Shell Bank: Oyster shell recycling, community involvement, student institute, and oyster health

Final Report for GLO Contract # 18-093-000-A604

Prepared for

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Acknowledgements

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Introduction

Eastern oysters, *Crassostrea virginica* are an ecologically and economically important species that provide many ecosystem benefits. As ecosystem engineers, oysters build reefs that increase abundance, biomass, and diversity of estuarine organisms, provide refuge for resident macrofauna, increase larval retention, enhance foraging, reduce competition and provide shoreline protection (Peterson et al. 2003, Soniat et al. 2004, Tolley and Volety 2005, Humphries et al. 2011, Grabowski et al. 2012). As suspension feeders, oysters enhance nitrogen removal (Grabowski and Peterson 2007, Beseres Pollack et al. 2013) and increase water quality and clarity (Kirby 2004). Oysters also provide the basis of a valuable commercial fishery, generating over $17M in Texas and $91M in the Gulf of Mexico in 2016; NOAA 2019).

Oyster reefs are one of the most degraded marine habitats, due in part to their commercial value and sessile nature (Lotze et al. 2006, Jackson 2008). Oyster reefs have declined by an estimated 64-91% in areal extent, and 88% in historic biomass compared to historic levels (Lotze et al. 2006, Beck et al. 2011, zu Ermgassen et al. 2012). A number of factors, both natural and human-influenced, have likely contributed to observed declines, including: unsustainable harvest, disease, and changes in coastal hydrology (Rothschild et al. 1994, Kirby 2004).

Habitat restoration has become a widely used approach for reestablishing lost ecological benefits (Grabowski et al. 2012, George et al. 2015). The Gulf of Mexico is an ideal location for restoration activities due to relatively abundant source populations of native oysters to produce larvae to populate restored reefs (14-50% of historic levels; Beck et al. 2011). One complication for reef restoration efforts is a shortage of oyster shell, the preferred substrate for use in reef restoration. Free-swimming oyster larvae depend on shells of older generations for attachment and growth. When reefs are degraded and harvested shells are not returned to bay waters, essential habitat is lost. The Shell Bank program provides a solution, utilizing community partnerships to reclaim oyster shells from restaurants, wholesalers, and festivals, and to recycle these shells back into local bays to build reefs and provide the fundamental building blocks for oyster attachment and growth.

Shell Bank Project partners

The Shell Bank Project is the first integrated oyster shell reclamation, recycling, and restoration program in Texas, and is supported by The Texas General Land Office Coastal Management Program. Shell Bank Project partners started as a local group within Corpus Christi proper, and included: Water Street Seafood Restaurants (providing shucked oyster shells), the Harte

Research Institute for Gulf of Mexico Studies (HRI) and Texas A&M University-Corpus Christi (TAMU-CC) (project execution and partner coordination), and the Port of Corpus Christi Authority (housing the stockpile location for the recycled oyster shells).

The project has evolved to include partners who donate shells from across a larger region of south Texas, including Austin Oyster Festival (Austin), Groomer's Seafood (San Antonio and Corpus Christi), and Fiesta Oyster Bake (San Antonio). We are actively seeking and testing out new project partnerships for shell recycling across the region.

One unique aspect of the Shell Bank Project is the large number of acres of habitat that have been restored using reclaimed oyster shells. We have restored over 20 acres of oyster reef to date with external funds, and anticipate another large-scale project to kick off in 2020 using reclaimed shells to restore oyster reef in the Mission-Aransas Estuary, again with external funds. These projects would not be possible without the investment of the Coastal Management Program to reclaim oyster shells for use in habitat restoration. External funding for reef restoration has built upon these investments, with project sponsors including Building Conservation Trust and the Coastal Conservation Association, the National Fish and Wildlife Foundation, Fish America Foundation, Gulf of Mexico Foundation, Texas Parks and Wildlife Department, NOAA, Texas Sea Grant, and Environmental Protection Agency (anticipated start date late-2019). We continue to seek new partners and new funds for habitat restoration, using shells reclaimed as part of the Shell Bank Project, including planned submissions this month to USDA and NOAA.

CMP 22 Project Objective and Goals

As part of CMP Cycle 22, we sought to build on previous achievements of the Shell Bank Project and to support goals and priorities defined in the Coastal Bend Bays Plan, including Bay Tourism and Recreation, Habitat and Living Resources, and Public Education and Outreach. The project was divided into tasks in support of four project goals:

Goal 1: Oyster shell recycling.

TAMU-CC will work with restaurants, seafood wholesalers, and festivals to recycle shucked oyster shells for reef restoration. TAMU-CC will continue to reclaim shells from Groomer's Seafood wholesaler and Water Street Restaurant group and continue their partnership with Fiesta Oyster Bake in San Antonio. TAMU-CC will formalize a partnership with the Austin Oyster

Festival to increase oyster shell collection and educational opportunities. Working with festivals allows us to reach a wider audience and provide educational opportunities for over 100,000 festival visitors in San Antonio and Austin.

Goal 2: Citizen engagement.

TAMU-CC will host two community oyster restoration events at a new location in Goose Island State Park. Funds will be provided for local schools to participate in each event. During each event, students and community volunteers will fill 2,000 specialized mesh bags to create oyster reef building blocks. With funding from our restaurant partners, these shell bags will be used to restore oyster reef as part of a living shoreline project.

Goal 3: Hands-on learning.

We will facilitate two field sampling events (fall/spring) for 150 students from underrepresented /at risk groups to perform restoration monitoring activities. Hands-on learning is known to foster skills such as critical thinking, cooperation, and creativity. We will facilitate each event and provide funding and specialized resources to maximize the student engagement. Educational materials will be provided to teachers to bridge the gap between classroom and field-based learning.

Goal 4: Reef characterization.

An ongoing challenge facing oyster resource management is a lack of standardized metrics for comparing and evaluating reef health between bays, states, and across the Gulf of Mexico. Texas oyster resource monitoring relies on oyster dredges which can severely underestimate populations and do not provide quantitative data on oyster density or shell volume. TAMU-CC will sample oyster reefs across Texas using paired methods: quantitative diver quadrats and dredges. TAMU-CC will compare sampling methods and share results with resource managers to enhance conservation and restoration planning.

CMP 22 Project Accomplishments

1. Oyster shell recycling

Oysters are economically important natural resources that also provide many ecological benefits to coastal environments. Unfortunately, oyster reefs are the most degraded marine habitat on earth. Because oyster shell is the preferred substrate for oyster reef restoration projects, we reclaim and recycle shucked oyster shells from restaurants, seafood wholesalers, and festivals for use in reef restoration. Since 2009, we have reclaimed and recycled over one million pounds of oyster shell and have used these shells to restore over 20 acres of oyster reef in the Mission-Aransas Estuary.

As part of CMP 22, we have continued to reclaim and recycle shucked oyster shells from Water Street Oyster Bar, and Water Street Restaurant, as well as Fiesta Oyster Bake in San Antonio, where we collect shucked shells from their 2-day festival with approximately 100,000 visitors. We also formalized a new partnership with Austin Oyster Festival, where we reclaimed more 3,000 pounds of oyster shell and transported them to the coast for use in reef restoration, ensuring that this valuable resource is not lost to the landfill. Groomer's Seafood is not currently shucking oysters; their original location in North Beach was recently demolished as part of the Harbor Bridge project in Corpus Christi. They have identified a new location along South Padre Island Drive, but they are not currently up and running. We are in active communication with Mr. Groomer, and he assures us that they will start their shucking operation again in the future, although it will take some time to get there. We continue to work with the Port of Corpus Christi to maintain our secure shell stockpile location, where shells are held for at least 6 months to eliminate potential disease or invasive species before they are ready for use in reef restoration. We have also started piloting two new restaurants for inclusion in the program in the future. All reclaimed shells are then placed where they are needed most: in Texas bays to restore degraded oyster habitat.

In Texas bays, a key impediment to oyster reef restoration is a lack of hard substrate for larval oyster attachment and growth. Oyster shells are the preferred substrate for habitat restoration because they are the natural reef-building material. However, oyster shells can be lost naturally in the environment, due to sedimentation or dissolution, or due to human activities, such as dredging and unsustainable harvest. Oyster shells can also be lost to other competing uses, providing a calcium supplement for chicken feed, or for controlling acidity in landfills or soils. In all of these circumstances, the building blocks of the reef are lost.

Using recycled oyster shells to restore oyster reefs is a relatively straightforward approach that works because of the of the life cycle of the oyster. Oysters spawn by releasing eggs and sperm into bay waters, and after fertilization, larvae remain in the water for about two-three weeks. In their final metamorphic stage, oyster larvae demonstrate a negative phototactic response; they move down toward the bay bottom (away from the light) to seek a suitable surface upon which to permanently attach. In Texas, oyster populations tend to be "substrate limited", meaning that there is a sufficient larval supply but a limited amount of hard substrate for recruitment and growth. This is in contrast to a healthy bay system, where existing reefs would provide the attachment points for newer generations of oysters. As oyster populations have experienced losses in size and distribution, there are fewer reefs for larval oysters to attach to and spend the remainder of their life cycle. The Shell Bank Program meets this need by reclaiming shells that would be otherwise destined for the landfill and using them to restore degraded oyster reefs.

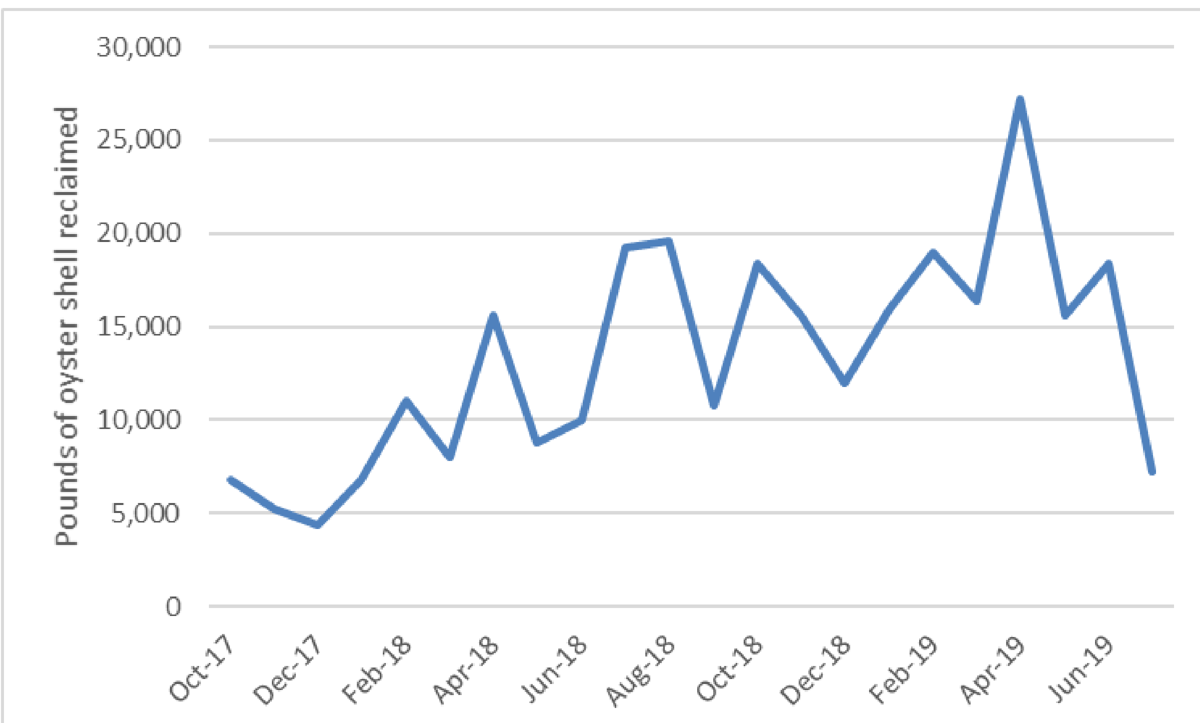

Figure 1. Pounds of oyster shells recovered from seafood restaurants, wholesalers, and festivals.

As part of CMP Cycle 22, the Shell Bank Oyster Recycling program reclaimed approximately 292,000 pounds oyster shells from seafood restaurants, wholesalers, and festivals (Figure 1).

The amount of reclaimed shells steadily increased over the period of the grant. The greatest amount of shell was collected during April 2019 (27,200 lbs).

We also recycled oyster shells from two large regional festivals: Austin Oyster Festival on February 24, 2018 (Figure 2, Figure 3, Figure 4, Figure 5) , and St. Mary's Fiesta Oyster Bake in San Antonio on April 20-21, 2018 (Figure 7, Figure 8, Figure 9). For each event we transported trailers from Texas A&M University-Corpus Christi and placed them on the festival grounds ahead of the event. Throughout the festivals, we collected shucked oyster shells directly from the shuckers as well as from festivalgoers, and placed them into the trailers. We walked around with buckets and we also placed buckets on tables throughout the event for folks to more easily recycle their shells. By walking through the festival, it was much easier for us to talk to festivalgoers about the Shell Bank project, and to explain the importance of oysters and habitat restoration. People were excited to hear that they were contributing shells for rebuilding reefs simply by putting their shells into the collection buckets. We recycled an estimated 5,000 lbs. of oyster shells from Austin Oyster Festival and an estimated 8,000 oysters from Fiesta Oyster Bake. As part of Austin Oyster Festival, we were interviewed by Fox7 news and appeared on Austin local news promoting the Sink Your Shucks program (Figure 6). At the conclusion of each festival, we picked up our trailers on transported the reclaimed shells to our stockpile location at the Port of Corpus Christi.

Figure 2. Sink your Shucks volunteers at Austin Oyster Festival.

Figure 3. Volunteers at Austin Oyster Festival.

Figure 4. Dumping recycled shells into the collection trailer at Austin Oyster Festival.

Figure 5. Talking about oyster shell recycling and reef restoration at Austin Oyster Festival.

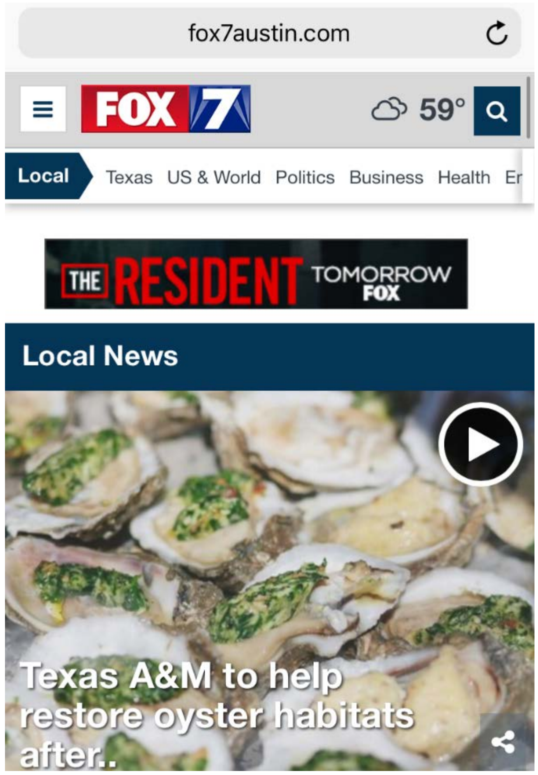

Figure 6. Sink Your Shucks Program featured on Fox 7 Austin News Station.

Figure 7. Sink Your Shucks Volunteers at Fiesta Oyster Bake

Figure 8. Sink Your Shucks trailer filled with recycled oyster shells at Fiesta Oyster Bake.

Figure 9. Two full trailers of reclaimed oyster shells at the end of Fiesta Oyster Bake.

2. Citizen engagement

Public participation and citizen involvement in habitat restoration increases awareness about the coastal environment and promotes a culture of stewardship. Our habitat restoration activities provide active, field-based opportunities for students and community groups. As part of CMP 22, we hosted two community shell-bagging events, on April 7, 2018, and May 5, 2018 (Figure 10, 11, 12). We had student involvement from Judson High School (San Antonio), Moody High School (Corpus Christi), and Texas A&M University-Corpus Christi. At each event, volunteers learned about oyster reef restoration and created the building blocks for an oyster reef by filling mesh bags with reclaimed oyster shells. We hosted these events in the spring to correspond with the period of highest oyster recruitment. Each event lasted from approximately 8:30-11:30 am, during which the volunteers rotate through a number of stations: (1) cutting the tubular mesh and tying off one end to create the bags, (2) filling the mesh bags with reclaimed shells, (3) transporting the bags to the shoreline. On April 7, 128 volunteers placed over 16,000 lbs. of recycled oyster shells into 731 bags of for oyster reef restoration at the park. On May 5, 116 volunteers participated in the event, placing over 23,000lbs. of shell into 1,054 bags for use in habitat restoration. We had the benefit of using existing supplies (shovels, buckets) to minimize costs.

Figure 10. Measuring and cutting the tubular mesh before tying off one end to create shell bags at a community-based restoration event at Goose Island State Park.

Figure 11. Volunteers fill mesh bags at a community-based restoration event at Goose Island State Park. The mound of recycled shells is visible in the background.

Figure 12. Placing filled shell bags along the shoreline at a community-based restoration event at Goose Island State Park.

With external funding from the Coastal Conservation Association, we used these shell bags to restore oyster reef at a new location at Goose Island State Park, along an eroding portion of the St. Charles Bay shoreline (Figure 13, 14, 15). This area experienced severe erosion as a result of Hurricane Harvey and needs shoreline stabilization. These shallow reefs are enhanced by a larger reef (~6 acres) that was constructed in deeper water in 2017 to reduce wave energies, and enhance habitat connectivity for oysters, as well as for the numerous fish, shrimp, and crabs that inhabit oyster reefs. We worked with TPWD State Parks staff at Goose Island State Park on all aspects of this task to maximize benefits to managers and visitors.

Figure 13. Volunteers pass bags of recycled shells down to the restoration site as part of a community-based restoration event at Goose Island State Park.

Figure 14. Goose Island State Park Ranger looks on as volunteers pass bags of recycled shells down to the restoration site at a community-based restoration event.

Figure 15. Sink Your Shucks volunteers at the completion of a community-based restoration event at Goose Island State Park.

3. Hands-on learning

Hands-on learning provides many benefits for students. Students who practice scientific skills in a real-life situation "learn by doing" and can extend their understanding beyond what they read in a textbook. As part of CMP 22, we provided hands-on learning opportunities to students from underrepresented / at-risk groups to participate in hands-on restoration monitoring training and activities (Figure 16, 17, 18, 19, 20, 21). Students participated in one of our community-based restoration events at Goose Island State Park and learned about habitat restoration and its role in conserving coastal environments. Students were encouraged to think about and discuss any other observations that they feel are important to evaluate the health of the ecosystem.

One of the major challenges in outdoor education is how to reach a large number of students with relevant, science-based material in a unique and exciting way. For this project we decided to use a "jigsaw" educational approach. The "Jigsaw Method" is a teaching strategy of organizing student group work that helps students collaborate and rely on one another. This teaching strategy is effective for accomplishing multiple tasks at once and for giving students a greater sense of individual responsibility (Catapano, 2019). This technique allows us to break the group down into smaller groups, deliver the specified information, and then recombine the larger group and have them discuss/teach the others about what their smaller group experienced. This technique helps to build comprehension, encourages cooperative learning among students, and improves listening, communication and problem-solving skills (Aronson, 1997).

Our first phase of this project involved determining what oyster-related topics would be relevant for student to learn. After discussions with other project personnel, it was determined to share the following topics: Water Quality, Oyster Life Cycle, Oyster Reef as Habitat, Oyster Diseases, Oysters and Humans (see Appendix). Members of the project team (professors, staff, and graduate students) then chose specific topics that they would research and present at the events.   All specific topics/lessons were designed to appeal to students and presented in a hands-on way.

Upon arrival at the events, all participants were given a colored tag. These tags would be used later during the event to randomly divide the group into the five smaller satellite groups. At the designated time, the students were directed to find the presenter holding a colored flag corresponding to their tag. The various satellite groups then met with their presenter and received their lesson involving oyster related topics. After completing the satellite lessons, the larger group was brought back together, and the students were then charged with teaching their topic to their home campus peers.

Figure 16. Sink Your Shucks Staff prepare the students for the "Jigsaw" learning portion of the event. They are learning about the process and how they will break into groups.

Figure 17. Sink Your Shucks Staff members Abby Williams and Abe Margo holding up the colored flags so students can find the group they need to report to for the hands-on learning.

Figure 18. Jay Tarkington gathering students to teach about "Oysters and Humans" so they understand the important relationship between the two.

Figure 19. Natasha Breaux teaching students about the importance of water quality and how it can impact the distribution and abundance of oysters.

Figure 20. Abe Margo teaching students about "Oyster Reef as Habitat" so they can learn the physical complexity of an oyster reef.

Figure 21. Students learning about reef-associated fauna that inhabit restored oyster reefs and utilize the habitat for nursery and forage.

4. Reef characterization

An ongoing challenge to managing oyster populations is the lack of standardized metrics for evaluating reef health and making comparisons between bays, states, and across the Gulf of Mexico. In Texas, oyster populations are sampled using an oyster dredge, which cannot provide oyster density or shell volume as a comparable, quantitative metric (e.g. per square meter). It is recognized that oyster dredges are inefficient samplers; they do not collect everything in their path and can vary widely across replicate samples (Chai et al. 1992). Dredge results can also be affected by towing speed, bottom characteristics, and length of towline (Meyer et al. 1981; McLoughlin et al. 1991). Resulting data may underestimate oyster densities (Chai et al. 1992) and limit the ability to assess populations across states and/or regions.

Accurate assessments of oyster density, size, and shell volume are needed, requiring the use of quantitative methods. As part of CMP 22, we sampled oysters on reefs across Texas using paired gear-type methods: dredges and quantitative diver-sampled quadrats. To maximize the utility of results, multiple sites were chosen in each targeted bay. Four locations each were sampled in the Trinity-San Jacinto Estuary, the Lavaca-Colorado Estuary, and the Guadalupe Estuary. Seven locations were sampled in the Mission-Aransas Estuary (Figure 22).

At each site, we first collected 3 replicate samples using diver quadrats, followed by 3 replicate dredges, to minimize the chance of sampling previously disturbed reef. For each sample, all live oysters were counted and measured, as were all dead oysters (shell > 25 mm), and all materials were removed from the top 10 cm of diver quadrats. Oyster size, density, and shell volume were standardized as number per square meter. Results from diver quadrats were compared with results from dredge sampling to determine if relationships exist.

In general, higher densities of oysters were sampled using quadrat methods compared to dredges, although the results varied by sampling location and estuary (Figure 23, 24, 25, 26). The lowest overall densities of oysters were observed in the Trinity-San Jacinto Estuary, regardless of sampling gear. Oyster densities were highest, and showed the greatest variability, in diver quadrats in the Guadalupe and Mission-Aransas Estuaries.

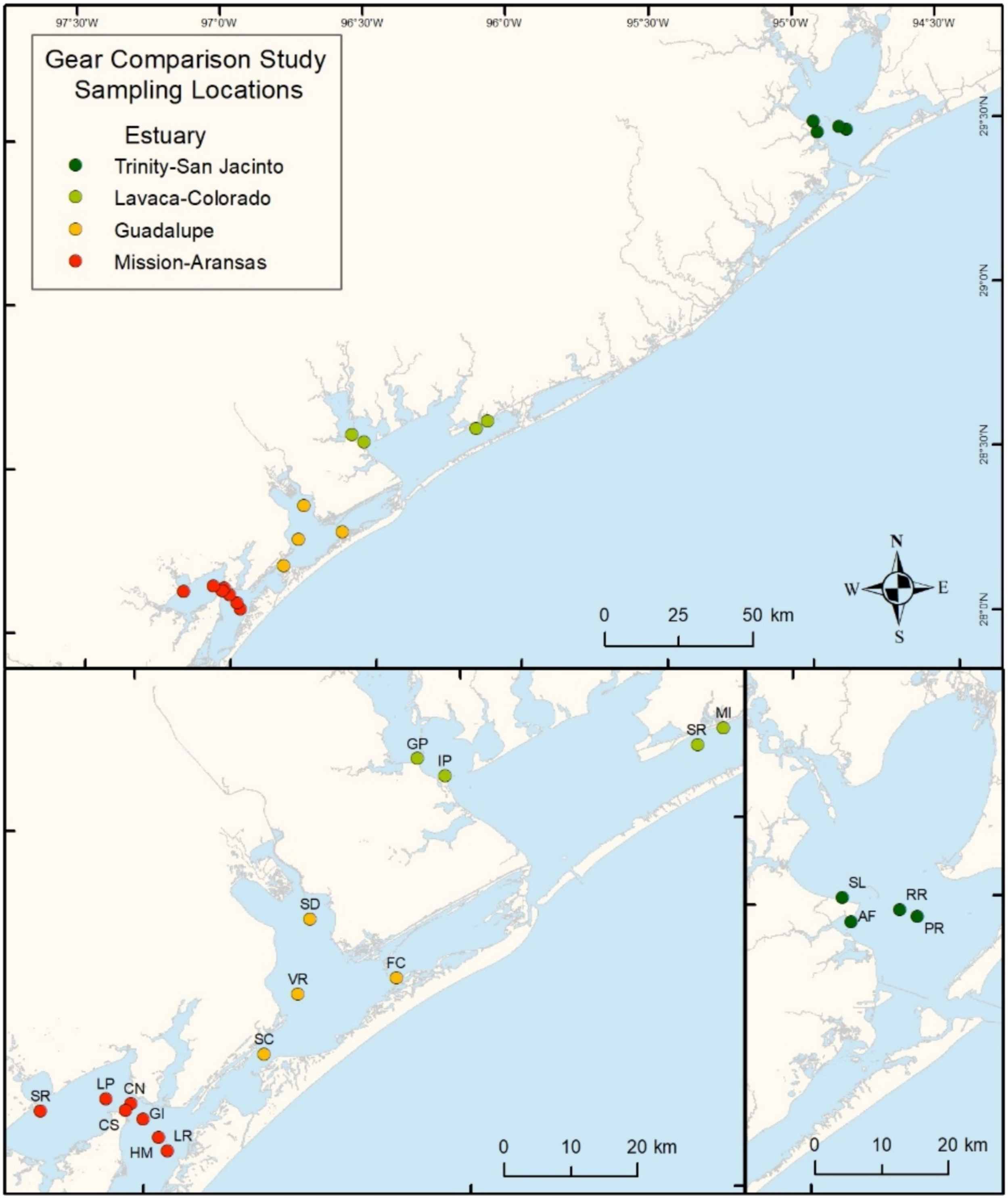

Figure 22. Sampling locations for reef characterization using paired dredges and diver quadrats.

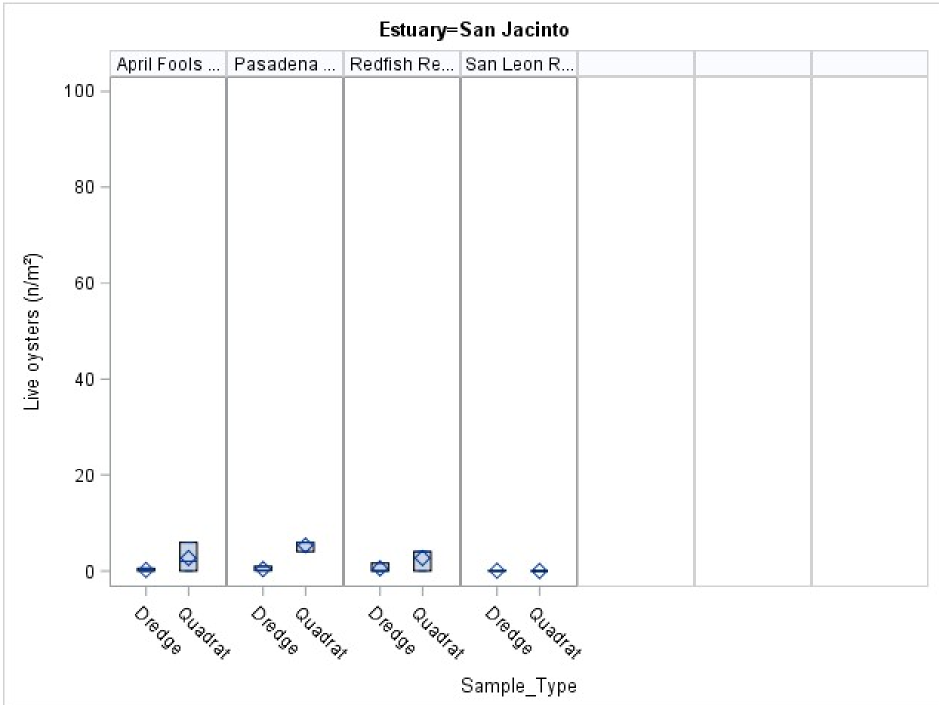

Figure 23. Number of live oysters collected by dredges versus diver quadrats at 4 sampling locations (3 replicates each) in the Trinity-San Jacinto Estuary (Galveston Bay system).

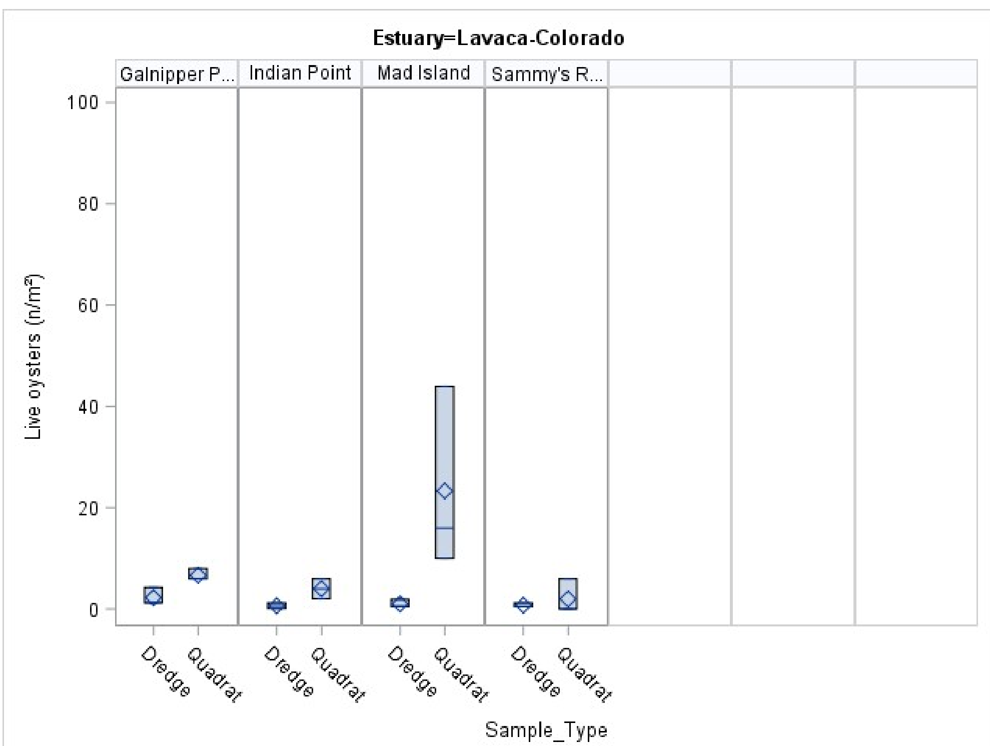

Figure 24. Number of live oysters collected by dredges versus diver quadrats at 4 sampling locations (3 replicates each) in the Lavaca-Colorado Estuary (Matagorda Bay system).

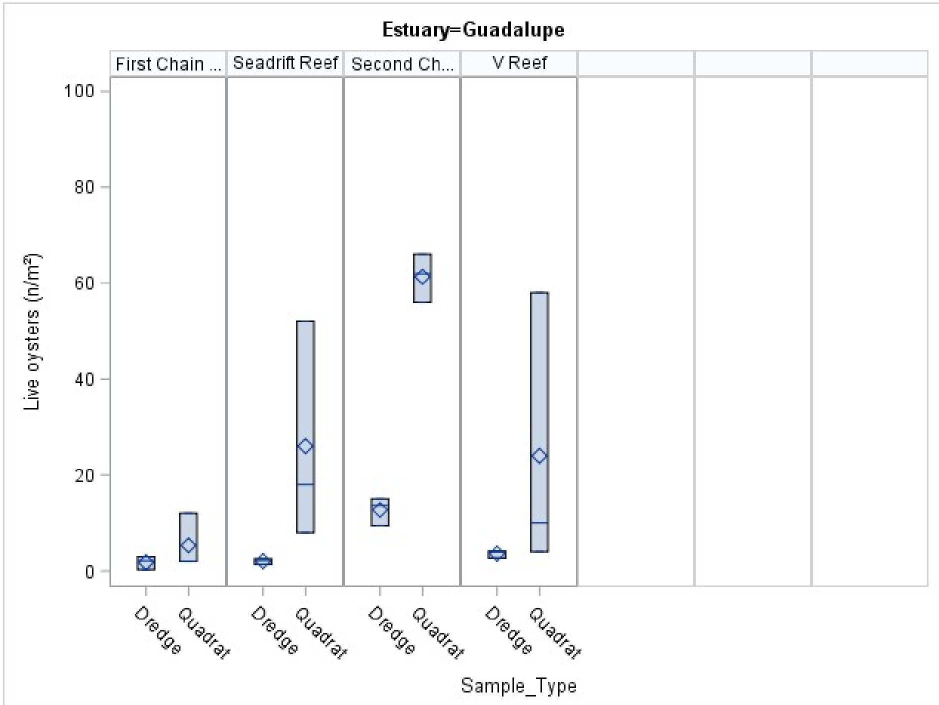

Figure 25. Number of live oysters collected by dredges versus diver quadrats at 4 sampling locations (3 replicates each) in the Guadalupe Estuary (San Antonio Bay system).

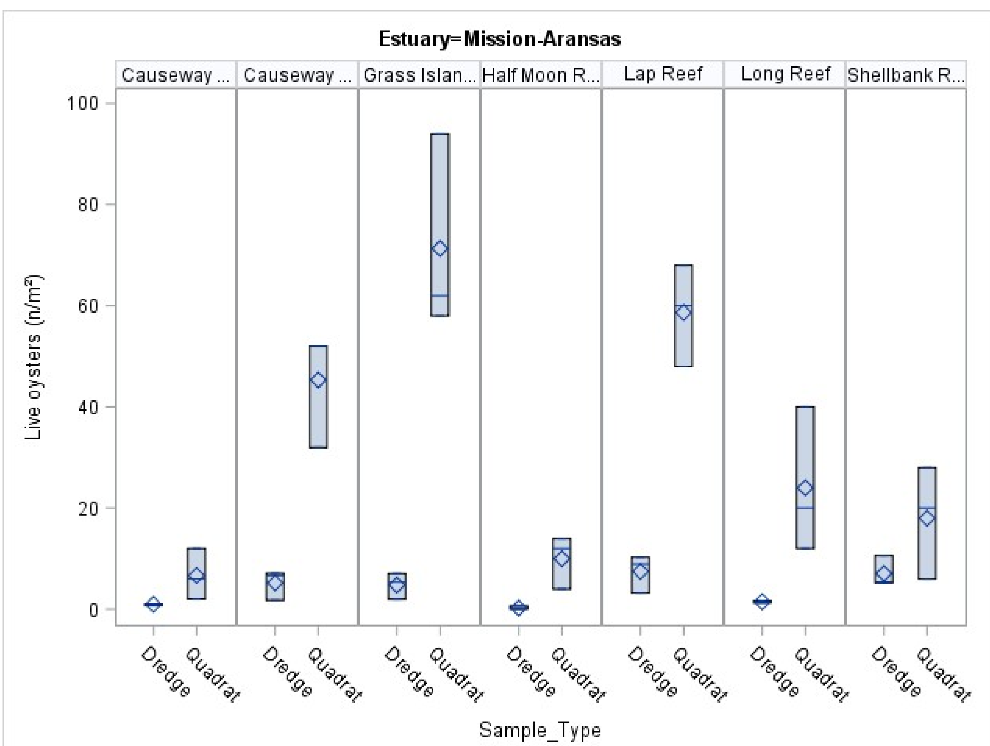

Figure 26. Number of live oysters collected by dredges versus diver quadrats at 4 sampling locations (3 replicates each) in the Mission-Aransas Estuary (Aransas Bay system).

We next assessed the size frequency distribution of oysters (shell height) collected in dredges versus diver quadrats (Figure 27, 28, 29, 30). Results varied by bay system: the quadrats missed the large oysters in the Lavaca-Colorado Estuary and the opposite was true in the Trinity-San Jacinto Estuary. Size distributions were similar between gear types where oyster densities were highest (Guadalupe and Mission-Aransas Estuary).

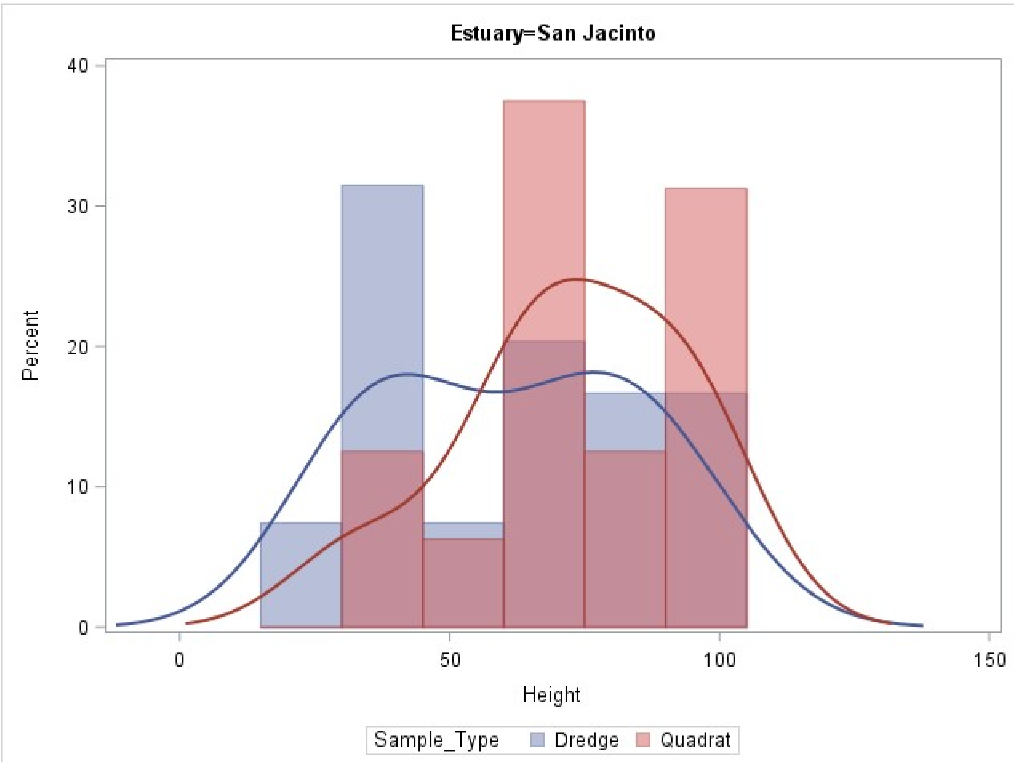

Figure 27. Size frequency distribution (shell height, mm) of oysters collected by dredges and diver quadrats at 4 sampling locations (3 replicates each) in the Trinity-San Jacinto Estuary (Galveston Bay system).

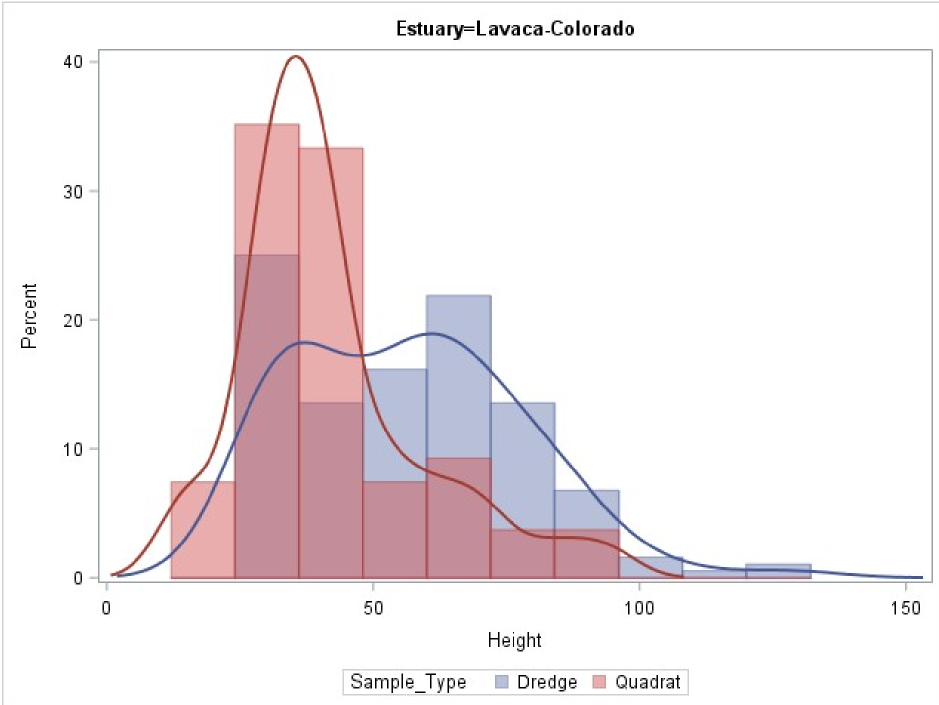

Figure 28. Size frequency distribution (shell height, mm) of oysters collected by dredges and diver quadrats at 4 sampling locations (3 replicates each) in the Lavaca-Colorado Estuary (Matagorda Bay system).

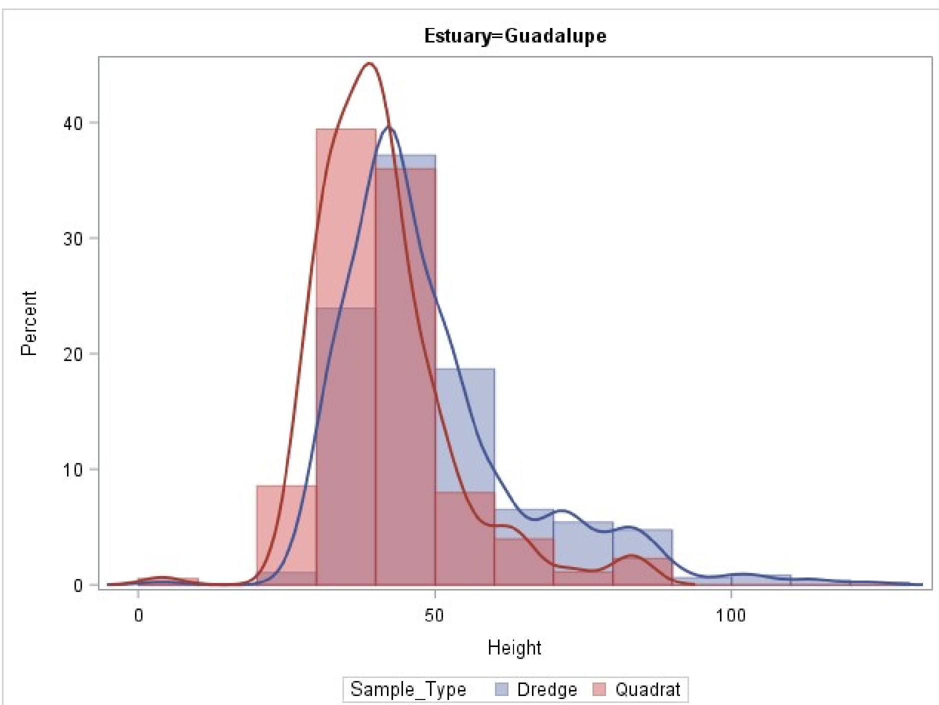

Figure 29. Size frequency distribution (shell height, mm) of oysters collected by dredges and diver quadrats at 4 sampling locations (3 replicates each) in the Guadalupe Estuary (San Antonio Bay system).

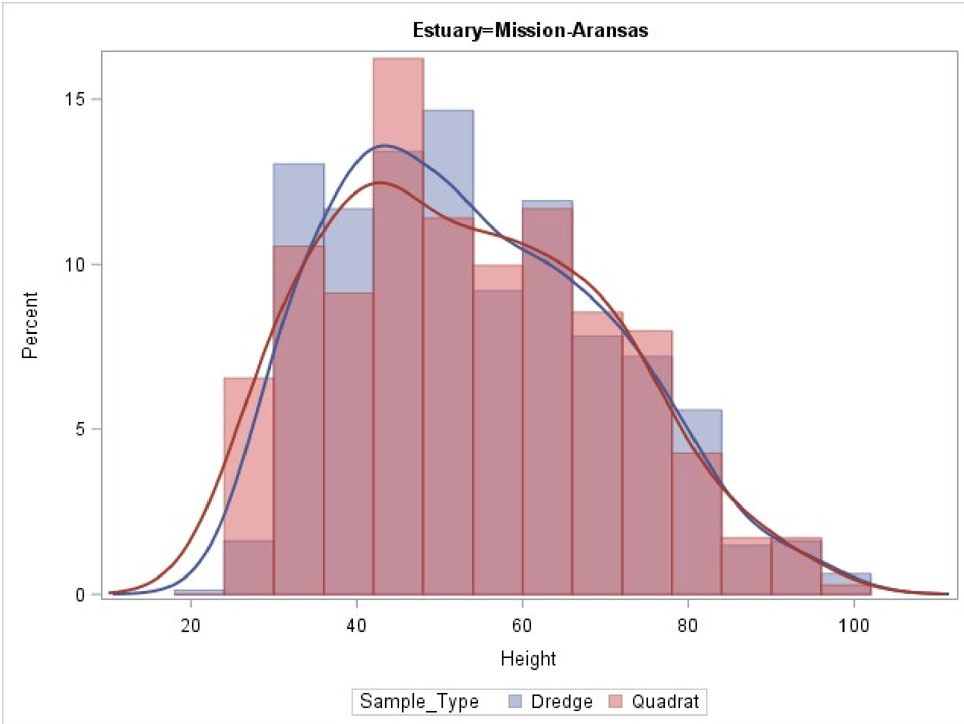

Figure 30. Size frequency distribution (shell height, mm) of oysters collected by dredges and diver quadrats at 4 sampling locations (3 replicates each) in the Mission-Aransas Estuary (Aransas Bay system).

We then used Pearson Correlation to assess the relationship between the average density of oysters collected in quadrats versus oysters collected in dredges. For live oysters (n m^{-2}), dead oysters (n m^{-2}), and the volume of live oysters (L m^{-2}), there were significant ($p < 0.05$) positive linear relationships (Figure 31, 32, 33). For live oysters, the intercept of the regression line = 5.26, indicating that dredge samples resulted in oyster density estimates that were approximately 5x lower than were present when assessed using quantitative methods. For dead oysters, the intercept of the linear regression = 6.96, indicating that dredge samples again underestimated densities of dead oysters. When looking at the volume of live oysters, the intercept of the linear regression = 9.14, indicating that dredges produced almost 10-fold lower estimates of live oyster volume, an important characteristic of reef health. These multipliers could be used as a coarse adjustment of qualitative dredge densities to reflect quantitative densities. There was not a significant relationship between the volume of dead oysters (L m^{-2}) or the volume of live+dead oysters (L m^{-2}) between quadrats and dredges.

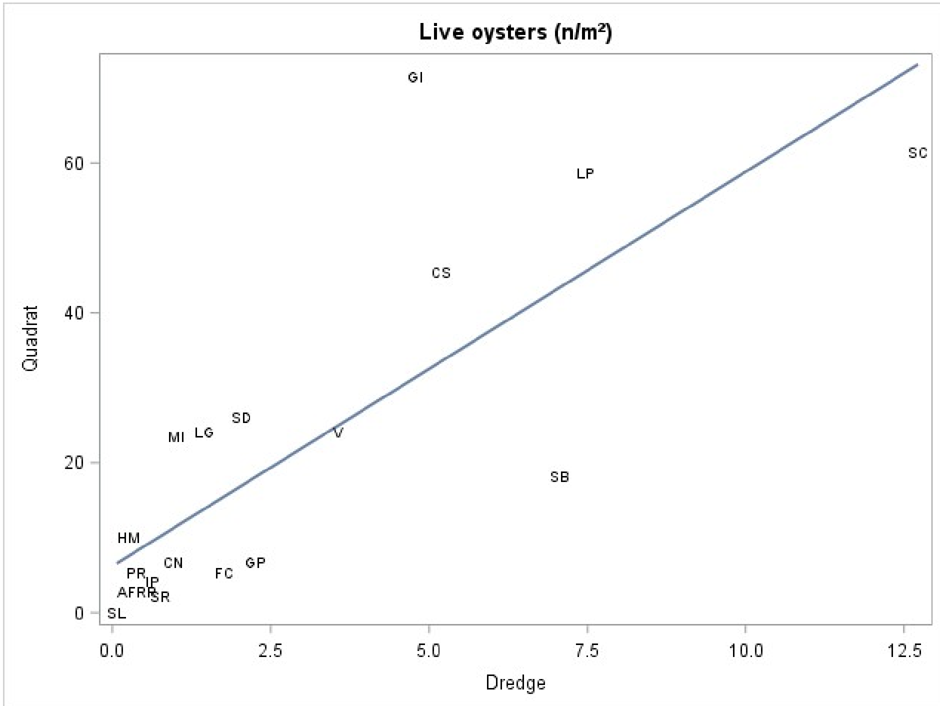

Figure 31. Linear regression between live oyster densities using quadrats and live oyster densities using dredges. Each point represents the mean for that sampling location.

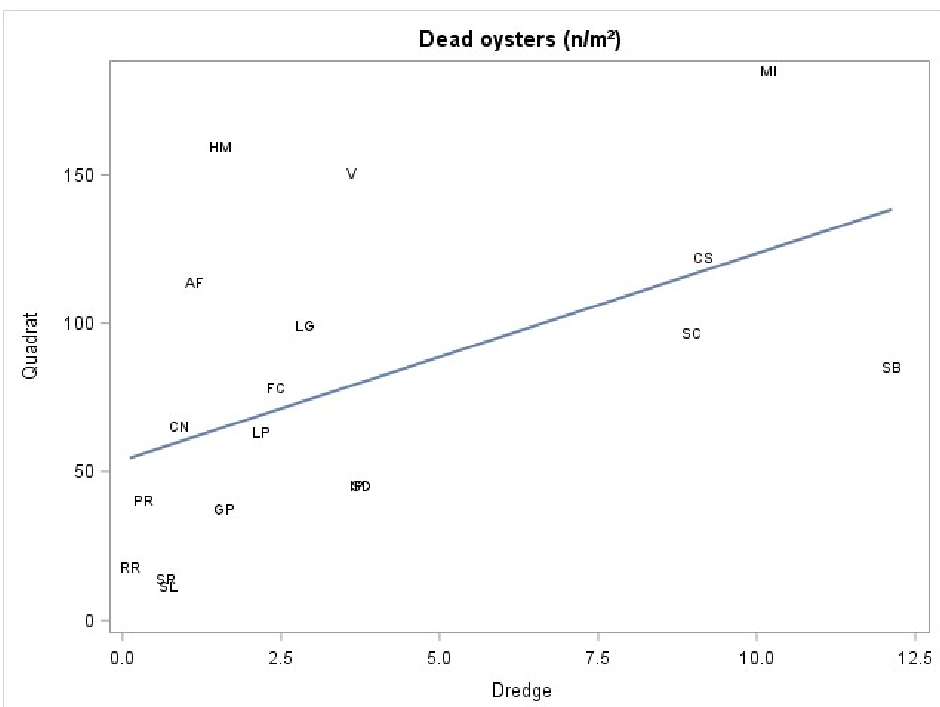

Figure 32. Linear regression between dead oyster densities using quadrats and dead oyster densities using dredges. Each point represents the mean for that sampling location.

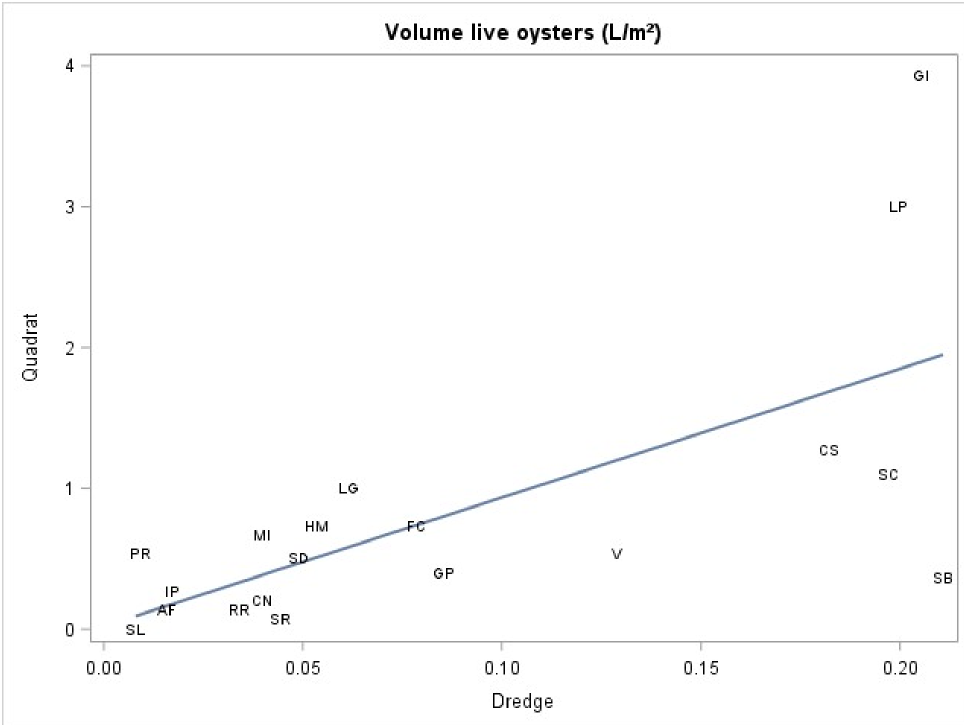

Figure 33. Linear regression between the volume of live oysters using quadrats and volume of live oysters using dredges. Each point represents the mean for that sampling location.

These key habitat measures are being shared with Texas Parks and Wildlife Department's Habitat Team Lead to assist with future monitoring and management efforts. These results improve our understanding of the characteristics of oyster reefs in estuaries along the Texas coast, and may allow coarse adjustments of dredge data to more quantitative scales. Ultimately, these data will provide additional information to support effective management of oyster populations.

Conclusion

As part of CMP 22, the Shell Bank Project achieved a number of key goals. In partnership with local and regional partners, we reclaimed 292,000 pounds of oyster shells that would have otherwise ended up in landfills. Using these shells, we conducted 2 community-based oyster reef restoration events in cooperation with TPWD staff and Goose Island State Park. As part of these events, we engaged over 240 people in hands-on habitat restoration activities, and returned over 39,000 pounds of shell back where nature intended: in the bay to restore degraded oyster reef. We have received new funding from TPWD and EPA that will allow us to use the remaining recycled shells from CMP 22 in future restoration projects. We also provided hands-on education to students from underrepresented groups, teaching them about water quality, the oyster life cycle, oyster disease, oysters as habitat, and oysters and humans, to provide historical and ecological context for our habitat restoration efforts. We also sampled oyster reefs across the coast to compare traditional dredge sampling methods with quantitative diver quadrats. The relationships observed between these two gear types may be useful for coarse adjustments of qualitative dredge data into quantitative estimates that could then be compared across broader regions.

Texas General Land Office Coastal Management Program funding has been key to the success of the Shell Bank Program, planting the seeds for over 20 acres (and counting) of restored oyster reefs across the Texas coastal bend region, for engaging hundreds of youth and adults in stewardship activities, and for increasing our understanding of oyster populations across the state to inform resource management. Moving forward, we at the Shell Bank program will continue to recycle oyster shells, restore oyster reef habitat, engage the public in environmental training and stewardship activities, and provide science-based solutions to support conservation and management of oyster reefs throughout Texas.

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Appendix A: Hands-on learning material

1. Water Quality

Question:

Why is water quality important for oysters?

Objective:

To understand the impact of water quality on the distribution and abundance of oysters.

Materials:

Secchi disk

YSI multiparameter sonde

Plastic containers with saltwater (differing salinity)

Process:

Students will learn about various water quality parameters and how each relates to oyster growth, feeding, survival, and reproduction. Water quality measurements will be related in more familiar terms, e.g.: 'The water that you may get in your mouth while swimming in the Gulf of Mexico has a salinity of roughly 35, while that in your tap water is close to 0. Eastern oysters prefer salinities between these two.' Students will then gain hands-on experience using a Secchi disk to assess water clarity and a YSI multiparameter sonde to measure salinity, temperature, pH, and conductivity. Students will be asked to guess the salinity of the water by taste alone. Then one student can lower the sonde into the water and read out the measured salinity. Afterwards, the group of students will discuss briefly what salinity is as well as the causes of changes in salinity: primarily freshwater inflow and mixing with seawater. In addition, the consequences of salinity change on oyster health will be discussed, including the increase in predators and disease at higher salinities, decrease in osmoregulatory ability at lower salinities, and a happy medium of high productivity at moderate salinities. Another volunteer can then read out the temperature and dissolved oxygen concentration of the water, after which, the students will discuss seasonal variations in both variables, and their basic effects on oysters and other aquatic animals. Lastly, a student will read out the pH level and the group will discuss how this can change and why it matters to shellfish. We will reiterate that water quality is important because we can use it to assess the health of, and learn more about, oysters and estuarine ecosystems. Students will then be sent back to rejoin their school group to teach these lessons.

2. Oyster Life Cycle

Question:

What is life cycle of an oyster?

Objective:

To understand the basic stages of development in an oyster's life cycle.

Materials:

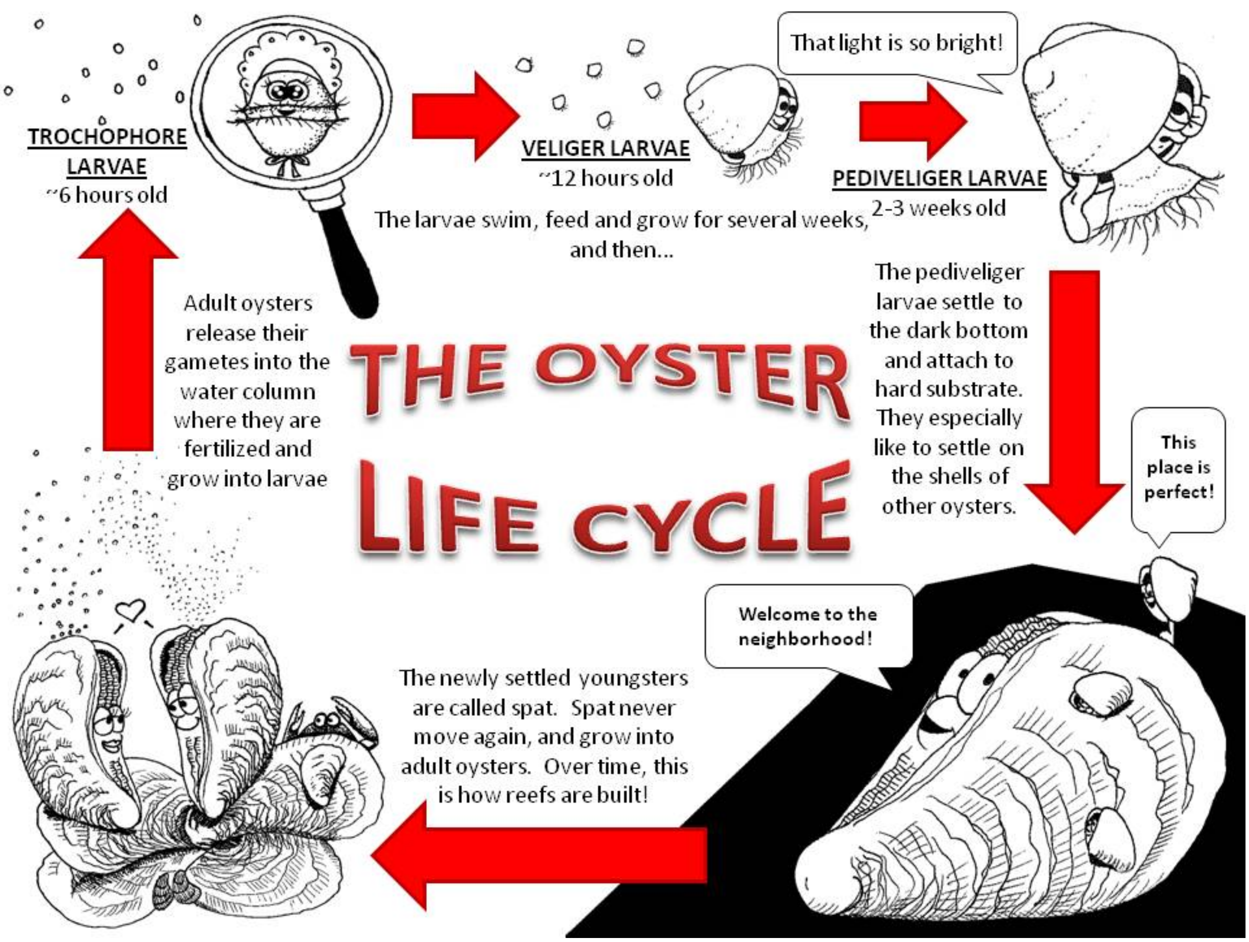
The Oyster Life Cycle poster (following page)

Oyster shell

Live oysters

Process:

Students will learn about the various life stages using The Oyster Life Cycle poster as a visual guide. Students will learn to identify the names, sizes and characteristics of each stage. A live oyster will then be shucked, and the students will observe the anatomy of the oyster. As part of the discussion, students will learn about the approximate number of larvae produced by an oyster during spawning, the names and approximate time spans of oyster life cycle stages from larvae to adult oysters, the ability of oysters to change genders during their life cycle, mechanisms for larval transport through the water column before attaching to substrate, including passive (tides/current), and active (minimal vertical activity), physical factors that may affect the growth, health, and reproduction of oysters such as salinity, temperature, predation, and competition, and harvest by humans, and the importance of substrate availability and restoration for all life cycles


THE OYSTER LIFE CYCLE
TROCHOPHORE LARVAE
~6 hours old
VELIGER LARVAE
~12 hours old
The larvae swim, feed and grow for several weeks, and then...
That light is so bright!
PEDIVELIGER LARVAE
2-3 weeks old
The pediveliger larvae settle to the dark bottom and attach to hard substrate. They especially like to settle on the shells of other oysters.
This place is perfect!
Welcome to the neighborhood!
The newly settled youngsters are called spat. Spat never move again, and grow into adult oysters. Over time, this is how reefs are built!
Adult oysters release their gametes into the water column where they are fertilized and grow into larvae

3. Oyster Reef as Habitat

Question:

What is an oyster reef and what habitat do they provide?

Objective:

To understand the physical complexity of an oyster reef, how it is formed and what inhabits an oyster reef.

Materials:

Plastic container

Live oysters

Other live organisms from the adjacent oyster reef

Process:

The students will first be polled to gauge their general understanding of what is meant by an 'oyster reef'. Then we will discuss that an oyster reef is a natural and living structure composed of many oysters that have cemented themselves to each other to form a reef. Students will learn how these reefs, or any hard structure, are necessary for recruitment of larval oysters. Students will be presented with information about the potential for unsustainable harvesting practices to damage these living oyster reef structures, and in response, the importance of oyster reef restoration for maintaining that structure as habitat. To demonstrate that oyster reefs provide habitat to many other species, a small touch tank will be filled with oyster reef associated fauna collected from a restored reef. Students will observe the organisms and learn that oyster reefs provide habitat and refuge to many crustaceans, fish, worms, and mollusks. Students will directly observe that these organisms live on top of, adjacent to, or within the interstices of the oyster reef matrix. The group will discuss how oyster reef communities facilitate a healthy food web all the way up to the predators that support the sport fishing industry. Students will come away with an understanding that oyster reef restoration events provide immediate habitat for a host of organisms, as well as a structure for new oyster recruitment.

4. Oyster Diseases

Question:

What diseases do oysters get and can they harm humans?

Objective:

To understand the role of oyster disease.

Materials:

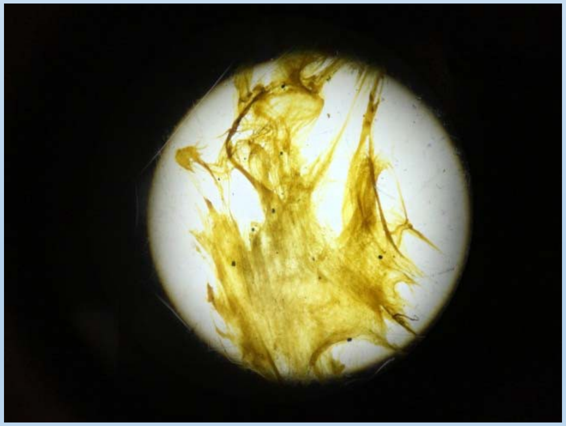
Posters

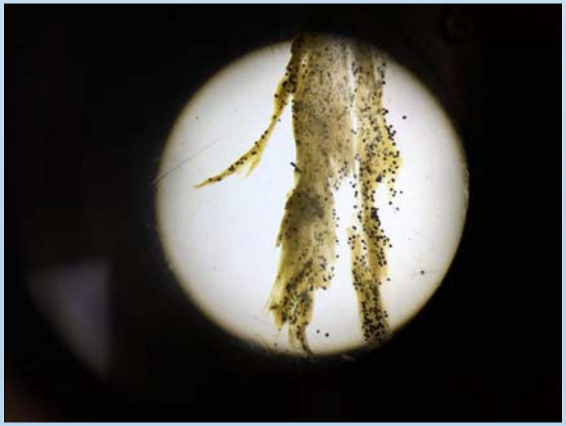
Live oysters

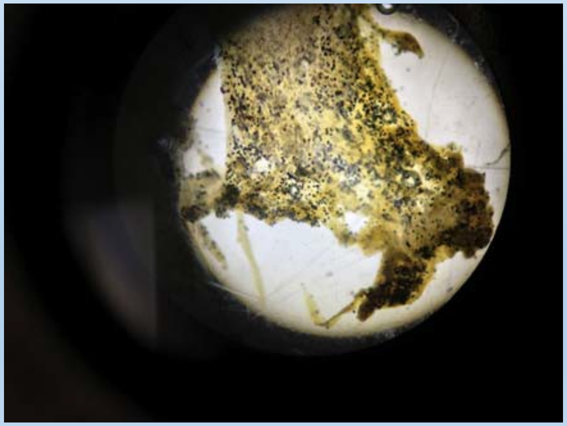
Other live organisms from the adjacent oyster reef

Process:

Students learned about various diseases oysters suffer from, with a major focus on Dermo, caused by the protozoan parasite, *Perkinsus marinus*. Because many of the diseases that affect oysters are caused by parasites, we will begin by asking students if they could tell the group anything they might know already about parasites. We will then discuss some of the parasites that affect oysters, such as oyster mud worms that burrow into oyster shells, boring sponge that eats away at oyster shells, and dermo disease where a small protozoan lives within oyster tissue. Students will then be asked if they know how the presence of oyster reefs can benefit people and the environment, and will then discuss how oyster diseases can take away these benefits, and what that means for oyster populations in the Gulf of Mexico. We will discuss how Dermo disease is measured in oyster tissues, and will look at photographs taken under the microscope that show oyster tissues that are stained to reveal the presence of the parasite (blue-black dots, see next page). We will discuss that the disease does not harm humans but, by leading to oyster mortality, reduces the number of oysters that humans can harvest. Lastly, we will discuss how water quality, salinity, and other environmental factors can stress the oyster causing it to succumb to diseases.







5. Oysters and Humans

Question:

What is the history and importance of oysters in relation to humans?

Objective:

To understand the historical importance between oysters and humans.

Materials:

Shucked oyster shells

Fossilized oyster shells

Process:

Students will learn about the history of oysters in relation to humans, both environmentally and economically. The attached paper "Bedding on the Future" will be provided as a basis for the discussion. Shucked and fossilized oyster shells will then be passed around so students can directly observe and compare the sizes and shapes of oyster shells that were recently dead versus those that were hundreds or thousands of years old.

Appendix B: Bedding on the Future

By Debra Young Hatch

In Texas, the story of the oyster begins long before recorded time. Discarded oyster shells found in piles, known as middens, left by native populations up and down coastal shores mark their first known days. Carbon dating of these shells, reflect oysters were harvested in coastal waters here as early as 5600 BP (3600 BC).

Native Americans plucked these hearty oysters from their beds, cracked their protective shells and ate them in the moment as they traveled up and down the state's coast from Corpus Christi to Galveston. At one time oysters in and around Corpus Christi and Nueces Bays were so thick they carpeted the muddy bottoms, often stretching for miles from shore-to-shore. And these bountiful Texas mollusks, left to their own devices – in their beds – for countless years, reproduced prolifically. Filtering bay water, growing into reefs, creating habitat for plankton, fish and crabs, the humble oyster was the bedrock of bounty in Texas' coastal waters. The notion that oysters could ever disappear from these waters was unimaginable.

The Karankawas: Their World, Their Oysters

The Karankawas, considered the predominant Native American tribe to traverse Texas' coastal shores between Corpus Christi and Galveston, are reported to have not only eaten oysters as part of their daily diets along with shrimp, fish, deer and turtles, but also used their remains – their shells – to create essential tribal tools and weapons. And the unused shells – piled high in their wake – served as historical markers, defining their lives, their culture and creating a tangible sign of the vast amount of oysters readily available to them along the coast for harvest and consumption.

These strong, fierce and independent Native Americans feasted specifically on *Crassostrea virginica* (eastern oyster) and their smaller cousin *Rangia cuneata* found in the pristine waters in and around Corpus Christi and Nueces Bays.

The Karankawas, also known as “water walkers” often used the bay’s vast oyster reefs as under water roadways, traversing the waters on the massive, continuous oyster beds resting just a few feet below the surface. In so doing, they appeared to walk on water. Early settlers in Corpus Christi and its neighboring city of Portland would often cross the bay via the aptly named “Reef Road” on horseback or in buggies on their way to and from San Antonio. The Reef Road existed and was still used extensively as late as 1886 when the San Antonio and Aransas Pass Railroad built a trestle bridge next to it which extended across Nueces Bay. Not until 1912, when the Nueces Bay causeway was completed, was the Reef Road abandoned as a means to travel from shore-to-shore.

Up until the early 1800s the Karankawas remained Kings of the Texas coast, and as such their waters, their fish, and particularly their oysters remained virtually undisturbed. But the whispers of change for these South Texas shores had already been heard some 300 years before, with the arrival of the first string of Spanish and French explorers, and the pioneers and settlers were not far behind. By 1858, the Karankawas were gone – driven to extinction. And as for their oysters in the bays and estuaries on the Texas coast – and specifically in Corpus Christi – they were all still there, just under the surface, but their days too were numbered.

Oysters on the Rise

Settlers, explorers and naturalists who ventured to the Gulf coast beginning in the 1700s were amazed by the boundless fish and oysters found along these newly-discovered shores. French historian and author, Pierre de Charlevoix, so impressed by the remarkable oyster population, dubbed the Gulf of Mexico the “Kingdom of Oysters.” In 1845 Zachary Taylor’s troops – 4,000 of them – who camped on Corpus Christi Bay shores during the war with Mexico were amazed by the fact that anything on a hook would bring in a fish, as well as the endless supply of oysters and turtles, all readily available for the taking. American author, Sidney Lanier, remarked in 1876, “There seems to be literally no end to the oysters, the fish, the seabirds, the shells, the turtles along these waters.” In Texas, and along the entire Gulf of Mexico, oysters were abundant and thriving.

Rails, Roads, Canneries and Shells

Corpus Christi in the late 1800s was coming "into its own" and oysters were an integral part of the growth, commerce and infrastructure of this burgeoning coastal community. By 1886 Corpus Christi had two railroads – the Mexico Laredo and the San Antonio and Aransas Pass to transport goods and people in and out of the city. Electricity, the telegraph and telephone came to town and Corpus Christi began to transform itself into a bustling, desirable destination.

Canning houses opened shop, primarily canning the oysters, fish and turtles, gathered from the bay in massive amounts. And the city had two ice plants providing ice to cool down oysters and fish for transport. At that time, oysters could be found in saloons, hotels and restaurants. On the streets of Corpus Christi a whole bucket of oysters could be purchased for as little as 25 cents. Oysters were eaten every way imaginable, and oyster roasts on local beaches were a common affair. Early residents often plucked the oysters from the bays, built a fire on the spot and roasted their collected treasure - eating them right then and there among family and friends.

Discarded oyster shells – once again left in piles or mounds to dry in the South Texas sun – were crushed for paving city sidewalks and roads, and were turned into shellcrete via a burning process for use in adobe bricks to construct houses, churches and commercial buildings.

A Fishery Found

In the late 1800s oyster production world-wide topped out, and demand began to overtake supply. Global population growth combined with effects of the industrial revolution began to exert extreme pressure on the bivalve and its habitat. Excessive harvesting with new and improved tools, the invention of refrigeration, new canning capabilities, faster transport via trains and the use of ice to keep oysters cold and fresh, all fatigued the once indomitable oyster. From 1880 up until 1910, oysters were harvested from coast-to-coast on a massive scale. During that 30-year span, the oyster harvest around the world peaked at 160 million pounds of oyster meat. The U.S. and Canada combined harvested an excess of 27 million bushels per year during that time period.

In Texas, a survey conducted by the U.S. Commission of Fish and Fisheries – established in 1871 – reported in 1880 a total of 95,625 bushels of oysters were taken from the bays in the state. By 1890 that number had jumped to 440,800 bushels. In 1880, there were 200 oystermen working in Texas and by 1890 that number had increased to 369 oystermen steadily engaged in harvesting oysters by hand in Texas via tonging with 100 more engaged in transporting and marketing the catch. The report also stated that from 1880-1890 the total area of the sea bottom within the state of Texas encompassed 2,471 square miles, with total oyster production taking place within137 square miles. Corpus Christi Bay for that same 10-year-period reported having 13 square miles (approximately 10% of the total bay area) of producing oyster grounds.

All the pieces seemed to come together at exactly the right moment for the oyster fishery to be found in Corpus Christi in the late 1800s. In 1885 the city's newspaper, The Corpus Christi Caller stated, "…Corpus Christi has grown to be a prominent market for fish and oysters, her dealers supplying all towns along the Texas Mexican and Mexico National railways to Saltillo, Mexico as well as points along the International road and towns in Central and Northern Texas…The oysters in this market are excellent and always have ready sale from September through June…"

In 1888, The Caller Times reported, "The fish and oyster business of Corpus Christi is reported assuming immense proportions… Heavily loaded wagons are noted every morning leaving from John Superach's and Corpus Christi Reef Fish and Oyster Co.'s establishment going to depots."

With its fishery found, by 1888, Corpus Christi sported several seafood canning houses; the first one – established by Royal Givens – was located on North Beach and was dubbed the Givens Packing Co. At the Givens cannery, oysters, clams and turtle soup were the products of choice. Oysters and fish were iced in barrels and shipped daily by rail heading as far north as Kansas City and Baltimore, and south to Laredo and Mexico.

Tonging – Harvesting Method of Choice

In Corpus Christi at the time, tongs were considered essential tools of the oysterman's trade. The shafts of the tongs were 8 to10 feet long, made of ash or oak, and they were pinioned like scissors with a steal head and two rakes on the end sporting 12-18 inch teeth on each side. Oysters were harvested from shallow draft schooners anchored over the beds and men leaned over the low gunwales with heavy tongs to scrape their quarry from the bottom.

From 1887 to 1890, the harvesting of oysters in bushels increased in Corpus Christi Bay from 36,000 bushels at a value of $8,400 to 65,400 bushels valued at $18,350.00. The average annual income of the oystermen along the Texas coast at the time was $230. In today's dollars that translates to an annual income of $6,372.92 (Bureau of Labor 2018).

The Steam Dredge: Bigger, Better, Faster, Deeper

The invention of the steam-powered oyster dredge in the 1800s, brought about the opportunity for a more efficient, bigger, better, faster and deeper collection of oysters. Oysters could now be harvested from beds which previously sat too deep for a tong's reach. Steam-powered dredges, would significantly, and as it turned out devastatingly, increase the harvest. When a dredge was scoured across a reef, it could potentially bring up seven to eight bushels of oysters in a single pass, increasing the amount of oysters brought to market as much as twelve times. From 1880 to 1910, with the use of dredges, oysters from coast-to-coast were harvested in massive amounts.

The Experiment: Steam Dredging in Corpus Christi Bay

The steam dredge was given its first Texas trial in Corpus Christi Bay in 1890. During the oyster season, one schooner – the C. Highland – used dredges experimentally for harvesting oysters from their beds in the bay. Dredges were not used during that time in any other bays along the Texas coast due to the unevenness of reefs and the lack of knowledge of the methods used for handling the dredges.

Upon witnessing the rapacious results of this initial experiment in Corpus Christi Bay – on April 11, 1891 – Texas enacted a law prohibiting the use of any form of oyster dredge in the waters of the Lone Star state. The U.S. Commission of Fish and Fisheries dubbed this law potentially short-sighted, as they pointed to the potential for expansion and growth and, in turn, determined dredges could be used with excellent results. At the time, Texas lawmakers did not agree, so for the moment, oysters in Corpus Christi Bay remained safely in their beds

Oysters in the 20th Century: Mass Production, Mass Reduction

With the turn of the century, oysters remained in high demand. Between 1880 and 1910, the oyster industry boasted production of 160 million pounds of oyster meat. And with the growing use of steam dredges, digging ever deeper oysters with increasing success. Oysters continued to be harvested as though their supply was infinite. But in reality, the country was beginning to reap the consequences of long-term oyster overharvesting.

Chesapeake Bay – the oyster producing mecca at the turn of the century, producing 20 million bushels of oysters in one year – by 1920, it too had been virtually stripped clean. Its oyster beds had been completely wiped out. So decimated were those once prolific reefs that even today – after a century of conservation efforts – they sit at only one percent of their peak. And hope is slim that they will ever be able to regenerate to historic levels, even with the supportive and successful underpinnings of oyster aquaculture.

In Texas and along the entire Gulf Coast, oysters dominated the fisheries in every state in the early 1900s. In 1902, the U.S. Fish Commission on Fish and Fisheries reported in their statistical fisheries report of the Gulf States that between Texas, Florida, Alabama, Mississippi, Louisiana, “The more important species in the fisheries of these states are oysters, the yield of which is 34,115,935 pounds or 4,873,705 bushels valued at $1,263,689.” Texas’ contribution to those numbers in 1902 was 343,113 bushels valued at $100,359.

While many New York bays in the early 1900s sat closed – out of oysters and out of time – Corpus Christi, in 1908, was declared to have the best fishing waters along the Texas coast. Fish and oysters caught in the morning were often at their destination by that same afternoon. Corpus Christi had four oyster plants and fish packing houses. In 1907, Corpus Christi shipped out 10 million oysters and one million pounds of fish (Walraven 1990).

Texas Fish and Oyster Commission – Setting Sights on Solutions

Even before the turn of the century, Texas recognized the potential and long-term possibilities of the oyster fishery. Along with that understanding, came the state's concern for oversight of this burgeoning industry – including maintenance of the oyster's environment and habitat.

The first oyster law operative in the Lone Star State was enacted on March 8, 1879 entitled "An Act for the preservation of oyster beds, and for protecting the rights of persons to the same, and affixing penalties." Embedded deeply within that bill was the first recognition of private and public oyster beds. Specifically the oyster bill stated that all natural oyster beds in navigable waters were made public. All grounds, whether with or without oysters, in waters not navigable were made the exclusive property of the owners of the adjoining shores. These early riparian rights gave water-front land owners control of all littoral area within 100 yards of the shore's low-watermark. This same law, as it relates to oysters and a property owner's riparian rights - codified in 1925 (Vernon's Ann. P.C., 1925) - still exists today (TPW 1975).

In 1895, acknowledging the rising value of oysters, the state established the Texas Fish and Oyster Commission, and appointed I.P. Kibbe as its first Commissioner. Kibbe subsequently taught himself and Texas oysterman he administered how to cultivate oysters and maintain their proper habitat. By 1904, the industry had leased 4,950 acres of oyster beds, and was shipping out 200,000 barrels of oysters – a high water mark in the state (TGFOC 1929). And Corpus Christi's Nueces Bay – still a prolific oyster haven – reportedly contributed 400,000 gallons of oysters to the state's oyster bounty that same year (TGFOC 1937).

A year later, the state's leased oyster beds grew to 6,486 acres. By all appearances, Texas was on an oyster upswing that was translating into dollars and jobs. But, as in The Chesapeake, oysters were being severely over harvested. As Early as 1907, warnings were beginning to be heard about the supply of Texas oysters unable to meet demand, and Kibbe himself was one of the first to fire a warning shot, "…demand is increasing and prices are increasing and within five or six years there will be scarcely enough to supply the state."

Sounding the Oyster Alarm Early On…

Dr. William Brooks, with Johns Hopkins University was one of the first to sound the national oyster alarm. In the 1880s, Brooks clearly understood and stated plainly the implications of overharvesting in Chesapeake Bay where oystermen were harvesting 120 million pounds of oyster meat a year, or 17 million bushels saying, "…. history tells the same story. In all waters where oysters are found at all they are usually found in abundance, and in all of these places the residents supposed that their natural beds were inexhaustible until they suddenly found that they were exhausted. Our present system can have only one result – extermination."

Military surveyor Lt. Francis Winslow in 1887 in his report on the waters of North Carolina candidly shared his own oyster overfishing warning… "the beds are rapidly and surely deteriorating from excessive fishing…there can be no doubt that the beds of North Carolina, if they continue to be exposed to an unrestricted fishery and obtain no measure of relief will share the [oyster's] universal fate and be destroyed." And by 1910, Texas - among the last bastions of oyster abundance - was also echoing the oyster alarm as Texas Fish and Oyster Commissioner Wood that year stated flatly, "…the public reefs [of Texas] cannot produce sufficient oysters to supply our increasing population." Wood was certainly correct at the time, but what was not yet clear was that the Texas oyster would soon face a new, unexpected challenge to its ultimate survival – fresh water, or perhaps more accurately, the lack thereof.

All Dammed Up!

Early on, in 1887, as Corpus Christi was finding its footing as a growing community, its leaders recognized the need for a more stable water supply for the city and its residents. City leaders settled on the building of a new saltwater dam located about10-and-a-half miles upstream from the mouth of the Nueces River. The plan was a success, and the saltwater dam was completed by 1913. The much needed reservoir became the major source of water for the flourishing community of 7,000.

By 1926 a new dam – the La Fruta Dam – a 3,000 foot-long earth embankment dam on the Nueces River some 30 miles north of Corpus Christi was under construction. Designed to impound 50,000 acre-feet of water, La Fruta was completed and in use by 1930. Twenty-five years later, in 1955, a new, improved and significantly larger dam – the Wesley Seal Dam – six times the size of La Fruta, just west of the small community of Mathis. Still, Wesley Seal dam was not enough. By 1978 construction began on the Choke Canyon Dam on the Frio River – a significant Nueces River tributary – and was completed in 1982 providing a maximum capacity of 695,000 acre-feet of water.

Nueces Oysters Set for a Deep Downshift

With the damming of the Nueces River, leaders provided a healthy supply of fresh water for residents, agriculture, industry, business, tourism and development in South Texas, but the oyster – the bivalve naturally cleaning the Nueces River and the coastal waters downstream – did not fare quite so well. Slowly, without the saline diluting effect of the river's natural flow, oysters began to disappear. Today there are no more oysters in the lower Nueces River. And the Nueces River Estuary – because there is no longer a natural fresh water inflow – has become a reverse estuary where water flows into the river from Nueces Bay prohibiting the natural exchange of tidal waters from taking place. *

The perfect environment for oysters is found in brackish water along coastal shores in bays and estuaries with optimal salinity levels ranging from 10-30 ppt. (parts per thousand). Fresh water inflow from rivers and streams help to create this balanced environment. There, not only do they grow, but as filter-feeders – each oyster filtering and cleaning up to 50 gallons of water a day – they serve as an essential support for the ecosystem — keeping bays and estuaries clean, and, in turn, supporting a plethora of sea life swimming amid their beds just below the surface.

Between the dams along the Nueces River resulting in increasing salinity levels in the bays, years of over fishing and the dredging of massive amounts of oyster shell from Corpus Christi Bay beginning in 1934 – 160,000 tons a year – for roads and construction history for the oyster was set to repeat the disastrous examples of New York Harbor and Chesapeake Bay.

In 1904 Nueces Bay produced 400,000 gallons of oysters. By the 1930s that number had slipped to 200,000 gallons, with some years no more than 70,000 gallons. Oyster landings in Corpus Christi continued to make a significant contribution to Texas' total oyster harvests, peaking at 23 percent in 1939. The warnings of what was to come, however, were in plain sight, as the Annual Report by The Fish and Oyster Commission concerning Corpus Christi and Nueces Bays in 1937 stated bluntly"….Oystermen overfished the public reefs and they [oysters] probably will never come back…." (Oyster Commission 1932-1950). The oysters simply could not keep up with the pace or the pressure dredging had brought to bear on their beds. And by 1947 – as a result of excessive overfishing – the majority of oyster reefs in Texas lay exhausted and out of oysters. Collectively, the once prolific Texas shores – covered in a seemingly perpetual supply of oysters – had in 1947 produced a mere 38,515 gallons of oysters, or 25,600 barrels.

But in Texas, as in every other state, there had been warnings. The signs were all there…But no one paid attention and the frustratingly, predictable cycle repeated itself.

The most strident voice came from Dr. Paul S. Galstoff of the U.S. Bureau of Fisheries who visited Texas at the request of the state's Game, Fish and Oyster Commission to survey the Commission's experimental oyster beds. Galstoff stated candidly, "…Oyster production in Texas in 1947-48 dropped to a low…mainly as the result of heavy overfishing of the reefs, with no attempt on the part of producers to cultivate and replenish the crop. This was not unexpected… A year ago, I pointed out to producers…that this was to be expected, but they shrugged it off with usual 'Oh there'll be plenty of them [oysters]; it just doesn't look like it now'… There aren't, and there won't be until we establish an oyster industry in the state."

Galstoff went on to say, "…by establishing oyster farms…it may substantially contribute to the rehabilitation and conservation resources of the State which are rapidly approaching annihilation." Might have to change attribution – found some conflicting data on who said this, so am clarifying - but quote is still good. Year was 1947.

**It should be noted that no significant oyster beds exist along the Texas coast below Corpus Christi Bay. This is due to the fact that no fresh water flows into the Lower Laguna Madre between the Nueces River and the Rio Grande.*

A Point of No Return

Fortunately, 1947 did not bring the complete demise of the Texas oyster industry. There has been somewhat of a recovery in the ensuing years with private leasing, seeding and rudimentary farming efforts in leased beds. Initiatives in returning discarded oyster shells to the bays to enhance oyster habitat have gained significant ground in recent years. But in Corpus Christi and Nueces Bays for the once ubiquitous oyster, there was no going back. The oyster was out of time and out of luck.

In Corpus Christi Bay, by 1961 marine biologists reported a few oyster reefs sitting on a meager 565 acres, (less than 1/13 of the 1890 survey), with only one bed considered commercially viable. By 1980, they had all been successfully wiped out. Oysters which had grown and multiplied for thousands of years, and were once so prolific you could cross Nueces Bay on their backs were gone — the same ones that had kept the bays clean, clear and teeming with abundance, had completely disappeared.

History had repeated itself. The cycle of unsustainability was complete and unfortunately Corpus Christi and Nueces Bays were added to oyster casualty list — dredged and harvested to extinction. Today, almost 40 years later, there is not one acre of commercially viable oyster bed to be found anywhere in the shallow waters of Nueces or Corpus Christi Bay.

Bedding on the Future: Oyster Aquaculture in Action

Today Texas sits as the only coastal state nationwide which is currently not part of a renewable, sustainable oyster aquaculture, an aquaculture that is growing and thriving along the Gulf Coast and throughout the entire U.S. Currently the Texas oyster industry contributes $72 million economically to the state's coffers in terms of oyster processing which translates to 33% of the $217 million Texas oysters contribute to the seafood industry on the whole nationwide. Even so, the fact remains Texas oyster beds have been under tremendous pressure with increasing demand on a dwindling supply caused by overfishing, droughts, floods, pollution and natural predators, and time is running out.

"Oysters are on the decline," says Jennifer Pollack, Chair for Coastal Conservation and Restoration at the Harte Research Institute at Texas A & M University Corpus Christi, a solution driven, marine research institution established in 2000 with the generous donation from newspaper publisher and conservationist, Ed Harte. “Unfortunately we have lost 50 to 85 percent of our oyster habitat in Texas and 85 to 91 percent of oysters worldwide. Everyone wants more oysters,” Pollack says thoughtfully, “but the question becomes what is the path forward.”

Certainly, the path forward is a collaborative one with support emanating from an understanding that for the oyster what exists today is not enough. With our current harvesting system and the continued increasing demands on the bivalve, the oyster and the industry as a whole cannot maintain itself in Texas waters at the current level much less potentially increase its output.

“We are at a crossroads,” explains Dr. Joe Fox, Chair of Marine Resource Development, Harte Research Institute,” we can choose to go down the predictable path and fish our oysters out completely along our coastal shores, or we can embrace the underpinnings of oyster aquaculture. By establishing and growing a sustainable oyster aquaculture industry in Texas – one that will allow us to take pressure off our existing oyster beds – oysters can continue to thrive in our bays and estuaries as a vital food source and a valuable economic driver. And in so doing,” Fox says, “we can simultaneously set in motion a practical and attainable path forward on which we can keep our Texas coastal waters clean and clear”

Aquaculture itself – growing or farming in the water – is nothing new. In fact, the practice by which oysters have been grown as a food source was initiated by the Romans as early as the 1st century B.C. What is new is that with a growing population we can no longer sustain our seafood industry and our consumption of seafood without embracing aquaculture. With the

use of aquaculture, oysters are grown in suspended baskets along the shore. They can be easily monitored, moved prior to a hurricane or any other looming natural disaster and essentially be kept out of harm’s way as they mature.

In 2015, according to the National Oceanic and Atmosphere Administration (NOOA), oyster aquaculture production contributed $173 million dollars to the total $1.4 billion aquaculture production nationwide. The Gulf states in that same year produced 23 percent of the nation's aquaculture seafood production compared to the Atlantic coast which produced 41 percent of the total and the Pacific coast, 36 percent.

In 2013, Louisiana contributed $13.3 million to the nation's oyster aquaculture. That same year, Alabama had no oyster farming at all along its shores. However, a short three years later, in 2016, oyster aquaculture statistics reflected 2,698,777 oysters were sold in the state of Alabama with a farm gate value of $1.9 million, and those numbers are continuing to grow significantly.

"I view oyster aquaculture as an economic development opportunity for the state of Texas," says Brad Lomax owner of WaterStreet Restaurants in Corpus Christi, "especially in the very hard hit coastal counties from Galveston down to Rockport. I have visited Alabama, Florida and both Carolinas to see their oyster farms in action. Oyster farming is environmentally beneficial; it creates jobs and produces a delicious, sustainable product. We need to be doing this — raising Texas Oysters in Texas waters to sell in Texas restaurants."

Lomax, a native Texan, who has been shucking and selling Gulf oysters in Corpus since 1983, recently had both of his sons join him in the business. And he says, it is, in fact, his sons and this second generation who are recognizing the long-term beneficial impact of oyster farming.

"Our customers," explains Richard Lomax, Director of Operations at Water Street Oyster Bar, "not only want to know the origin of our menu offerings but also if their food is being harvested using sustainable methods. Frankly," he says candidly, "I'm jealous of restaurants in the Southeastern states. If we had access to Texas oyster farms, we could offer our guests bay-to-table service and at the same time present them with a more consistent, sustainable, locally-grown Texas product."

Lomax, also recently discovered the industry's youth movement is not confined to the retail end of the farmed seafood chain. "When I attended the Oyster Conference South in Decatur Georgia," explains Lomax, "I met growers my age – men and women, often with young families – who are approaching oyster aquaculture with an artistic enthusiasm, similar to the craft beer movement which changed the beverage industry so radically a few years ago. As oyster growers, they are proud of the quality of their product and," he concludes, "they take even greater pride knowing their efforts help relieve the pressure wild harvesting places on our coastal environment."

Texas: The State of Our Beds

"In Texas, overharvesting of our reefs," says Lance Robinson, Texas Parks and Wildlife Deputy Director "has played a role in the oyster industry as well as additional environmental issues, all of which have had a cumulative impact on our oysters and our reefs. Starting with Hurricane Ike in 2008, we lost 50 percent of our oysters in Galveston Bay. Then came the Deep Water Horizon Oil spill in 2010, the drought from 2011 – 2014, creating saltier bays, and finally two major flooding events in 2016 and 2017. Before Ike, 80 percent of the oysters in Texas came from Galveston Bay. Now it's split between Galveston, Matagorda and Aransas Bays."

Robinson explains further: "By bringing oyster aquaculture to Texas we have a unique opportunity to develop a brand new fishery, and we can take some pressure off our existing reefs. The result and benefit of establishing oyster aquaculture in Texas is that we will be able to shift some of the production from our public reefs and we can delay some of the harvest from those reefs. That means," he concludes, "ultimately there will be more oysters and the value of the industry and oysters in Texas will go up."

Today there are approximately 50,000 acres of fishable oyster reefs in the state of Texas, with 2,300 of those acres being privately leased. And there are 549 commercial oyster boat licenses and 465 oyster-boat captain licenses. According to Robinson, the state's oyster beds are constantly being monitored to ensure there are viable oysters of the appropriate size for harvesting, plus there are multiple programs supporting oyster reef restoration.

"There are reef reclamation programs, reseeding of oyster beds and reefs, creation of new beds and collaborative programs to return oyster shell to bays and estuaries, similar to what we did in Corpus Christi with WaterStreet Restaurants and the Port of Corpus Christi," explains Gail

Sutton, Chief Operating Officer with the Harte Research Institute. "The problem is oysters cannot regenerate fast enough to serve our population, the economy, commercial and recreational fisheries and our environment. There are no two ways about it," Sutton says candidly, "in Texas we need oyster aquaculture, and we need it today."

To provide a sustainable path forward, grow the oyster industry and simultaneously keep the bays and estuaries clean and viable for sea life and recreational fishing, it will take everyone working together. By stepping confidently into the shallow waters of oyster aquaculture Texas can reclaim what once was, reduce pressure on natural oyster beds and reefs and bring a new economically impactful and environmentally sound industry to the state's coastal shores, offering significant benefits for all Texans now and for generations to come.