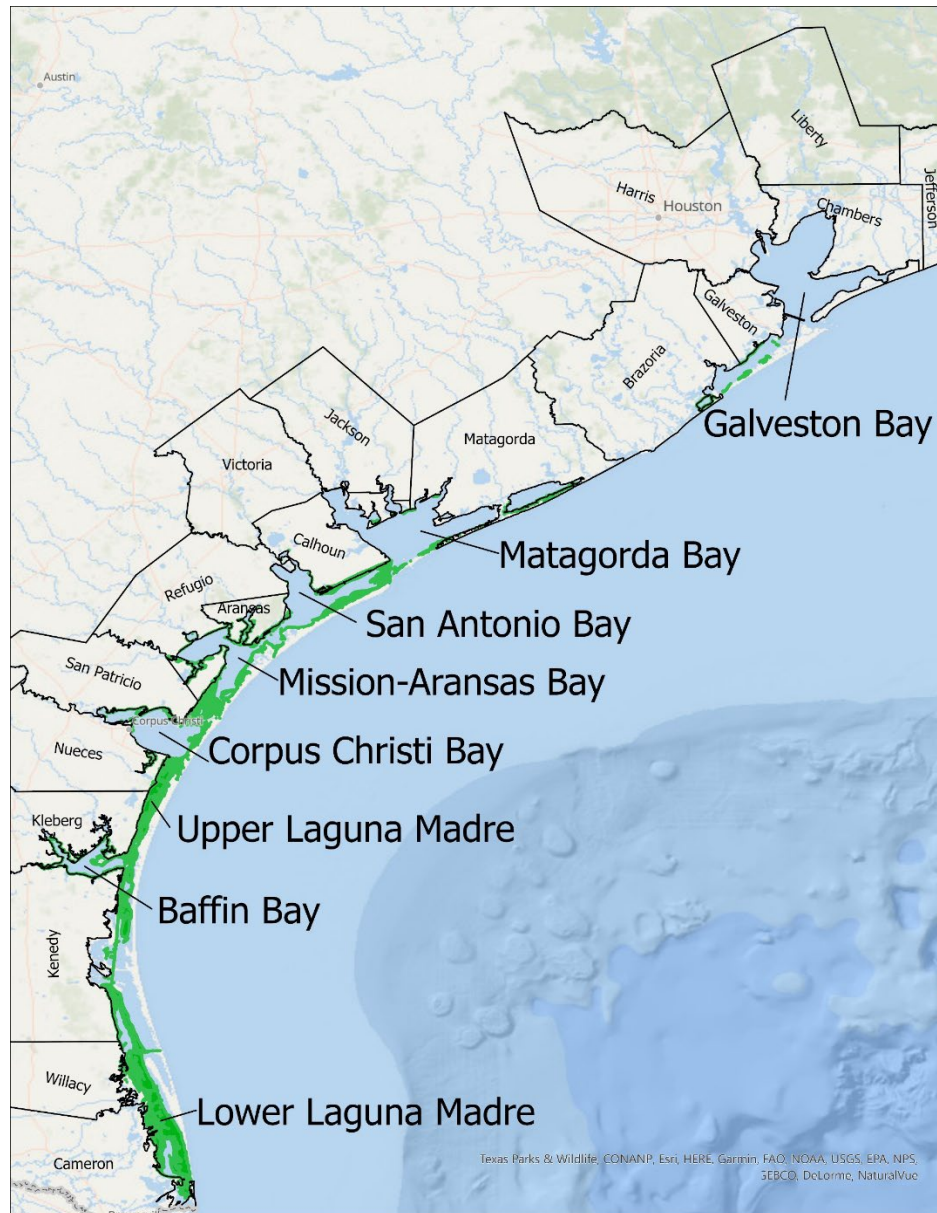


Figure 1: The known distribution of seagrass (green shading) within Texas' eight major estuarine systems.

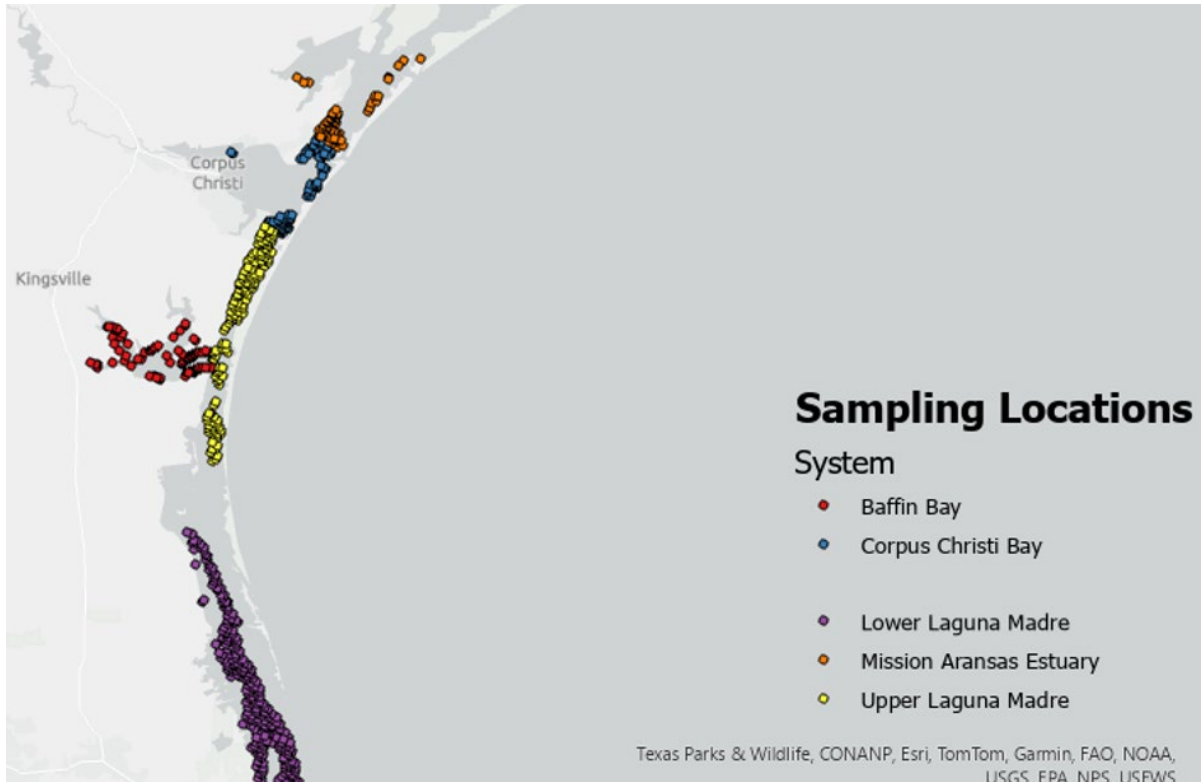


Figure 2: Tier-2 sampling locations regularly occupied by the University of Texas Marine Science Institute ($n = 677$). UTMSI also provides support to Texas Parks & Wildlife and Texas Commission on Environmental Quality for monitoring in San Antonio, Matagorda, and Galveston Bays ($n = 162$). Monitoring for this project occurred in 2022 and 2023.

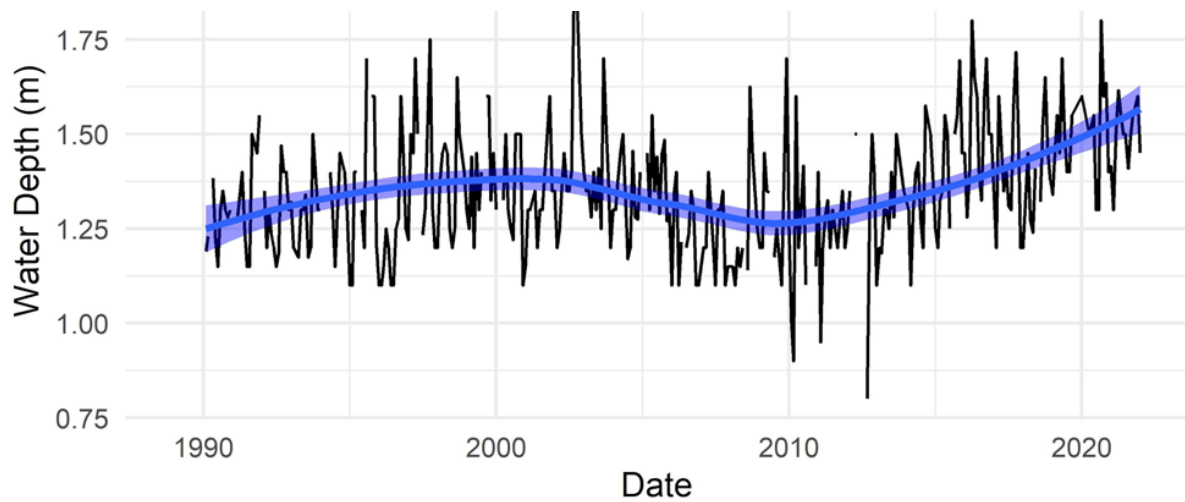


Figure 3: Water depth records from a fixed Tier-3 site (LM-151) taken over thirty years. The average condition (represented by the blue locally estimated scatterplot smoothing line) was significantly deeper in 2020 than 1990 (published in Capistrant-Fossa and Dunton, 2024).

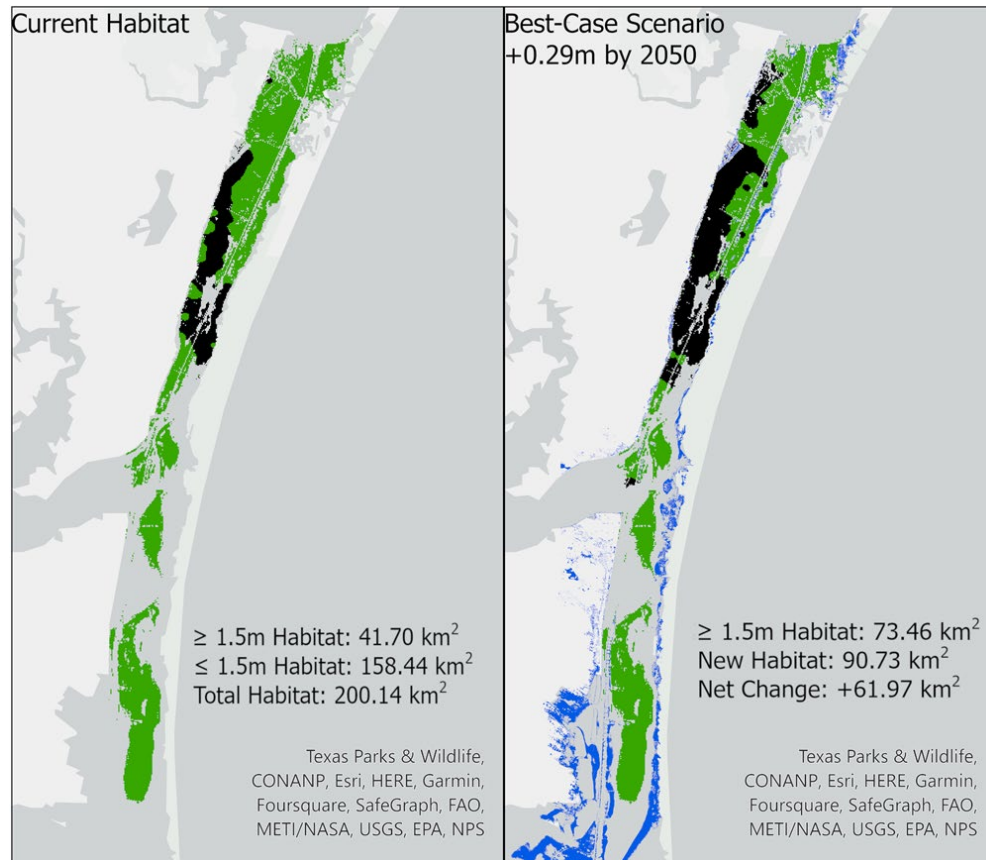


Figure 4: Distribution of seagrasses in the Upper Laguna Madre under current and projected future water depth scenarios. Green areas indicate known seagrass habitat; black areas represent historical habitat that has become too deep to support plant growth; and blue areas show newly inundated land. Reproduced from Capistrant-Fossa et al. (2024).

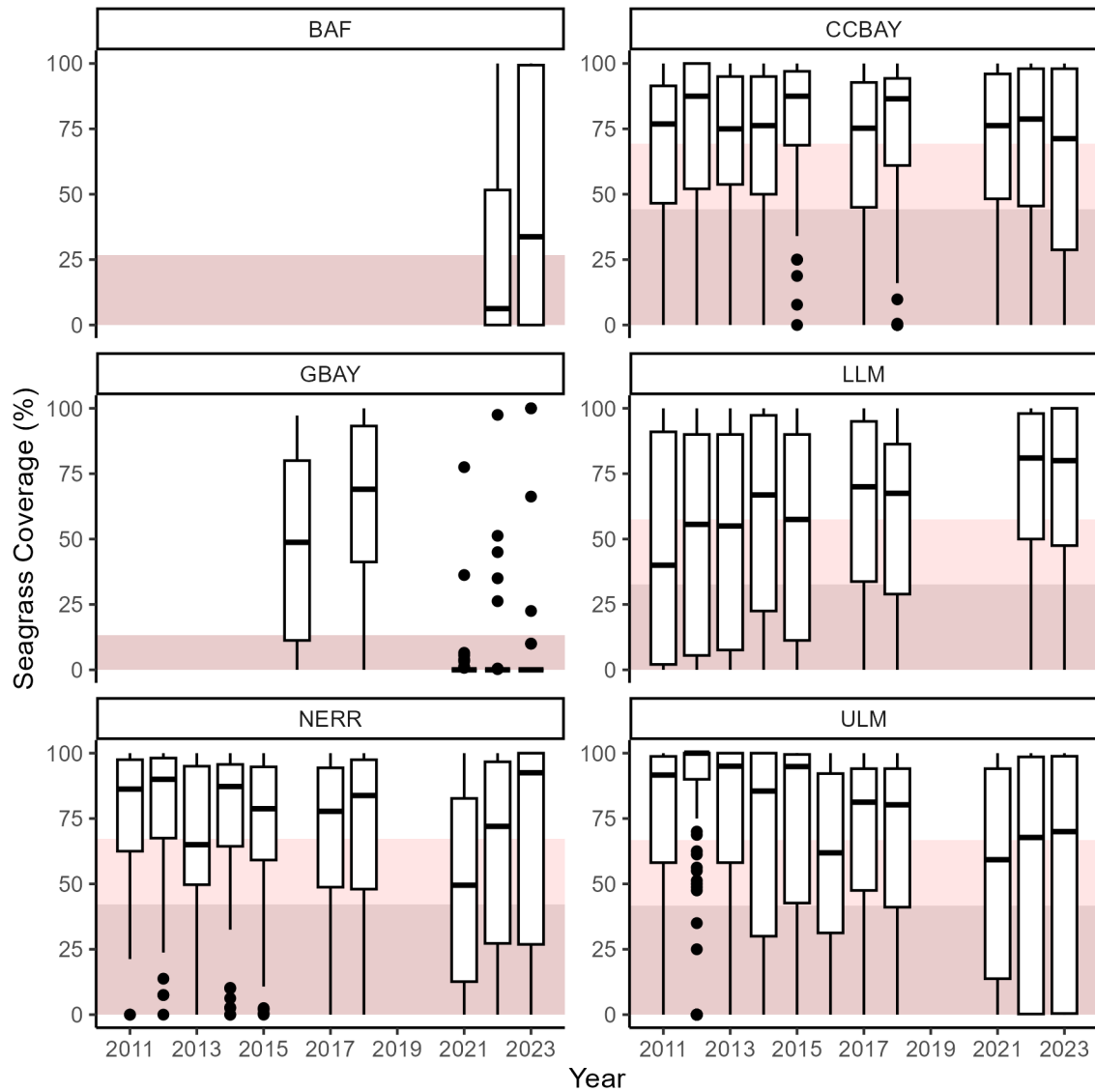


Figure 5: Each boxplot represents the distribution of total seagrass percent cover collected in a single year for each estuarine system. If the median coverage falls within a pink region, it indicates a mild deviation from the long-term average and is cause for moderate concern (see Congdon et al., [2023] for details). A median within the dark red region indicates a significant deviation and is considered highly concerning.

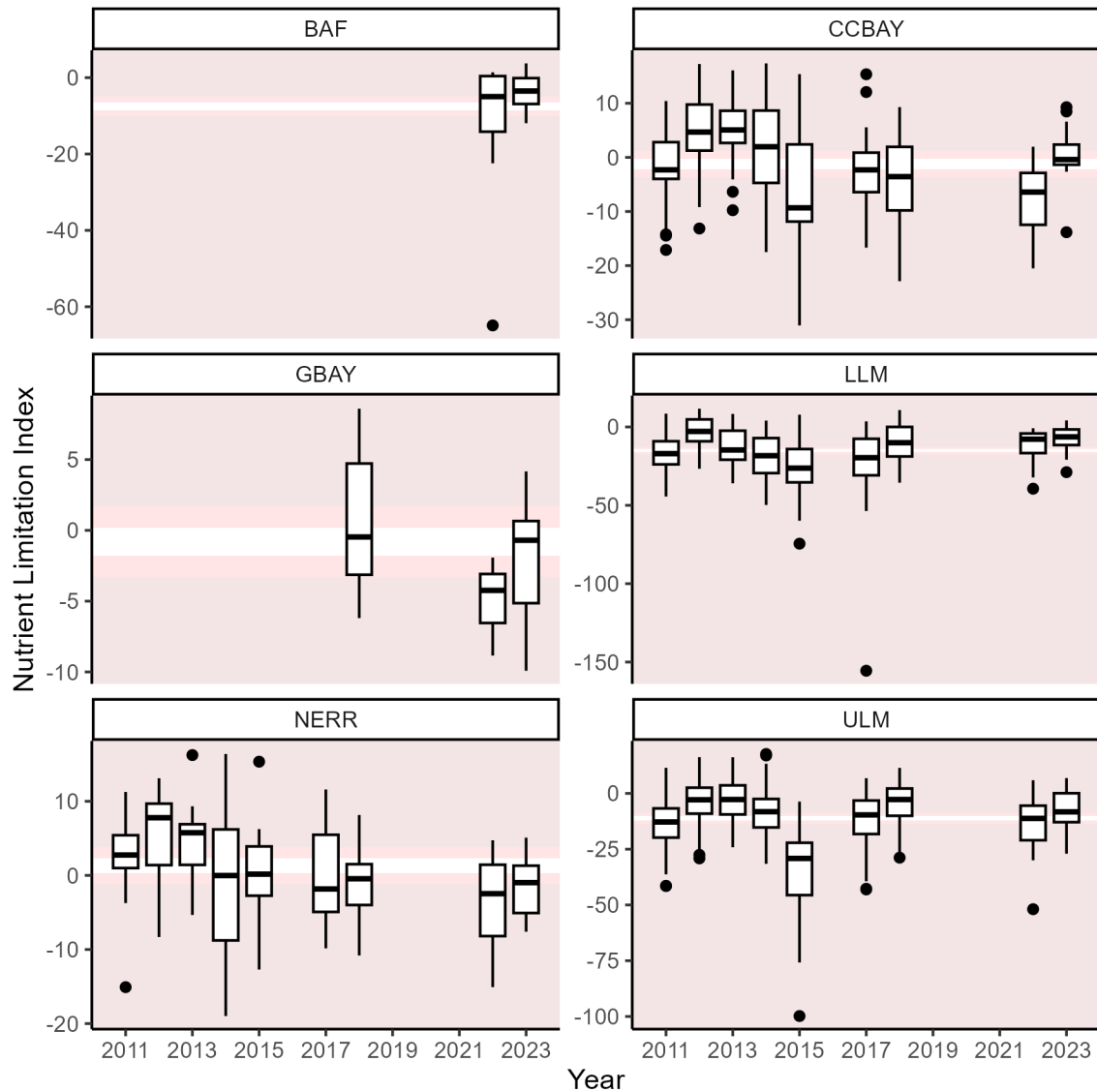


Figure 6: Each boxplot represents the distribution of the nutrient limitation index, a measure of nitrogen or phosphorous limitation in leaf tissues, collected in a single year for each estuarine system. If the median coverage falls within a pink region, it indicates a mild deviation from the long-term average and is cause for moderate concern (see Congdon et al., [2023] for details). A median within the dark red region indicates a significant deviation and is considered highly concerning.

Task 2: Experimental Intensive Remote Seagrass Monitoring (Tier – 3)

This project advanced our capacity to measure ecosystem processes in seagrass meadows using two innovative technologies: acoustic monitoring and aquatic eddy covariance. We selected East Flats in Corpus Christi Bay (Figure 7) as a Tier-3 site based on its long history of data collection, healthy seagrass meadows, and importance as a regional fishing hub. Additionally, we collected a limited acoustic dataset within the Upper Laguna Madre, but the seagrasses were significantly less productive than at East Flats, limiting the interpretation of the data.

We deployed an acoustic array consisting of a controller/recorder, sound source, and receivers spanning 12 meters of *Thalassia testudinum* to characterize the acoustic characteristics of the meadow (Figure 8; Ballard et al., 2024). This system recorded sound attenuation (“transmission loss”) every 10 minutes over two years and required both *in-situ* (Figure 9) and *ex-situ* (Figure 10) maintenance. Transmission loss within seagrass meadows caused by both gas bubbles (e.g., O₂, CO₂, CH₄) within the meadow or internal gas structures within seagrass leaves called aerenchyma. We also deployed sensors to measure environmental conditions critical for seagrass productivity including dissolved oxygen, salinity, temperature, irradiance, and water depth (Figure 11). Bubble traps were occasionally deployed to collect any gas bubbles released from the meadow.

We found that transmission loss during the daytime was primarily caused by oxygen bubbles on the surface of seagrass leaves formed by photosynthesis or by internal gas channels in the plant (Ballard et al., 2024; Capistrant-Fossa et al., 2025). There was a strong correlation between these gas bubbles (i.e., ebullition) and transmission loss (Figure 12). There is little information on the importance of oxygen ebullition within coastal oxygen budgets (Capistrant-Fossa et al., 2025). Warm, high-salinity seawater has low oxygen solubility, and when combined with the photosynthetic productivity of macrophytes in shallow, clear waters, oxygen ebullition frequently occurs. Therefore, we decided to understand its importance to net ecosystem productivity (NEP), which relies on diel changes in dissolved oxygen to determine if a system is net autotrophic (photosynthesis > respiration) or heterotrophic (respiration > photosynthesis). Using acoustic transmission loss as a proxy, we estimated ebullition rates and identified peak rates in July and August (Figure 13). NEP was estimated using Odum’s open water method that involves tracking changes in dissolved oxygen overtime (Capistrant-Fossa et al. 2025). While high respiration led to an apparent net heterotrophic NEP ($\bar{x} = -2.1 \text{ mmol O}_2 \text{ m}^{-2} \text{ d}^{-1}$; Figure 14), correcting for air–sea gas exchange and ebullition shifted the system to net autotrophic ($\bar{x} = 54 \text{ mmol O}_2 \text{ m}^{-2} \text{ d}^{-1}$; Figure 13). This study highlights the critical role of oxygen ebullition in NEP

calculations and demonstrates the potential of acoustic methods for monitoring aquatic ecosystem productivity.

We measured NEP using a second method, aquatic eddy covariance (AEC), to compare results with our acoustic monitoring. AEC is considered significant improvement over the open-water method that complimented our acoustic study because it allows for more precise estimates of benthic oxygen fluxes specific to seagrasses rather than water column processes. We consulted with Dr. Peter Berg who developed the technique to design a system appropriate for Texas with an ultra-high speed oxygen sensor paired with a water velocimeter (Figure 15). The system was tested in multiple aquatic systems to test its suitability, but we ultimately settled on deployments near Ransom Island, an island just north of East Flats. This location is protected by a breakwater that limits outside influences, funnels the water to adequate speeds, and is similar enough to East Flats for direct comparison. We directly compared the open water and AEC methods, finding they predicted similar oxygen fluxes (Figure 16). Further, both methods had similar changes in NEP in response to variations of irradiance and temperature, the two major controls of photosynthesis in seagrasses (Figure 17). Under high temperatures (i.e., $>30^{\circ}\text{C}$) the two methods diverged, but this may be because of these conditions were rare and limited data. The Ransom Island data showed varying agreement with those collected from East Flats (Table 1). Generally, the short-term open water data collected from Ransom were of poorer quality and didn't match the long-term data from East Flats, whereas the AEC data did. However, AEC is still prone to ebullition issues, but it may be a valid alternative for quickly assessing NEP in seagrass meadows.

There was significant transmission loss at East Flats during the night throughout the year (Figure 11 shows a snapshot). In the absence of photosynthesis and ebullition, this transmission loss was primarily caused by the seagrass leaves themselves (Ballard et al., 2024). As the signal increased over seasons, so too did seagrass biomass, indicated that nighttime transmission loss may be a useful proxy for biomass. This finding opens an exciting avenue for future research, as process-based acoustic models may eventually enable the accurate prediction of seagrass biomass, potentially reducing the need for labor-intensive field studies.

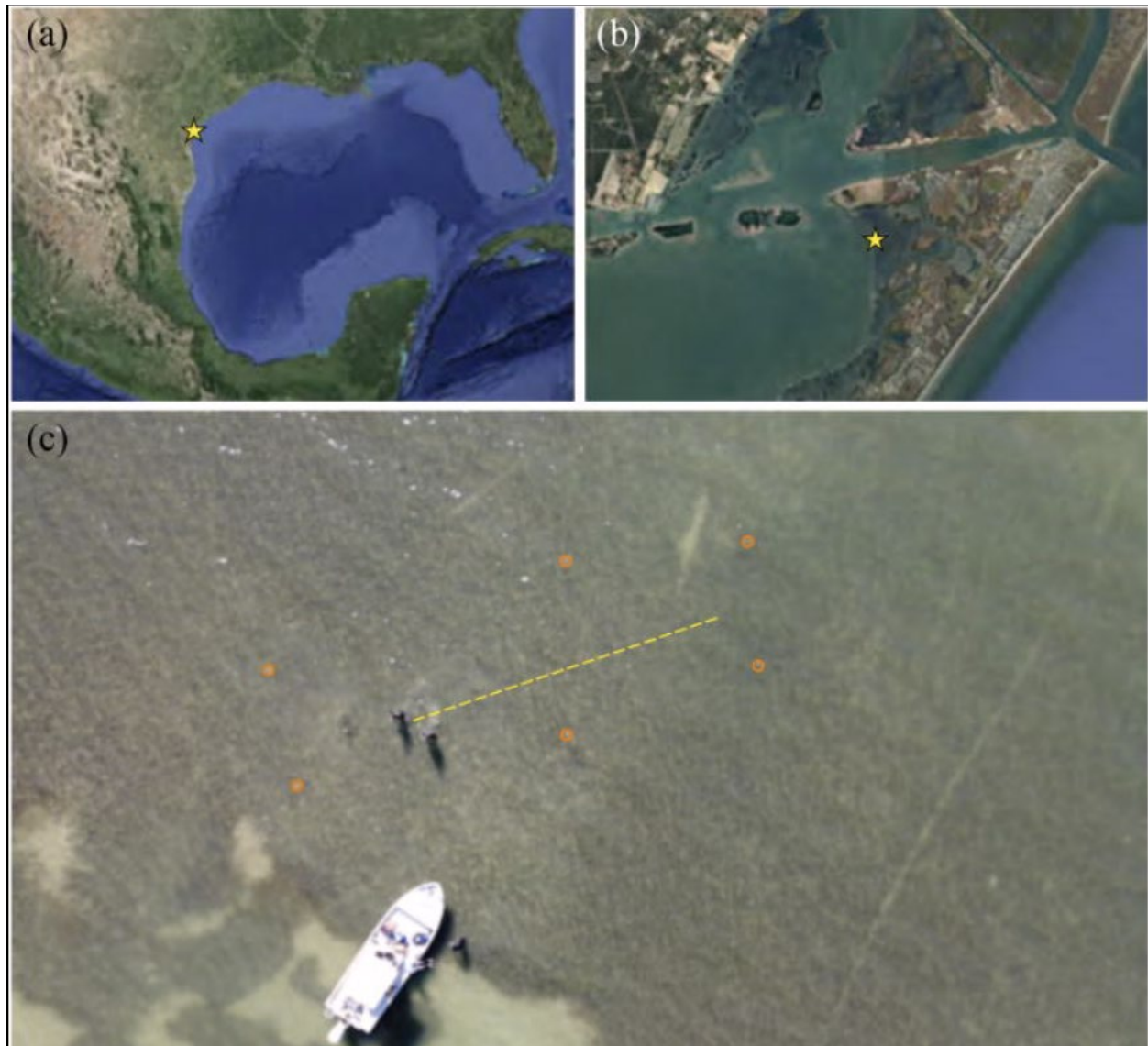


Figure 7: The location of East Flats (yellow star) within the (a) Gulf of Mexico and (b) Corpus Christi Bay. The Tier-3 site (c) was located within a near continuous patch of *Thalassia testudinum* with six poles marking the boundaries to prevent boat traffic. Reproduced from Ballard et al. (2024).

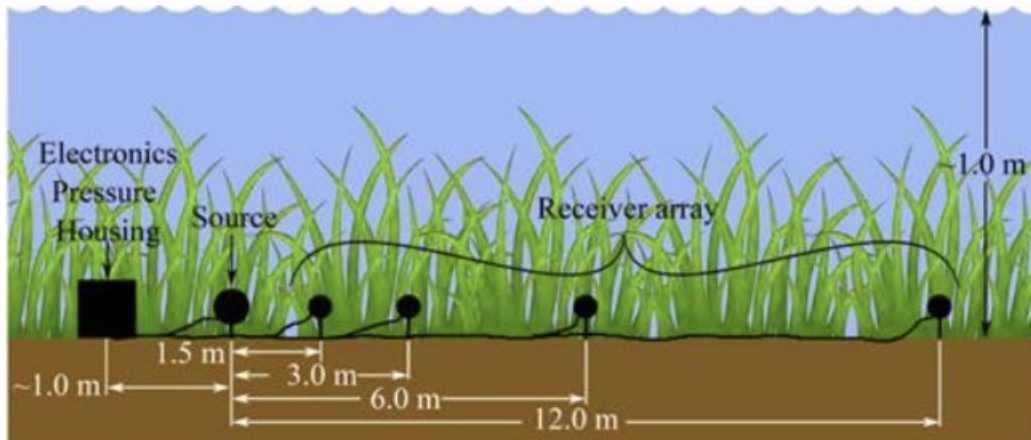


Figure 8: A schematic of the acoustic array deployed in East Flats and Upper Laguna Madre during the monitoring period. Reproduced from Ballard et al. (2024).



Figure 9: *In-situ* photographs of the acoustic source (top panel) and receiver (bottom panel) at East Flats. Biofouling required them to be gently wiped by hand in the field every few months.



Figure 10: The electronic pressure housing from the acoustic array after recovery during a service trip. Tasks included cleaning, data downloading, and battery replacement.

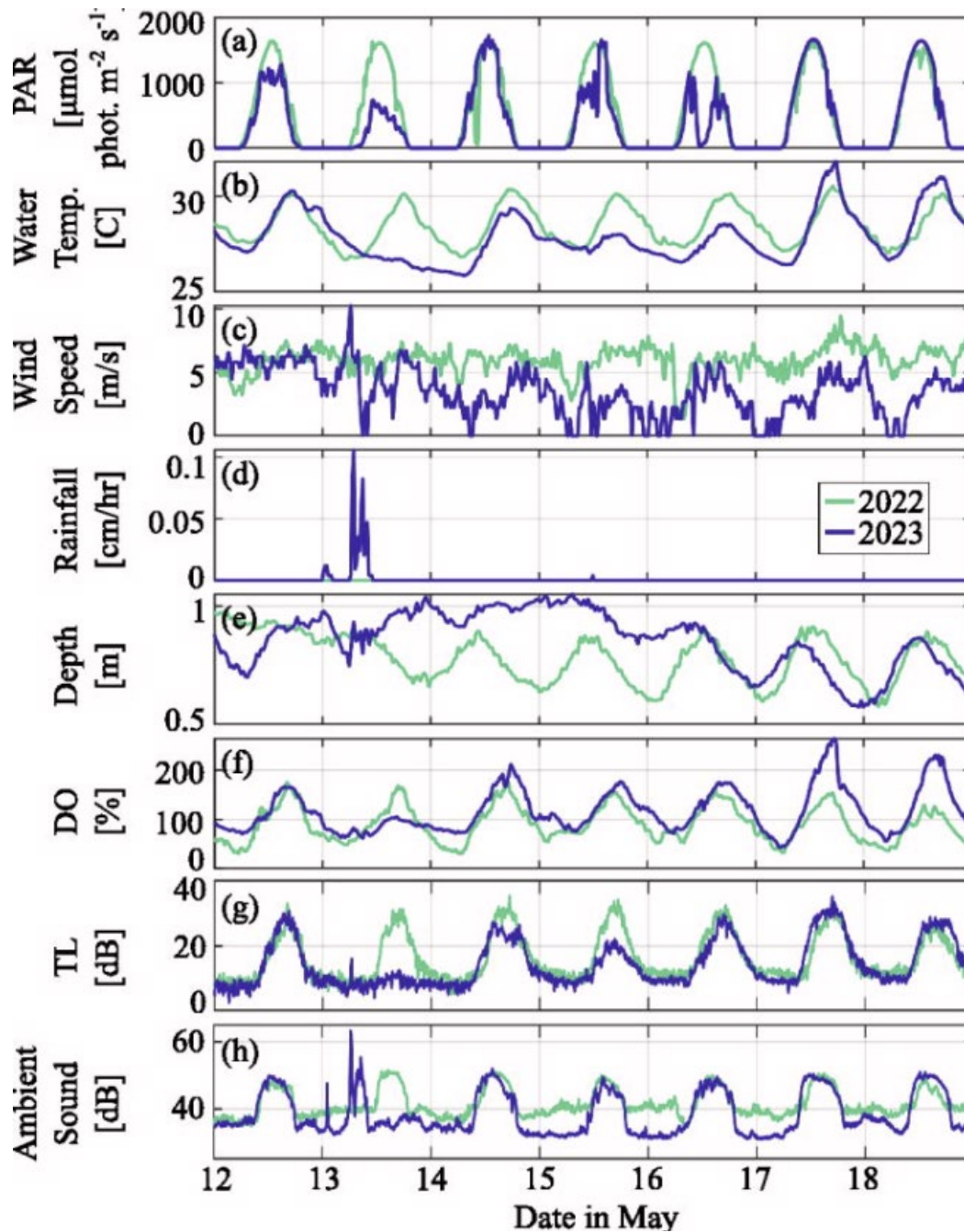


Figure 11: An example of data recorded during the deployment of the acoustic array. PAR is a measure of light reaching the seagrasses, DO% is the saturation percentage of dissolved oxygen, TL is the transmission loss of sound (i.e., attenuation) along the acoustic array, and ambient sound is the average noise levels located within the seagrass meadow. Notice the strong diurnal pattern in most variables relating to photosynthetic patterns. Nighttime TL levels slightly increase overtime with seagrass biomass. Reproduced from Ballard et al. (2024).

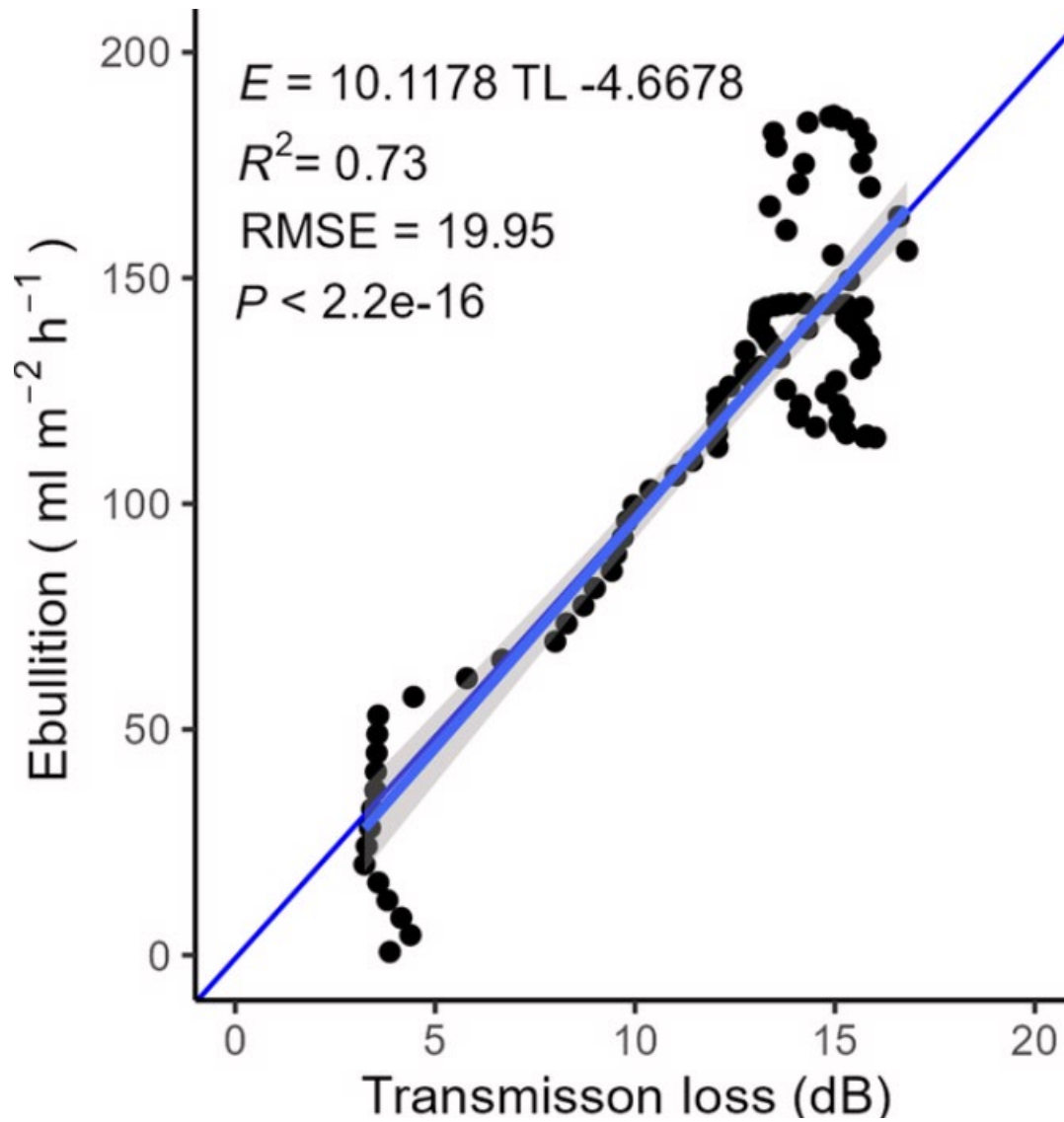


Figure 12: The linear relationship between transmission loss and ebullition at East Flats. The gray shading represents the standard error. Reproduced from Capistrant-Fossa et al. (2025).

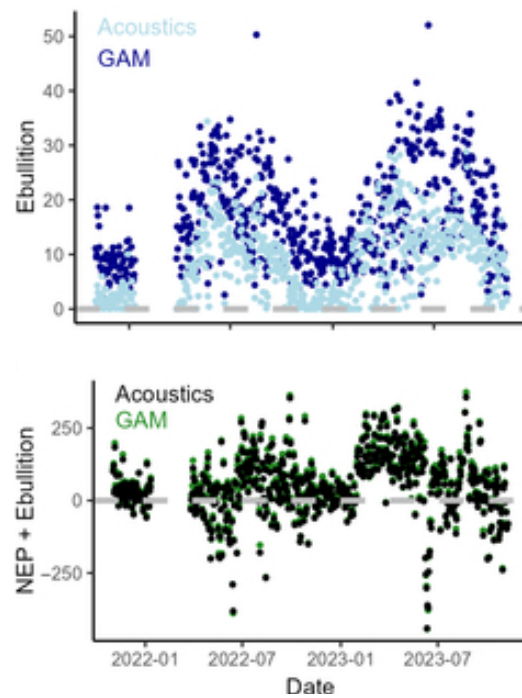


Figure 13: The estimated ebullition at East Flats over a two-year monitoring period (top panel). We correlation with acoustics or environmental conditions (i.e., GAM) to predict ebullition rates ($\text{mmol O}_2 \text{ m}^{-2} \text{ d}^{-1}$). Net ecosystem productivity after accounting for air-sea exchange and ebullition (bottom panel).

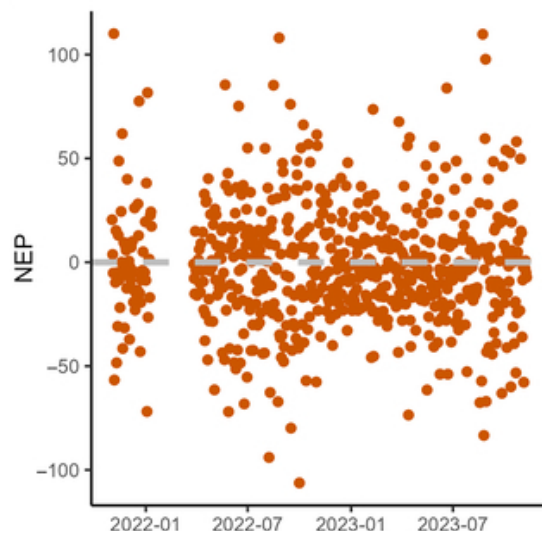


Figure 14: Net ecosystem production at East Flats over a two year monitoring period without accounting for ebullition or air-sea exchange.



Figure 15: K. Capistrant-Fossa on a boat next to a prototype version of the eddy covariance frame. It has an acoustic doppler velocimeter and high-speed oxygen sensor in the center. Additional sensors for dissolved oxygen and irradiance are attached to the side.

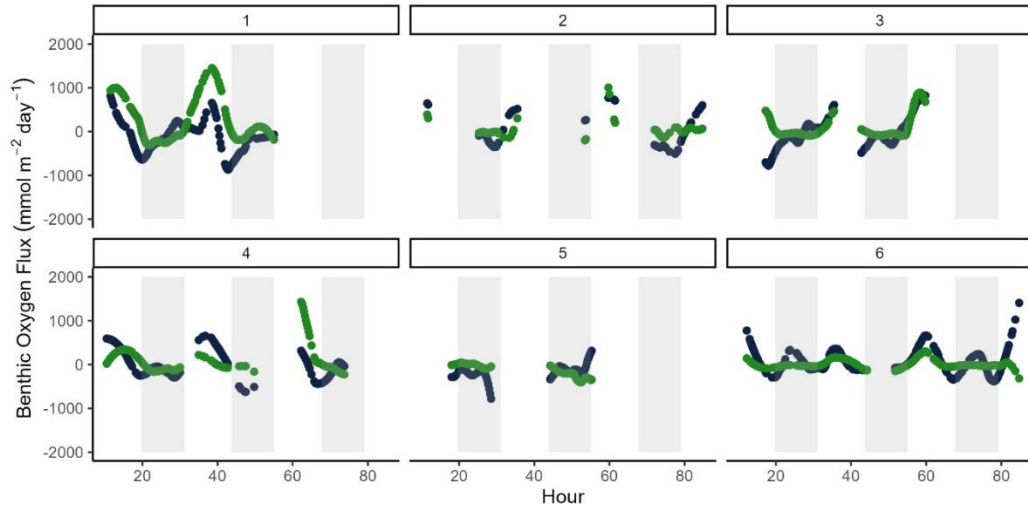


Figure 16: Net ecosystem productivity predicted from either the open-water method (black) or aquatic eddy covariance (green) during short deployments at Ransom Island.

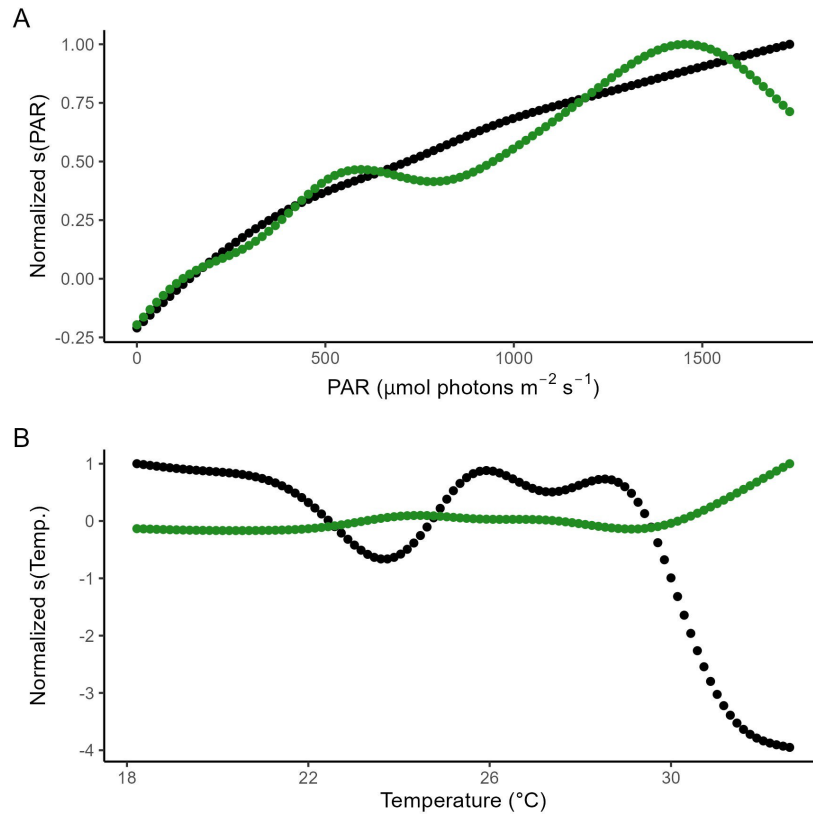


Figure 17: General additive modeling revealed that irradiance and temperature were the major controls of net ecosystem productivity at Ransom Island for both the open water (black) and aquatic eddy covariance (green) methods. These plots show the normalized effect size on NEP (i.e., relative deviation from the mean) for both variables.

Table 1: Monthly averaged benthic fluxes from Ransom Island (RAN), and East Flats (EF) for both AEC and OW measurements. E indicates values that have been corrected for O₂ ebullition.

Month	Metric	RAN - OW	RAN - AEC	EF - OW	EF - E
SEP	GPP	-145	442	508	
NOV	GPP	5	203	147	
DEC	GPP	123	15	109	
SEP	R	-241	-97	-454	
NOV	R	-156	-98	-110	
DEC	R	-64	-40	-102	
SEP	NEP	-387	346	49	67
NOV	NEP	-150	105	25	32
DEC	NEP	58	-25	18	23

Task 3: Data Archiving and Visualization for Website

TexasSeagrass.org, the official website of the Texas Seagrass Monitoring Program, has served as a source of information for the public, resource managers, and researchers since it was launched in 2011. However, by 2021 the web page became antiquated and difficult to update with timely information (Figure 17). In response, this project allowed us to migrate the website to a more user-friendly platform that would allow for greater control of the content (Figure 18). Since our migration in mid-2023, we have served over 1000 unique visitors to the webpage. This allows us to better highlight the Tier-2 and Tier-3 datasets generated during this project (Figure 19), updated Tier-2 maps (over 60 created for this project), educational resources, and new publications.



Figure 17: The former custom TexasSeagrass.org website was difficult to update and maintain, leaving it relatively unchanged between 2018 and 2022.

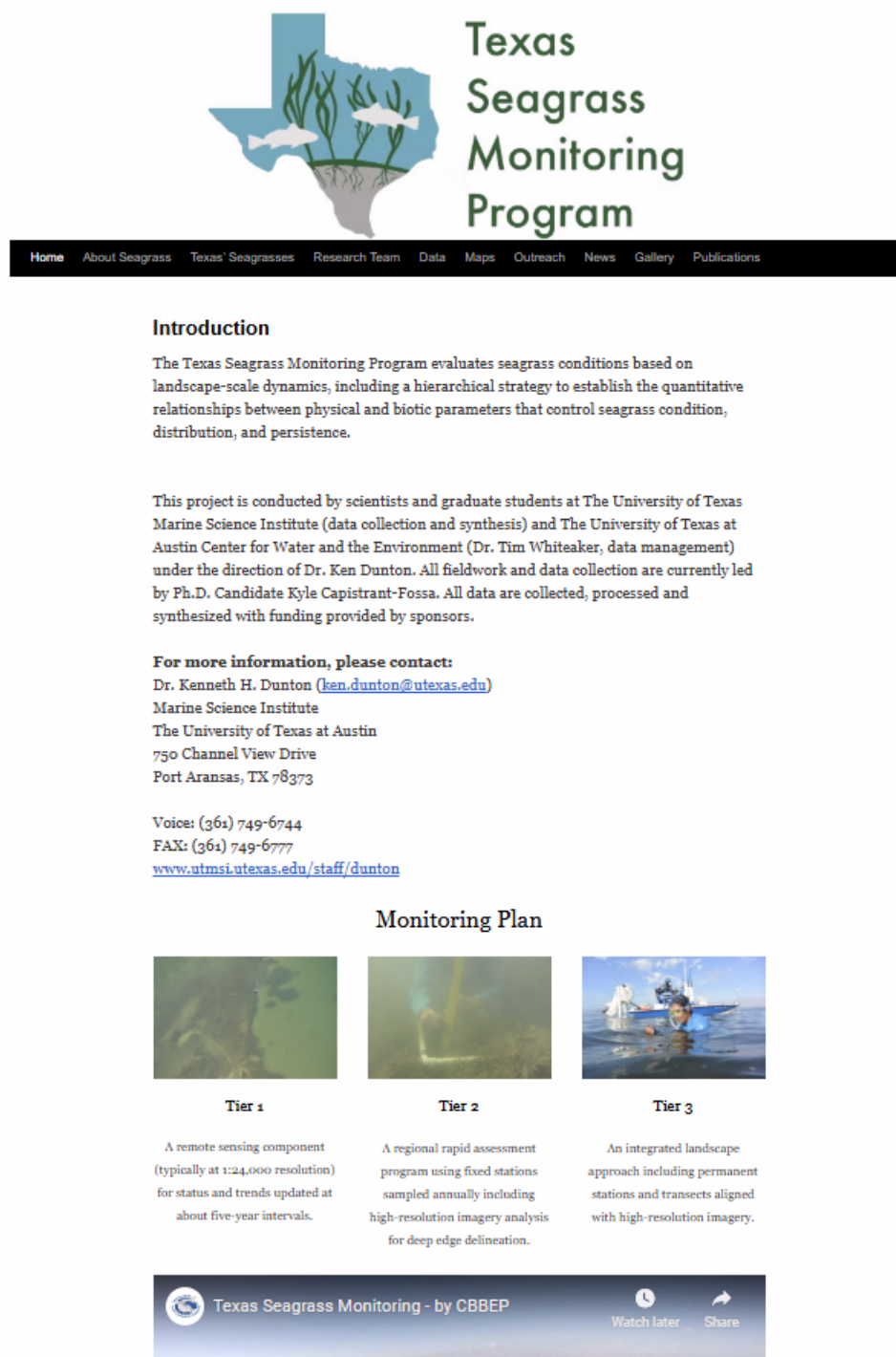


Figure 18: The new TexasSeagrass.org website is hosted on WordPress, a collaborative platform that allows multiple users to update and maintain the status of the website.

Data

Tier 2 Results (2011 - 2023)

Our annual, statewide Tier-2 data (2011 -2023) is [archived at NCEI](#) and we recommend the following citation:

Dunton, Ken; Jackson, Kim; Wilson, Sara; Congdon, Victoria; Capistrant-Fossa, Kyle; Young, Lisa; Cuddy, Meaghan; Hall, Wayne; Becker, Madison; Meiman, Joe; Whiteaker, Timothy L.; Bohannon, Patrick; Grubbs, Faye; Hobson, Cindy; Kelly, Marty (2025). Seagrass canopy height, water depth, chlorophyll-a concentration and other plant and water quality indicators in Coastal Waters of Texas (NCEI Accession 0181898). NOAA National Centers for Environmental Information. Dataset. <https://doi.org/10.25921/3gcr-4x94>. Accessed [date].

ArcGIS was used to create grids by interpolating from seagrass sample data for all available years in the study. These grids were used to create the map images available for download on this site. Results include seagrass coverage and abiotic variables such as salinity. Carbon, nitrogen, phosphorus, and isotopic analyses are not included in these results.

- [Seagrass coverage and abiotic data - Esri grid - zipped \(38 MB\)](#)

LM-151 Results (1989 - 2022)

LM-151 is a long-term seagrass monitoring station located within the boundaries of Padre Island National Seashore. Data from this monitoring station is [archived at NCEI](#) and we recommend the following citation:

Dunton, Ken; Jackson, Kim; Schonberg, Susan; Capistrant-Fossa, Kyle (2023). Seagrass density and biomass, and related data from seagrass monitoring station LM-151 in Laguna Madre Texas from 1989-03-24 to 2022-06-23 (NCEI Accession 0282643). NOAA National Centers for Environmental Information. Dataset. <https://doi.org/10.25921/w3c1-sx54>. Accessed [date].

Miscellaneous Seagrass Datasets

- [Raw CTD Data](#) (LM-151, Nine Mile Hole, Lower Laguna Madre Fix2; Coordinates available upon request)
- [Little Bay Seagrass Monitoring Data 2012-2015](#)
- Victoria Congdon's MS Thesis data (The effect of hurricane force winds on seagrass abundance and sediment physicochemistry) is [archived at NCEI](#).
- [Algal Epiphyte Biomass from Seagrass Tissue Along the South Texas Coast \(2011 - 2021\)](#)
- [Acoustic Monitoring of a *Thalassia testudinum* seagrass meadow in a shallow sub-tropical lagoon](#)

Figure 19: An example of the current “Data” webpage where both the Tier-2 and Tier-3 data generated during this project are displayed (<https://texasseagrass.org/results/>).

Task 4: K-12 Public Education and Outreach

Funding from this project supported the development of “*Seagrass Survival in Super Salty Lagoon*”, a K–12 lesson plan (<https://datanuggets.org/2024/06/seagrass-survival-in-a-super-salty-lagoon/>). This lesson uses the Data Nuggets framework (<https://datanuggets.org/>) to translate scientific data into engaging, classroom-ready investigations (Figure 20). This plan incorporates long-term Tier-3 monitoring data from Laguna Madre to help students explore: (1) the importance of seagrasses, (2) key environmental factors influencing seagrass growth, and (3) how these conditions are changing over time. Classroom activities included live seagrass identification, lectures, and/or practice using scientific sampling equipment (Figure 21).

We delivered this lesson each semester to students in the Port Aransas and Flour Bluff Independent School Districts, reaching approximately 10 classes per year. The lesson was also taught annually at the UTMSI Summer Science program, which attracts hundreds of students from across Texas (4 lessons per year). Weather permitting, we participated in field trips with Flour Bluff ISD students (~4 per year) to provide hands-on experiences in local seagrass meadows (Figure 22). A simplified version was delivered at the Trinity by the Sea Pre-K classroom to inspire early excitement in marine sciences (annually). Finally, we participated in World Migratory Bird Day outreach events (annually) to explain the importance of seagrasses to migratory birds and talk about our monitoring efforts.

Name _____

DATA *Nugget*

Seagrass survival in a super salty lagoon

Featured scientists: Kyle Capistrant-Fossa (he/him) & Ken Dunton (he/him) from the University of Texas at Austin

Research Background:

Seagrasses are a group of plants that can live completely submerged underwater. They grow in the salty waters along coastal areas. Seagrasses are important because they provide a lot of benefits for other species. Like land plants, seagrasses use sunlight and carbon dioxide to grow and produce oxygen in a process called photosynthesis. The oxygen is then used by other organisms, such as animals, for respiration. Other organisms use seagrasses for food and habitat. Seagrass roots hold sediments in place, creating a more stable ocean bottom. In addition, the presence of seagrasses in coastal areas slows down waves and absorbs some of the energy, protecting shorelines.

Unfortunately, seagrasses are disappearing worldwide. Some reasons include damage from boats, disease, environmental changes, and storms. Seagrasses are sensitive to changes in their environment because they have particular conditions that they prefer.

Temperature and light levels control how fast the plants can grow while salinity levels can limit their growth. Therefore, it is important to understand how these conditions are changing so that we can predict how seagrass communities might change as well.



Manatee grass (*Syringodium filiforme*)

Ken is a plant ecologist who has been monitoring seagrasses in southern Texas for over 30 years! Because of his long-term monitoring of the seagrasses in this area, Ken noticed that some seagrass species seemed to be in decline. Kyle started working with Ken during graduate school and wanted to understand more about what environmental conditions might have caused these changes.

Texas has more seagrasses than almost any other state, and most of these plants are found in a place called Laguna Madre. During his yearly seagrass monitoring, Ken noticed that from 2012 – 2014 one of the common seagrasses, called **manatee grass**,

Data Nuggets co-developed by Michigan State University scientists and teachers in the GK-12 Partnership.

Figure 20: A K-12 lesson plan developed during this project that teaches students about the importance of seagrasses and the environmental factors that affect them. The lesson plan is freely available online and published as part of a collection of open-source lesson plans (<https://datanuggets.org/2024/06/seagrass-survival-in-a-super-salty-lagoon/>).

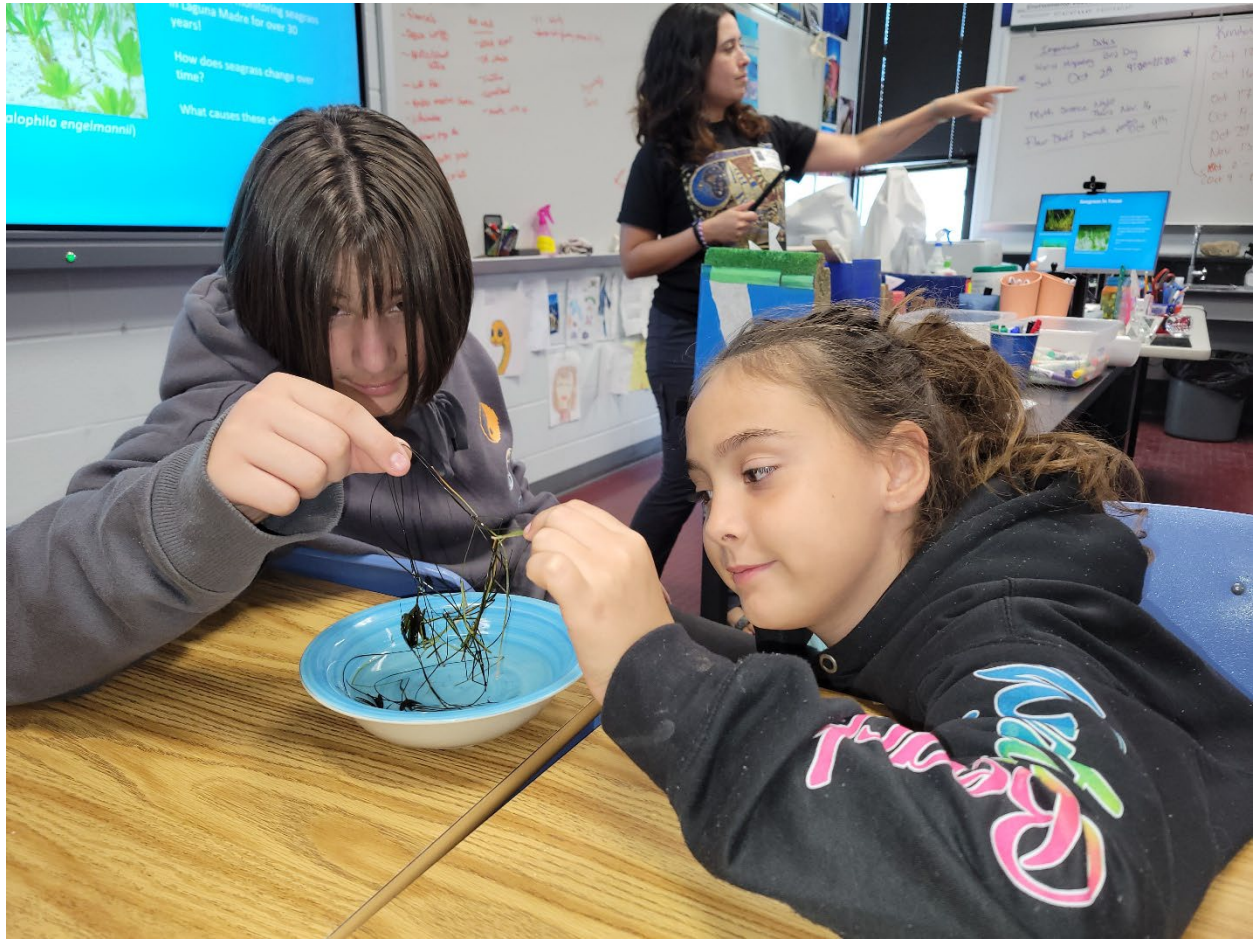


Figure 21: Students at the Flour Bluff ISD are practicing their identification skills on local seagrasses collected by UTMSI researchers during a classroom visit. Ms. Sofia Armada Tapia is in the background answering a student's question during her presentation.



Figure 22: Flour Bluff ISD students were joined in the field by UTMSI researchers to learn about seagrass. The students were able to use scientific equipment (YSI datasonde) to learn about the conditions seagrasses were living in and take sediment cores in the meadow to investigate the diversity of life present.

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