

Closing the loop: Recycling shells and restoring reefs for resilience and recovery

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Prepared for



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Restaurant Partners



Oyster Farm Partners



Community Partners



Introduction

Oysters are economically and ecologically important coastal natural resources in Texas. Oyster reefs increase resilience of coastal environments and economies by buffering storm surges, improving water quality, supplying critical habitat, providing fresh seafood, and supporting tourism and recreation. However, over the past two decades, Texas oyster populations have experienced critical declines. Restoration has emerged as an important tool for enhancing coastal natural resources, including oysters and the complex habitat they create when free-swimming oyster larvae attach to and grow upon the shells of older generations. Oyster shell is the preferred substrate for oyster reef restoration, but it is in limited supply.

Texas A&M University-Corpus Christi (TAMU-CC) utilized Coastal Management Program Cycle 26 Gulf of Mexico Energy Security Act (GOMESA) funds to close the loop, directly coupling shell recycling with reef restoration. To do this, TAMU-CC aimed to conduct three tasks: 1) Reclaim at least 225,000 lbs. of shucked oyster shell from various seafood industry partners; 2) Use recycled oyster shells to restore 4.5 acres of oyster reef complex in ~1.5 m water depth in St. Charles Bay, adjacent to Goose Island State Park (GISP), expanding an area of previously restored reef to a total of 18 acres—because St. Charles Bay is closed to commercial harvest, this location was chosen to protect restored oyster populations as well as create essential habitat, protect an eroding marsh shoreline, and facilitate natural reef recovery; 3) Host biannual community events for coastal residents and visitors to participate in hands-on reef restoration at GISP. At these events, volunteers fill biodegradable cotton mesh bags with recycled shells and place them in the intertidal zone to expedite reef regeneration along the shoreline adjacent to the large-scale restoration site. This project implements Texas Coastal Resiliency Master Plan Tier 1 Project ‘Goose Island State Park Habitat Restoration and Protection’ (ID 70) and restores oyster reefs as a coastal resiliency strategy. The adjacent coastal marsh is important habitat for the world's only flock of migrating whooping cranes. The restored reef provides natural protection to slow coastal marsh erosion to preserve critical habitat for this endangered and iconic species.

Project accomplishments

Goal 1: Reclaim shucked oyster shell from seafood industry partners

Oyster reefs are vital ecological and economic resources, but their populations are in decline throughout the Gulf of Mexico. Oysters depend on hard substrate, ideally the shells of other oysters, for larval settlement and growth. However, the availability of restoration material is limited and often costly. Our “Sink Your Shucks” (SYS) program addresses these issues by reclaiming shucked oyster shells and recycling them into Texas Coastal Bend bays to restore crucial habitats.

The program has achieved substantial growth throughout CMP cycle 26. While we began by collecting shells from two key contributors: Water Street Restaurants in Corpus Christi and Virginia’s by the Bay in Port Aransas (Figure 1, Figure 2), we now regularly collect shell from ten restaurant partners and three oyster farms (Including those in Figure 3, Figure 4, and Figure 5). Regular pickups are maintained 1-3 times per week, with shells transported to our stockpile at the Port of Corpus Christi (Figure 6). Shells are quarantined for at least six months, per TPWD guidelines, before being used for habitat restoration.

The cumulative weight of shells reclaimed increased steadily throughout the project period, with a total of 650,000 pounds of oyster shells (nearly triple our original target of 225,000 pounds!) reclaimed throughout CMP Cycle 26 (Figure 7). During the project period, Mike Osier was brought onto the project team to lead program expansion efforts. Mike and the team have succeeded in growing the program in restaurant participation, shells collected, and community reach. Shell collection was highest in March 2024, when we collected 34,000 pounds of shell in total. Collections were also notably high in April and June 2024 (> 28,000 pounds each month, Figure 7).

We are particularly proud of the geographical expansion of the program into Rockport during the project period. Latitude 28° 02’ and Copano’s have been the first Rockport participants, and we aim to include more in the future. Community members in Rockport have shown a strong interest in the success of Sink Your Shucks, as they directly witness the impact of oyster shell recycling

in their own backyards. Their support has been instrumental in forming connections with the organizers of Fulton OysterFest, where we collected shell for the first time in 2024. At this event, we were able to recycle approximately 10,500 pounds of oyster shell, more than at any other festival in the history of the program.

We are also thrilled with the addition of local oyster farms to our lineup. These partnerships have been particularly impactful, as oyster farmers are highly engaged and enthusiastic about contributing to restoration efforts. They take pride in their role and are eager to connect with the community and the restaurants they supply. This collaboration not only strengthens our program but also fosters a sense of community and shared purpose. The farmers are proud to demonstrate that their shells come ‘full circle’—harvested from the bay, distributed to local restaurants, and eventually returned to the bay to support new oyster growth and habitat restoration.

As we conclude CMP cycle 26, our “Sink Your Shucks” program has demonstrated increased growth and impact that we are proud of. We remain committed to expanding our network of participants in the shell collection program.



Figure 1. Shell collection at Water Street Oyster Bar in Downton Corpus Christi. Water Street is our longest-standing and highest-producing contributor.



Figure 2. Program Coordinator Mike Osier speaking with Virginia's Restaurant manager. Virginia's in Port Aransas is a long-term participant in the Sink Your Shucks program.



Figure 3. Black Diamond Oyster Bar was added as a SYS restaurant partner in May 2023.



Figure 4. SYS Staff worked with Black Diamond Oyster Bar to set up shell pick up that worked best for the restaurant's unique needs.



Figure 5. The Corpus Christi Yacht Club was added as a restaurant partner in September 2023.



Figure 6. Recycled shells are brought to our stockpile location at the Port of Corpus Christi, where they are quarantined before being used for oyster reef restoration.

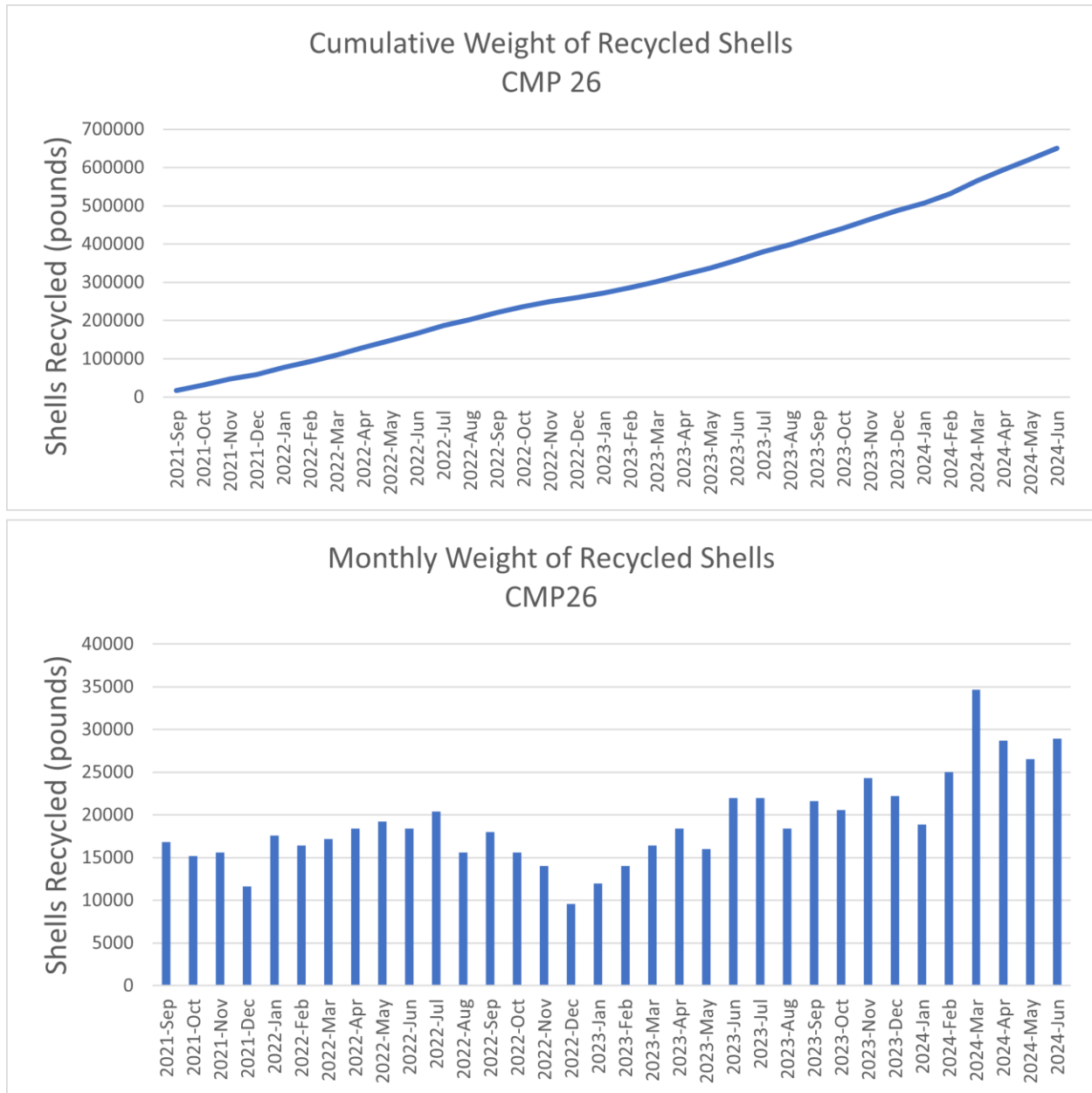


Figure 7. (Top) Monthly weight of shells recycled during CMP 26, and (Bottom) cumulative weight of shells recycled during CMP 26.

Goal 2: Restore 4.5 acres of oyster reef complex in St. Charles Bay

Oyster reef restoration projects have been initiated globally to enhance water quality, biodiversity, and harvestable oyster stocks (Fitzsimons et al., 2020). In the United States, more than 1,800 oyster reef restoration projects have been implemented since 1964, and 4.5% of lost reef area has been recovered (Berssoza Hernández et al., 2018). In the Gulf of Mexico, at least 259 oyster reefs have been restored, with 28% of the reefs being in Mississippi, 27% in Alabama, 22% in Florida, 15% in Louisiana, and only 8% in Texas (La Peyre et al., 2014).

In Texas estuaries, oyster reefs exist in both subtidal and intertidal areas where differences in exposure, submergence, and other environmental conditions may influence habitat provisioning (Gain et al., 2016). The Texas Parks and Wildlife Department enacted bay-wide closures to oyster harvest in St. Charles Bay and six other bays in January 2017 to facilitate oyster population recovery and protect sensitive habitats from damaging oyster harvesting activities. St. Charles Bay now functions as an oyster sanctuary where restored reefs are protected from harvest, allowing for increases in the population of spawning adult oysters whose larvae can help replenish nearby harvestable reefs in the greater Mission-Aransas Estuary (Powers et al., 2009). As part of CMP cycle 26, 4.5 acres of intertidal and subtidal oyster reef were restored in St. Charles Bay. Oyster recruitment and growth were monitored on those reefs to compare and understand restoration suitability and value by location.

In May 2022, 4.5 acres of subtidal and intertidal oyster reef complex were constructed in St. Charles Bay (mounds O, P, Q, R, Y1, Y2, Y3, and Y4; Figure 8, Figure 9), expanding upon a previously restored area for a total of 18 acres. The sampling area is within a larger restoration area encompassing restored reef “mounds” added in 2017 and 2020, adjacent to a community restoration area and the area of a bag comparison study funded by CMP 25 (Figure 8). All reefs were oriented parallel to the shoreline and were constructed using reclaimed oyster shells from the “Sink Your Shucks” shell recycling program.

After reef construction, a set of six standardized sampling trays was placed at each of six sites (three intertidal reefs: Y1, Y2, Y3, and three subtidal reefs: O, P, Q; Figure 8). Sampling trays

contained a single layer of representative reef material (recycled oyster shell; Figure 10). Sampling was conducted monthly for the first three months after reef construction, then quarterly for one year, then every six months for an additional year, for a total of two years of post-restoration monitoring (Figure 11, Figure 12).

Oysters from both restored reef types grew rapidly within the first three months after restoration, with average growth rates of 0.97 mm d^{-1} on intertidal and 0.95 mm d^{-1} on subtidal reefs. Oyster shell heights on intertidal reefs ranged from $28.2 \pm 1.6 \text{ mm}$ (mean $\pm$ standard deviation) at one month after restoration (June 2022) to $53.1 \pm 5.1 \text{ mm}$ at two years after restoration (May 2024), and on subtidal reefs from $26.5 \pm 0.0 \text{ mm}$ at one month after restoration to $65.3 \pm 5.4 \text{ mm}$ two years after restoration (Figure 13).

Oyster densities remained lower on intertidal than on subtidal reefs through most of the project period. Densities on intertidal reefs ranged from $2 \pm 1 \text{ ind. tray}^{-1}$ at one month after restoration (June 2022) to $51 \pm 52 \text{ ind. tray}^{-1}$ at 12 months after restoration (May 2023). On subtidal reefs, densities ranged from $1 \pm 1 \text{ ind. tray}^{-1}$ at one month after restoration to $286 \pm 35 \text{ ind. tray}^{-1}$ at six months after restoration (November 2022; Figure 14). Oyster densities on both reef types had increasing trajectories over time, until densities began to level out after peaking in November 2022 for subtidal and May 2023 for intertidal reefs.

Spat density was also higher on subtidal than on intertidal reefs throughout the project period, peaking shortly after restoration (Figure 15). The proportion of live shell on subtidal reefs remained above 70% after August 2022, while on intertidal reefs, the proportion of live material in trays remained below 25% throughout the project period (Figure 15).

The difference in oyster density and growth on subtidal and intertidal reefs highlights the need for differential success criteria. Intertidal reefs have the potential to carry extra benefits including increased carbon storage and marsh protection (Fodrie et al., 2017; Ridge et al., 2017; Theuerkauf et al. 2019), but could be more susceptible to various threats such as environmental stressors, disease infection, and predation, impacting oyster survival (Lenihan et al., 1999; McAfee and Bishop, 2019). Restoring both reef types could serve as an insurance policy for

continued sustainability. Understanding the habitat provisions offered by reefs in different tidal zones will assist resource managers who seek to enhance ecosystem service benefits while achieving economic goals.

The CMP cycle 26 addition to the oyster restoration project in St. Charles Bay successfully expanded the existing reef complex by 4.5 acres, contributing to habitat creation, shoreline protection, and natural reef recovery. The restored reefs exhibited rapid development, with oysters beginning to recruit immediately after construction and achieving growth rates more than double those observed on natural subtidal reefs within the region (Graham et al., 2017; de Santiago et al., 2019; Martinez et al., 2022). Within 18 months, restored intertidal reefs had an 11-fold increase in oyster densities, and restored subtidal reefs had a 215-fold increase. The project underscores the importance of continued efforts in oyster reef restoration to support the recovery of oyster populations in Texas estuaries. In an effort to share, grow, and expand upon this research, we presented preliminary results at the Benthic Ecology Meeting in Miami, Florida in April 2023 and at the Coastal and Estuarine Research Federation conference in Portland, Oregon in November 2023.

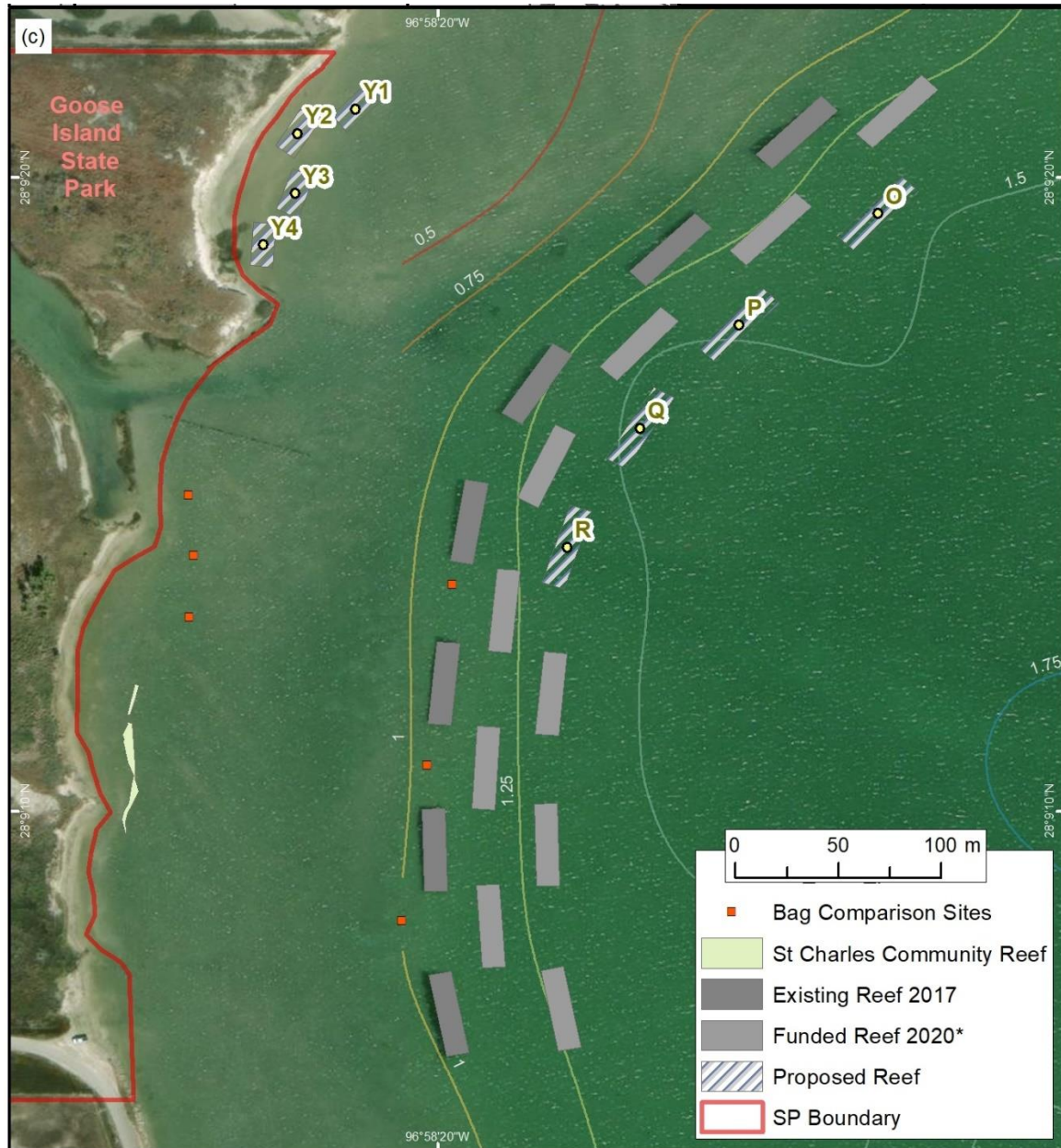


Figure 8. Map of the study area in St. Charles Bay, Texas, including previously restored reefs (2017, 2020, community), previous study sites (Bag Comparison Sites), and the current restoration and study site (mounds O, P, Q, R, Y1, Y2, Y3, and Y4).



Figure 9. Restored reef construction via barge in St. Charles Bay (top) and overhead view of study area after construction (bottom, photo credit CCA Texas).



Figure 10. A sampling tray with recycled oyster shell. An array of trays were placed at each sampling site and secured with rebar.



Figure 11. Spat on recycled shell in June 2022 (one-month after restoration/ deployment).



Figure 12. Staff and graduate students sampling a restored intertidal oyster reef.



Figure 13. A sampling tray retrieved from a subtidal restored oyster reef in November 2023.

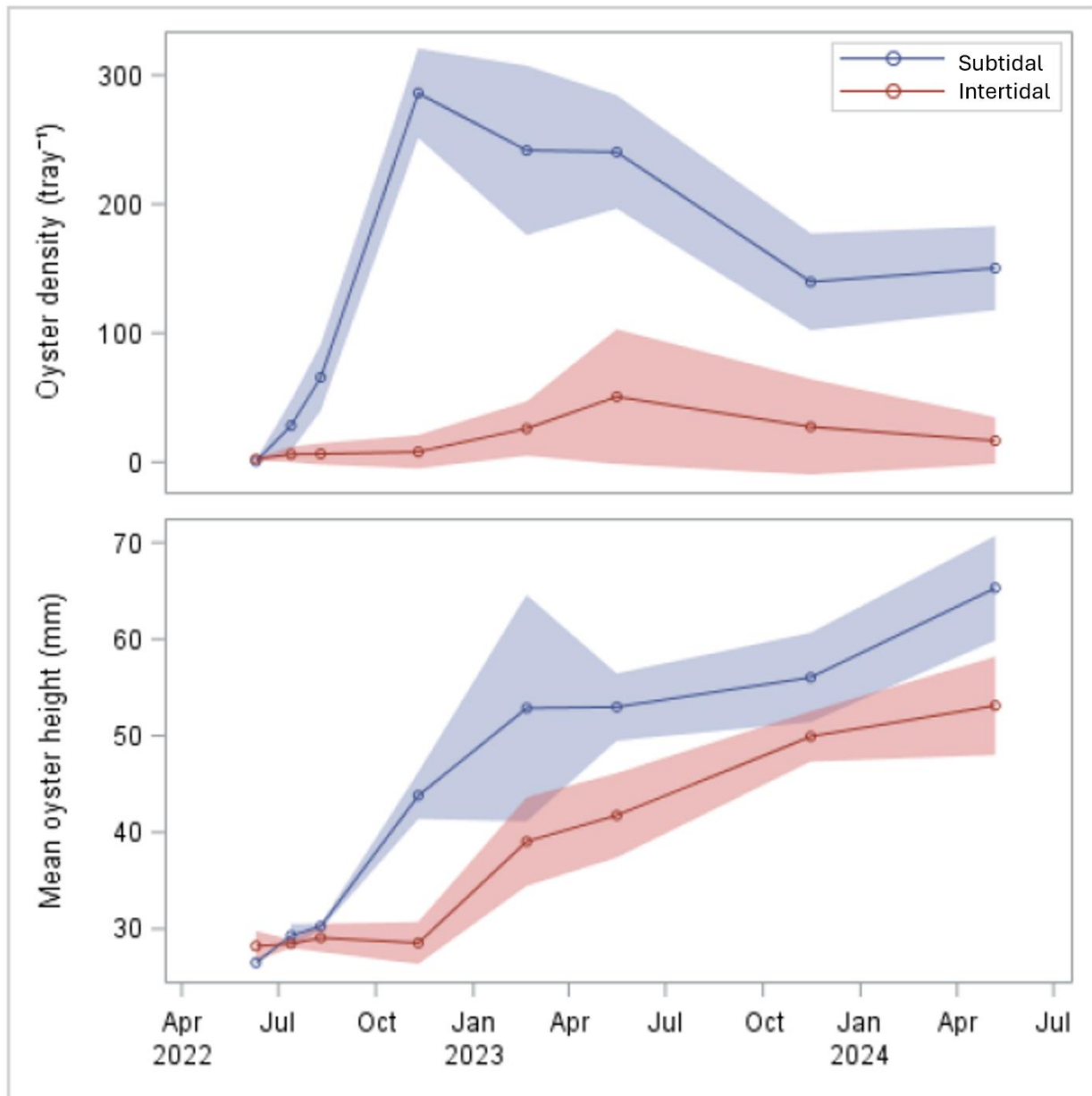


Figure 14. Density (ind. per tray) of oysters (Top), and mean oyster shell height (mm) measured at subtidal (blue) and intertidal (red) restored oyster reefs during sampling events from 1 month after restoration (June 2022) to two years after restoration (May 2024). Shading indicates standard deviation.

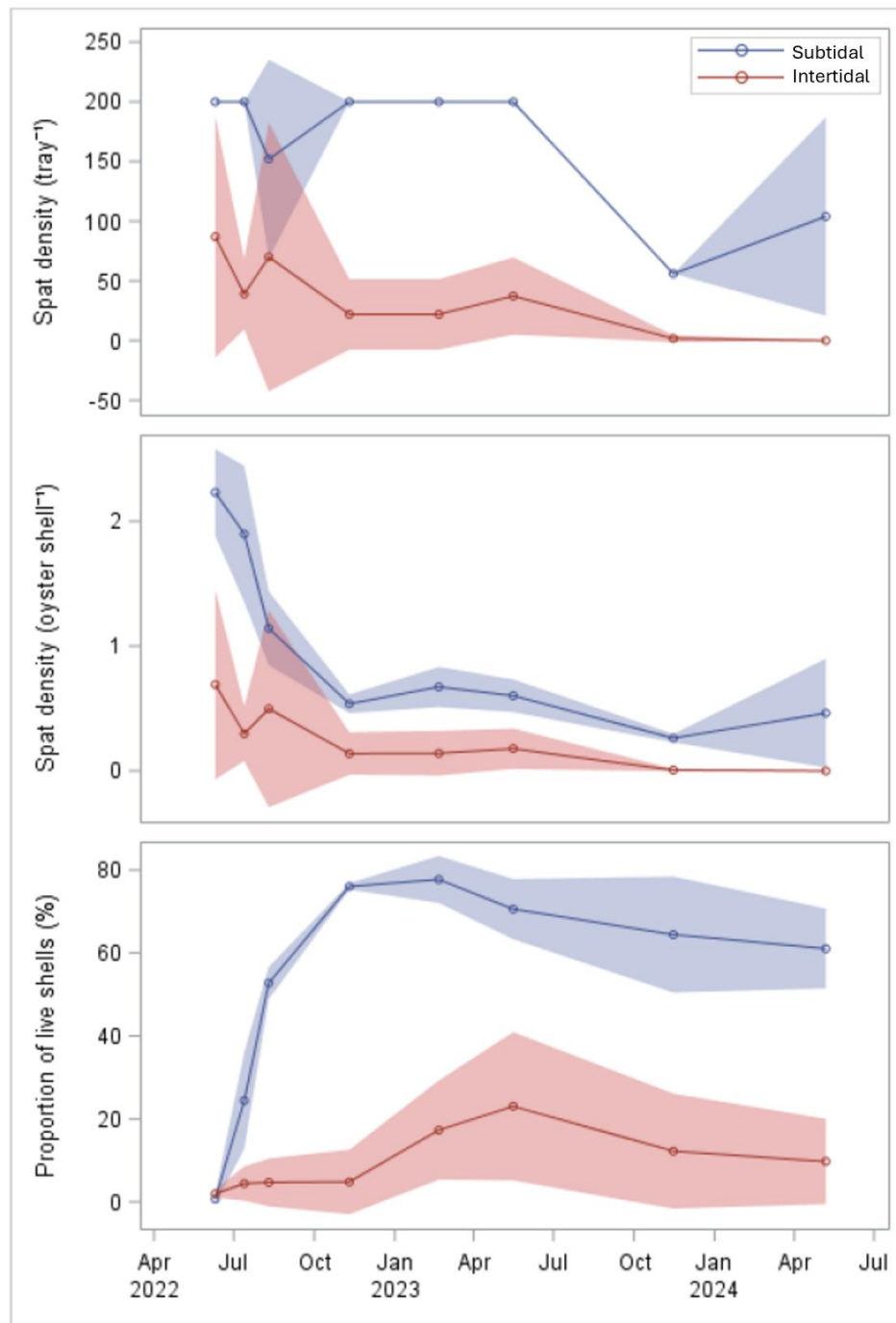


Figure 15. Oyster spat density (ind. per tray, top; ind. per shell, middle) and proportion of live oysters in sampling trays at subtidal (blue) and intertidal (red) restored oyster reefs during sampling events from 1 month after restoration (June 2022) to two years after restoration (May 2024). Shading indicates standard deviation.

Goal 3: Community Engagement

Community-based oyster reef restoration events are vital to the mission of the ‘Sink Your Shucks’ oyster recycling program, as they raise awareness and build stewardship. These events invite community members to take a hands-on role in building habitats, protecting shorelines, and reducing coastal erosion. For these events, we collaborate with Goose Island State Park (GISP) staff to work along shorelines in the park that have been identified as threatened by erosion. In 2022, our efforts focused on the shoreline of the park’s Big Tree Unit. Although our events were limited due to COVID-19 safety restrictions that year, we hosted two events with 26 volunteers in total. The small participant-to-staff ratio allowed for a personalized experience with plenty of time for questions and interaction.

In 2023, despite the lifting of many COVID-19 restrictions, our restoration permit from the U.S. Army Corps of Engineers was delayed. This hindered our ability to place shells into the water or hold events. However, we received an extension of the CMP cycle 26 project, allowing us to plan two large public events in 2024. This year's turnout was one of the largest in program history, with 250 attendees between the two events. The events were hosted at the Goose Island State Park Fishing Pier, an area well-suited for large groups and ideally situated to attract visitors who might not otherwise explore this part of the park. During these events, we engaged the community in placing 20 tons of recycled oyster shells into 3,000 cotton mesh bags (Figure 16, Figure 17), forming new reefs to protect the vulnerable shoreline around the fishing pier (Figure 18). Participants also visited educational booths to learn about oysters’ ability to filter feed, improving water quality, and witnessed a model demonstrating the shoreline protection ability of reefs (Figure 19). We are working with Goose Island State Park to install permanent signage near the restored reefs. This signage will inform visitors about the benefits of oyster reef restoration, allowing them to observe shoreline protection in action for many years to come.

While our 2024 community reef restoration events at Goose Island State Park were well-attended, we recognize that many community members cannot travel to Rockport. Therefore, as

part of Goal 3, we expanded the program's reach by participating in a variety of local events. Through CMP cycle 26, we:

- Held a mobile bagging event at Zachary Kolda Elementary School's STEAM Night on November 9, 2023 (Figure 20).
- Participated in Flour Bluff Elementary XSTREAM Night on February 8, 2024.
- Hosted a virtual laboratory tour for a high school biology class from St. John's School in Houston on February 20, 2024.
- Engaged with a large audience at Fulton Oysterfest in March (7-10), 2024.
- Participated in STEAM Day at Ella Barnes Elementary School on March 22, 2024.
- Welcomed students from Moody High School to the laboratory on March 22, 2024, to learn about oyster restoration and prepare for community bagging events.
- Participated in the Texas Oyster Roundup in downtown Corpus Christi on April 6, 2024.
- Collected shells and engaged with attendees at the Fiesta Oyster Bake in San Antonio on April 20, 2024.
- Hosted an educational booth at TGLO's Coastal Roundup on June 1, 2024 (Figure 21).
- Engaged with a large audience at Ace Hardware's Anniversary event in Rockport on June 29, 2024.
- Conducted laboratory tours focused on reef restoration for students from Flour Bluff Intermediate School, Shiner Catholic School, and TAMUCC Islander CCA throughout the reporting period.

We are proud to be part of the community through community-based restoration events, local schools, festivals, and by welcoming guests into our laboratory. We strive to continue to evolve our education program to ensure it is effective for each audience that we have the privilege of working with.



Figure 16. Participants at community-based reef restoration event preparing cotton mesh bags for recycled oyster shells to be placed within.



Figure 17. Volunteers shovel shell into buckets and use large sections of PVC to transfer shell to cotton mesh bags.



Figure 18. Volunteers move bagged oyster shell into the bay to form a new oyster reef.



Figure 19. Community-members visited educational booths to learn about oysters' ability to impact water quality (top) and to provide habitat for other fauna (bottom).



Figure 20. Sink Your Shucks staff members giving demonstrations on oyster shell bagging (bottom) and the formation of oyster reefs (top) at Kolda elementary school.



Figure 21. HRI students hosted an educational booth at the Texas Coastal Roundup.

Conclusion

Through CMP Cycle 26, we reclaimed over 650,000 pounds of oyster shells and restored 4.5 acres of oyster reef in St. Charles Bay. Our community engagement efforts have expanded, with increased participation in both restoration events and educational outreach, fostering greater public awareness and stewardship of coastal resources.

These achievements reflect the collaborative efforts of our partners, volunteers, and the broader community. As we continue to grow and evolve, we remain committed to enhancing the resilience of Texas's coastal ecosystems through innovative restoration practices and community involvement. The progress made thus far sets a strong foundation for future initiatives, ensuring that oyster reefs can continue to provide critical ecosystem services and support coastal resilience for generations to come.

Funding from the Texas General Land Office Coastal Management Program has been critical to the success and growth of the Sink Your Shucks program and related initiatives. Through this support, we have been able to provide natural oyster shell materials for restoring over 40 acres of oyster reef, creating opportunities for hands-on participation of the public in habitat restoration, and increasing scientific and public understanding of the value of oyster reefs as coastal natural resources.

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