# FINAL REPORT

# Shell Bank: An oyster shell reclamation, storage and recycling program for oyster reef restoration

## CMP Cycle 14 Final Report
## GLO Contract No.: 10-050-000-3746

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## ACKNOWLEDGEMENTS

We would like to acknowledge project partners Water Street Restaurants and the Port of Corpus Christi. The support of these partners was, and continues to be, crucial to the development and execution of this oyster shell recycling program.

## INTRODUCTION

The eastern oyster, *Crassostrea virginica*, is a molluscan bivalve found predominantly along the Atlantic and Gulf coasts, ranging from Canadian to Caribbean waters (EOBRT 2007). Oysters are gregarious, reef-building animals that are most abundant at a depth of 2.4–7.6 m in estuaries and bays, but can exist to depths of 11 m (TPWD 2009). Oysters are an important ecological and economic resource. They create fish habitat, filter and clean bay waters, protect shorelines from erosion, and are a valued fishery resource (Coen and Luckenbach 2000, Grabowski and Peterson 2007). Texas is among the top-three oyster producing states in the U.S., with an estimated 1,239 metric tons and $9.3 million generated in 2009 (NOAA 2009b). Yet, oyster reefs are one of the most threatened marine habitats on earth, with estimates of 85-91% lost globally and 50-80% lost from the Gulf of Mexico alone (Jackson 2008, Beck et al. 2011, Fig. 1). Besides harvesting oysters for food, historical shell dredging for industry and road construction has further altered the volume of oyster shells in Texas bays (Doran 1965), and recent storms such as Hurricane Ike in 2008 have incurred additional losses (McKinley and Crawley 2009).

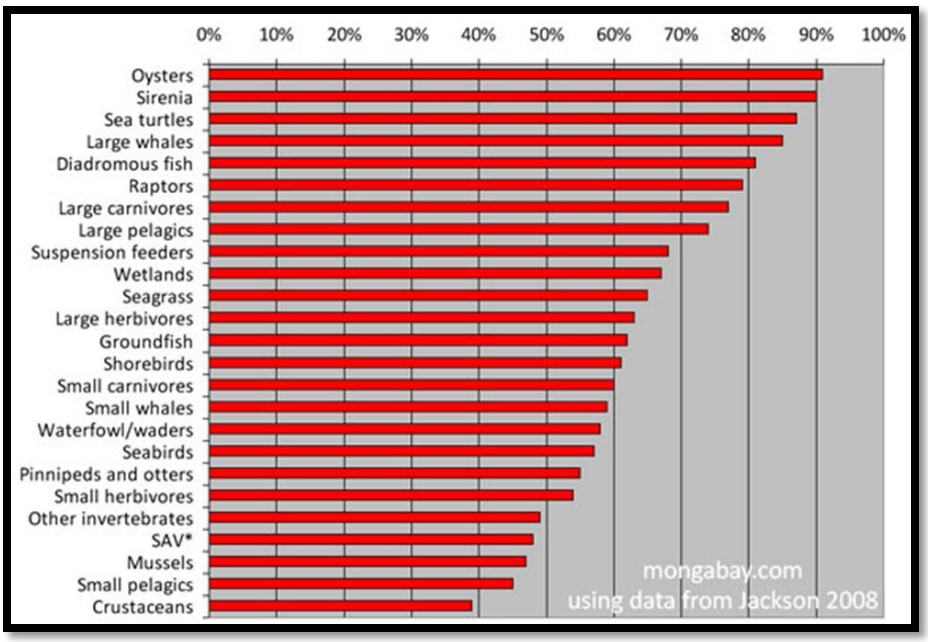


***Figure 1. Percent loss of populations globally in estuaries and coastal seas, compared to a pristine state. Figure from Mongabay.com, using data from Jackson 2008.***

Habitat loss is particularly damaging to oyster populations because of their life cycle (Fig. 2). The eastern oyster is a broadcast spawner, releasing both sperm and eggs into the water column (EOBRT 2007). Within hours of fertilization less than 1% of the eggs develop into planktonic trochophore larva (MacKenzie, 1996). Oyster larvae develop a shell between 12–24 h, becoming a veliger larva. Larvae of this stage remain planktonic for approximately three weeks, then forming a "foot" and becoming a pediveliger. The pediveliger uses its foot to probe for a hard surface; when a suitable substrate is identified, the oyster larva (spat) excretes a cement-like glue to adhere itself to the substratum (EOBRT 2007; NOAA 2009a). Spat can set on most surfaces, but prefer to set on other adult oysters which, in turn, form a reef (EOBRT 2007; TPWD 2009).

In soft sediment bays, such as those in Texas, oysters depend upon the hard shells provided by other oysters to settle and colonize. Thus as oysters are removed for harvest or are lost due to storms or other events, their habitat is reduced.

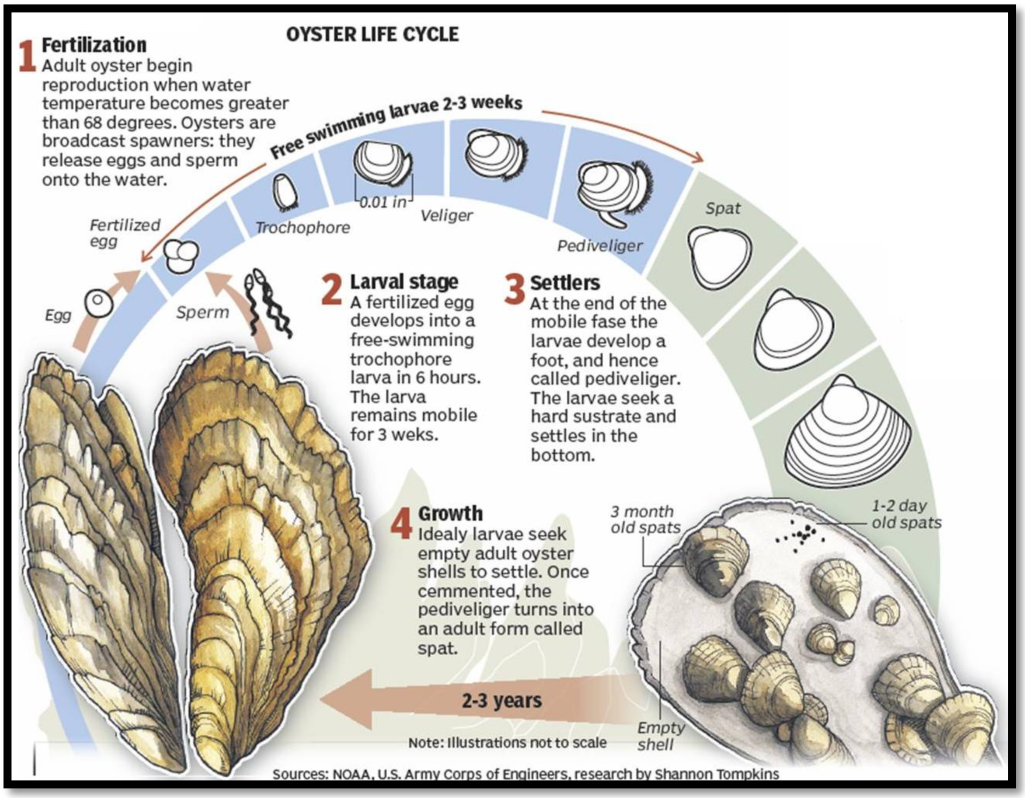


***Figure 2. Oyster Life Cycle. Image from Houston Chronicle.***

Eastern oysters prefer a temperature range of 20–30 C, but can survive at -2–36 C. Oysters close their shell at 4 C until the water becomes warmer (EOBRT 2007; TPWD 2009). Salinity tolerance of eastern oysters ranges from brackish to hypersaline waters (2-40 ppt) (EOBRT 2007) and they are remarkably tolerant to short-term environmental fluctuations, enduring wide ranges in salinity, temperature, and dissolved oxygen (EOBRT 2007; TPWD 2009; NOAA 2009a). The growth rate of oysters is influenced by temperature, salinity, and turbidity of its environment. Reduced turbidity and warmer waters in southern regions allow the oysters the advantage of rapid growth, reaching sexual maturity at seven weeks and harvestable size of 7.5 cm within 18–24 months (MacKenzie 1996; Hargis and Haven 1999).

Reef-building abilities of oysters are unique to an ecosystem. Oysters are often called “ecosystem engineers” because they are the first to colonize niches (Coen and Grizzle 2007). Shell from previous generations cultivates the substrate for future generations, allowing multigenerational procreation and colonization to occur. This method of procreation maintains genetic diversity; therefore promoting the oyster’s recruitment, growth, longevity, and sustainability within an ecosystem (Coen et al. 1999; Coen and Grizzle 2007).

The sustainability of current-day oyster reefs continues to be threatened because there is no mechanism for oyster shells harvested by fishermen to be returned to bay waters. Rather, once oysters have been eaten – most often in restaurants – large quantities of shells are typically discarded. In addition to occupying valuable landfill space, this upland disposal of oyster shell disrupts the natural process of oyster reef growth and regeneration by depriving reefs of their most fundamental building blocks. What's more, oyster reef restoration efforts are often limited by a shortage of available shell material.

## Project Goals and Partners

The Shell Bank Project is an innovative oyster shell reclamation, storage, and recycling program for the Texas Coastal Bend that meets the need for providing shell material for future oyster reef restoration projects. The process is a closed loop and is fairly simple (Fig. 3). First, oysters are harvested from bay waters using a dredge, which removes both live oysters and associated shell material. Next, oysters are sold to restaurants, where they are eaten and the shells are discarded. At this point, instead of allowing the shells to go to the landfill, our recycling program reclaims and stockpiles the shucked shells generated by Water Street Restaurants. Lastly, once enough oyster shells have been reclaimed, the recycled shells are placed back into bay waters to replenish and restore degraded reefs.

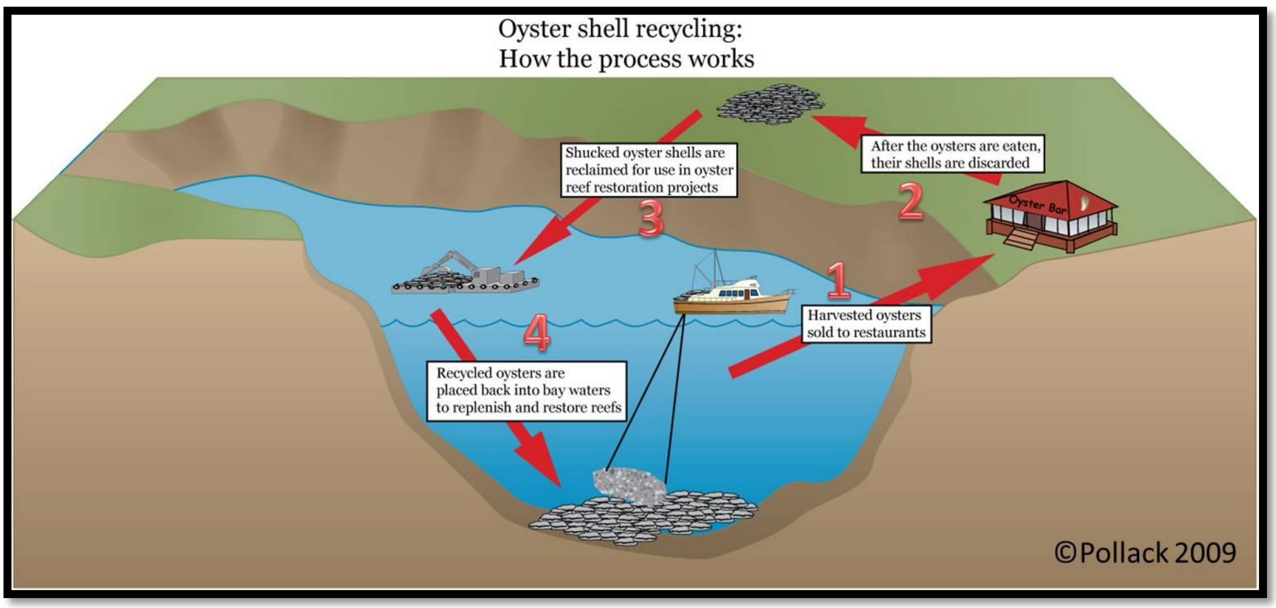


*Figure 3. The four steps of oyster shell recycling. How the process works.*

The goals of the Shell Bank project were to: 1) create the Shell Bank repository for the collection and stockpiling of shucked oyster shell from local area restaurants, 2) identify suitable locations for future oyster reef restoration projects, 3) perform an economic analysis of the Shell Bank, and 4) educate the public and increase awareness of oyster shell recycling.

The Shell Bank Project is a partnership between the Harte Research Institute for Gulf of Mexico Studies at Texas A&M University-Corpus Christi, the Port of Corpus Christi Authority, and Water Street Seafood Company in Corpus Christi, TX.

## SHELL COLLECTING ACTIVITIES

Oyster shell recycling programs are not new – they exist in several other states, including North Carolina, South Carolina, New Hampshire, Maryland and Virginia. Each state has created its own mechanism for reclaiming and stockpiling shucked oyster shells for use in future oyster reef restoration projects. For example, in Maryland, a majority of the shells are generated from catered events such as oyster roasts. In both North and South Carolina, several public oyster shell drop-off sites have been created to serve the large number of recreational oyster fishermen and consumers. In the Texas Coastal Bend, the majority of oysters are consumed in restaurants. Thus, we created a partnership with Water Street Seafood and Water Street Oyster Bar (collectively Water Street Restaurants) in Corpus Christi, to reclaim the estimated 60-70 tons of oyster shell generated each year.

### Shell Bank Repository

Before the oyster shells could be collected, we needed to create a stockpile location for storage and curing of the shells before use in oyster reef restoration projects. Our criteria for the stockpile location was that it needed to be: 1) secure, 2) located far enough from businesses and homes so that the fresh shells would not be a nuisance during the drying process, 3) large enough to allow for storage of large amounts of shell, and 4) cost-effective. To this end, Texas A&M University-Corpus Christi entered into a lease agreement with the Port of Corpus Christi to house the Shell Bank Repository (Fig. 4, 5).

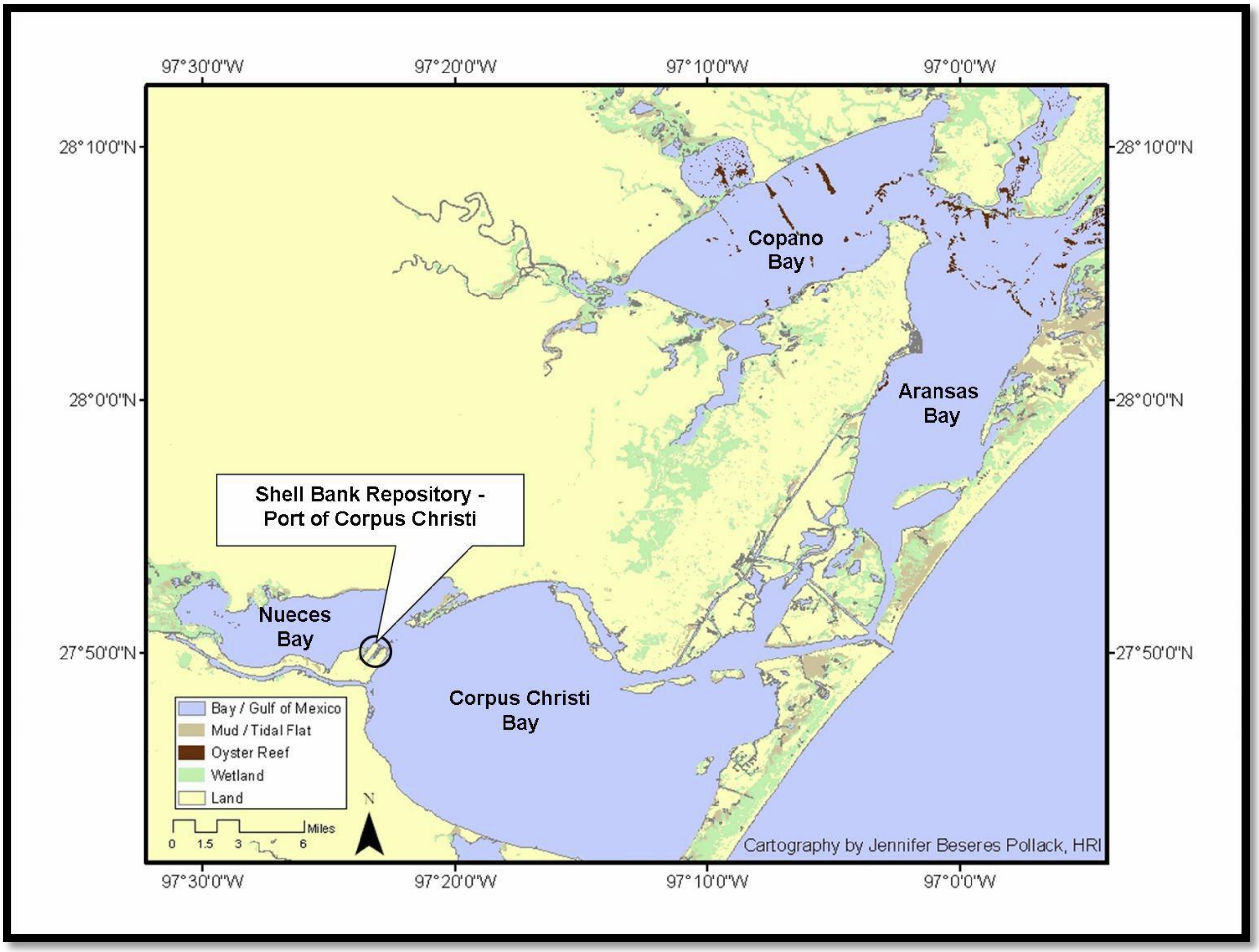


***Figure 4. Location of the Shell Bank Repository on land leased from the Port of Corpus Christi. To the northeast, existing oyster reefs are visible within the Copano & Aransas Bay system.***

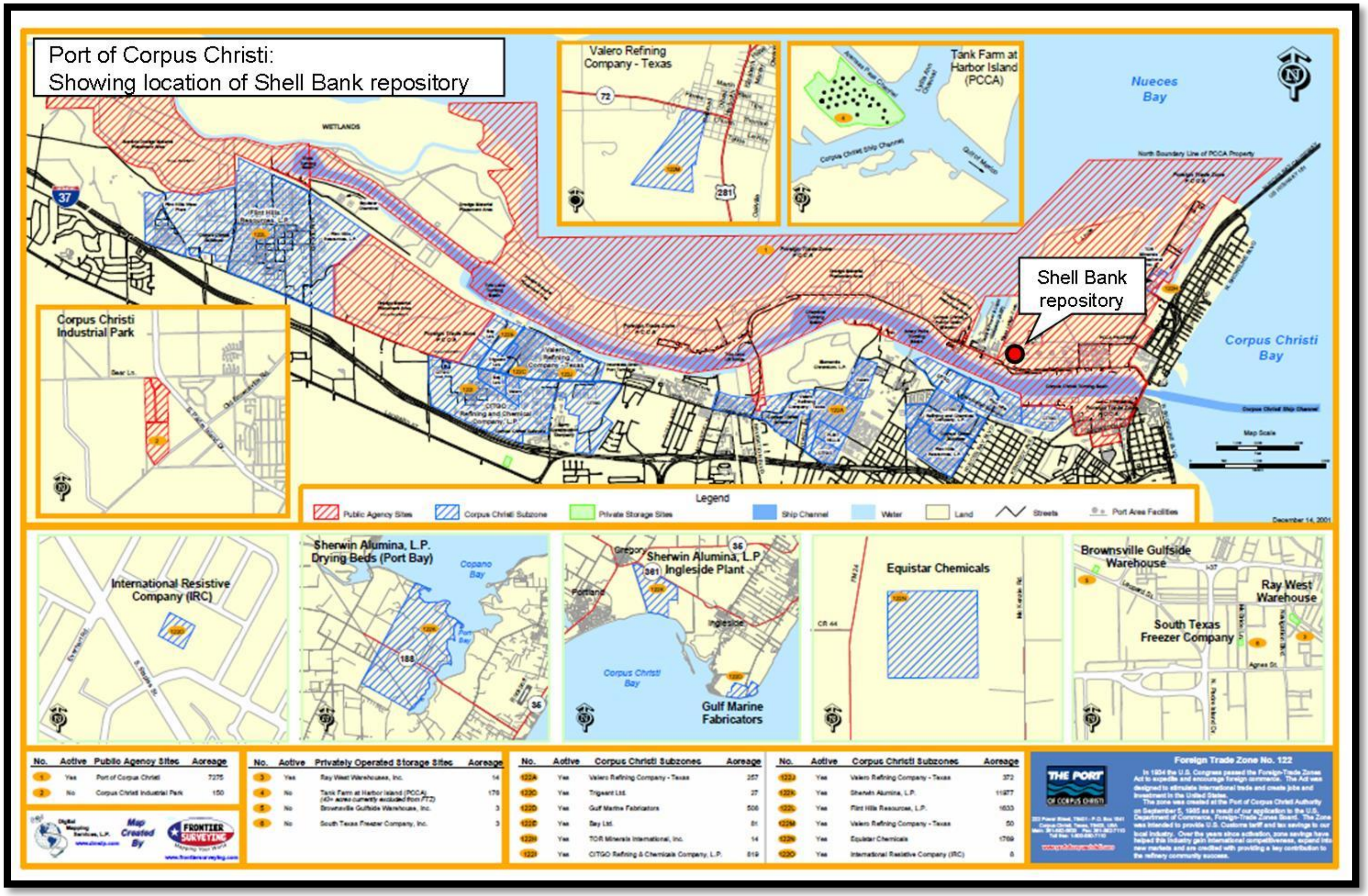


*Figure 5. Location of the Shell Bank Repository on land leased from the Port of Corpus Christi, adjacent to Nueces and Corpus Christi Bays.*

## Oyster Shell Recycling in Action

The Shell Bank program formally launched on November 17, 2009. We announced the launch in a media release (Figure 6) and received press coverage in the local television, newspaper (Fig. 7), and radio stations.

**Media Advisory**

For Immediate Release
November 16, 2009

Contact: Brad Lomax
361.882.2211

Larry McKinney
361.825.2020

***Sink Your Shucks! Water Street Restaurants and Harte Research Institute, Texas A&M University-Corpus Christi Join Forces to recycle oyster shells to build new habitat for young oysters***

*Corpus Christi, Texas....*Water Street Restaurants will kick off its new partnership with the Harte Research Institute, Texas A&M University - Corpus Christi, and the Port of Corpus Christi, to do what nature intended – use oyster shells to provide quality habitat for young oysters. The "Oyster Shell Recycling" program formally launches Tuesday, November 17, at 2:30 at the Water Street Oyster Bar.

This innovative program recycles large quantities of shells that are typically carted off to the landfill and puts them back where they are needed the most – oyster beds providing hard structures for young oysters to attach and grow.

"I am so excited about this project," said Brad Lomax, owner of Water Street Restaurants. "We will easily recycle 60 – 70 tons annually (or about the equivalent of 20 Shamu-sized Killer Whales, give or take a couple of tons). Not only do the young oysters win, but the landfills do as well."

An economic analysis will quantify the benefit. As part of her Masters Thesis, Gail Sutton, Assistant Director of Harte Research Institute, will identify all of the economic activities and determine a net benefit. "We'll take what we learn from this project and share it with key stakeholders to encourage them to take advantage of recycling."

Once collected, the shells will be transported to a storage location at the Port of Corpus Christi. The shells will stay there until the program accumulates a significant volume. The goal is to replace a minimum of an acre of habitat. While the shells are in storage, studies are being conducted to determine the best place to put them back. Areas in Copano and Aransas Bays will be reviewed. And stakeholders, including recreational users, industry, state agencies, and the scientific community, will be asked for their input on the ultimate location for the restoration project.

The Oyster Recycling Program is funded by a Texas General Land Office Coastal Management Plan Grant. Dr. Paul Montanga, Endowed Chair for Ecosystem Studies and Modeling, and Assistant Research Scientist, Dr. Jennifer Pollack, at the Harte Research Institute secured the funding and are directing the program.

*Figure 6. Media advisory announcing official launch of Shell Bank Project.*

Caller-Times

# Local

Section B

MONDAY, JANUARY 11, 2010

Family

HEALTH: Pediatric group changes ca

CHILDREN: Are rewards for kids effec

## Oyster shell recycling could catch on

A&M-CC program helps restore bay reefs

caller.com VIDEO

See part of the oyster recycling process in action.

FANNY S. CHIRINOS

chirinosf@caller.com / 886-3759

The idea started as one business owner's desire to save some money and save space at the local landfill. It grew into a pilot program that might be copied throughout other coastal communities in Texas.

Our Schools

Brad Lomax owns Water Street Seafood Co., among other businesses. On a given week, about 3,000 pounds of oyster shells are thrown out and sent to the landfill, he said.

"It's heavy and it costs us money," Lomax said. "So I talked with my neighbor who works at the Harte Research Institute. He pitched it around and they came up with the plan."

Jennifer Beseres Pollack, an assistant at the institute, said that initial conversation took place about a year ago. Pollack suggested a program popular in South Carolina, where she lived before coming to Corpus Christi.

Please see OYSTERS, 3B

GEORGE GONGORA/CALLER-TIMES

Adam Ersepke (left) and Clinton Witherell dump two containers filled with oyster shells in an area near the ship channel at the Port of Corpus Christi.

### HOW THE OYSTER PROGRAM WORKS

- Water Street Restaurants keep oyster shells in separate bins from the trash.
- Texas A&M University-Corpus Christi undergraduate students pick up the oyster shells on Monday and Friday mornings from Water Street.
- Students load the bins onto flat-bed trucks.
- Bins are hauled to a lay-down area at the Port of Corpus Christi.
- Oyster shells are treated by the sun and wind for about three months.
- Treated shells are stockpiled elsewhere on port property until researchers determine the best place in the bay to place them.

Source: Jennifer Beseres Pollack, Harte Research Institute

OWN A RESTAURANT AND WANT TO PARTICIPATE? Call the Harte Research Institute at 825-2220.

*Figure 7. Article in Corpus Christi Caller Times on January 11, 2010, describing the Shell Bank oyster shell recycling program. A video accompanied this article online, and is available at* ***http://www.caller.com/news/2010/jan/10/new-oyster-shell-recycling-program-could-catch/****.*

Oyster shell collection activities occur 1-2 times per week, depending on the shell volume generated by the restaurants. The collection activities occur using a flatbed trailer purchased using CMP cycle 14 funds and a Harte Research Institute vehicle. On each day of shell collection, two undergraduate student employees drive to Water Street Restaurants, and load 1-4 large bins filled with approximately 400 pounds of oyster shell each onto the flatbed trailer (Fig. 8). The students then drive to the shell repository at the Port of Corpus Christi to deposit the shells into an ever-growing pile (Fig. 9, 10). The students then wash the collection bins and return them back to Water Street Restaurants where they are refilled by restaurant staff (Fig. 11).

*Figure 8. Students securing bins of oyster shells to flatbed trailer. Photo courtesy of George Gongora, Corpus Christi Caller Times.*

*Figure 9. Students securing unloading oyster shells at Shell Bank repository located on land leased from the Port of Corpus Christi. Photo credit: Larry Hyde, HRI.*

*Figure 10.  Shucked shell stored at the Port of Corpus Christi.*

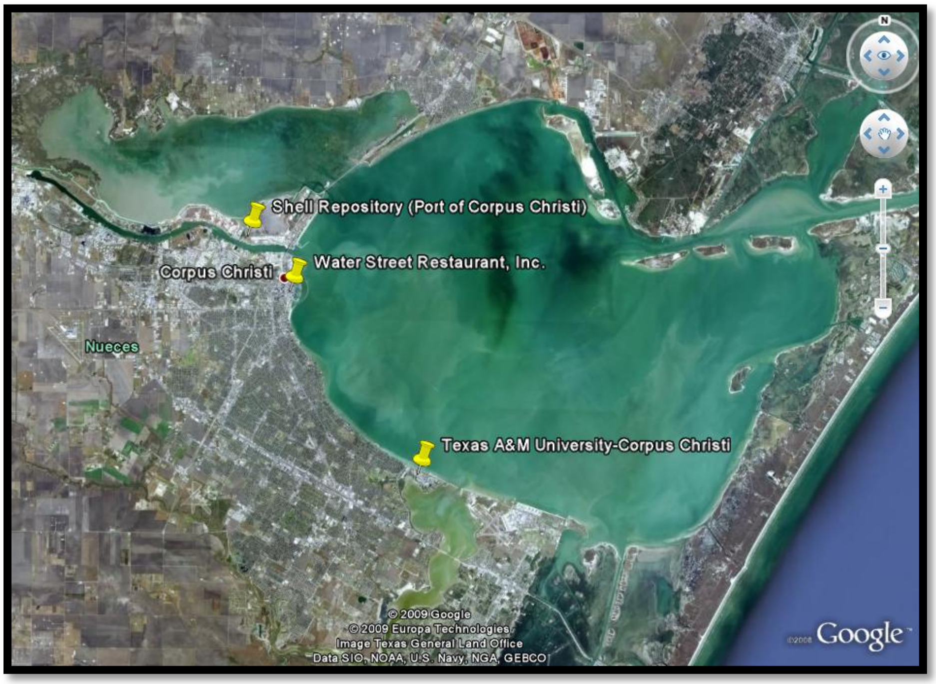


*Figure 11.  Map showing shell pickup location (WSR), shell repository location (POCCC) and TAMUCC.*

Initially, oyster shell collection activities increased steadily each month (Fig. 12). However, on April 20, 2010, the Deepwater Horizon oil spill occurred and was followed by three months of oil being released into the Gulf of Mexico. As a result of this event, oil washed ashore and affected numerous areas of coastal habitat, including important oyster producing regions in Louisiana. The impact of these events was felt at seafood restaurants around the country, and Corpus Christi was no exception. Water Street Restaurants suffered as 1) oysters became unavailable from areas directly affected by the oil spill, 2) fewer oysters were available from other parts of the country, significantly raising prices, and 3) customers were uncertain about consuming Gulf seafood. The oil spill affected Water Street Restaurant oyster sales and as a result, oyster shell collection volumes from May-August 2010. By September, 2010, oyster consumption had begun to increase to pre-spill levels. The total weight of shells collected since November, 2009, is estimated at 139,400 pounds, or 69.7 tons.

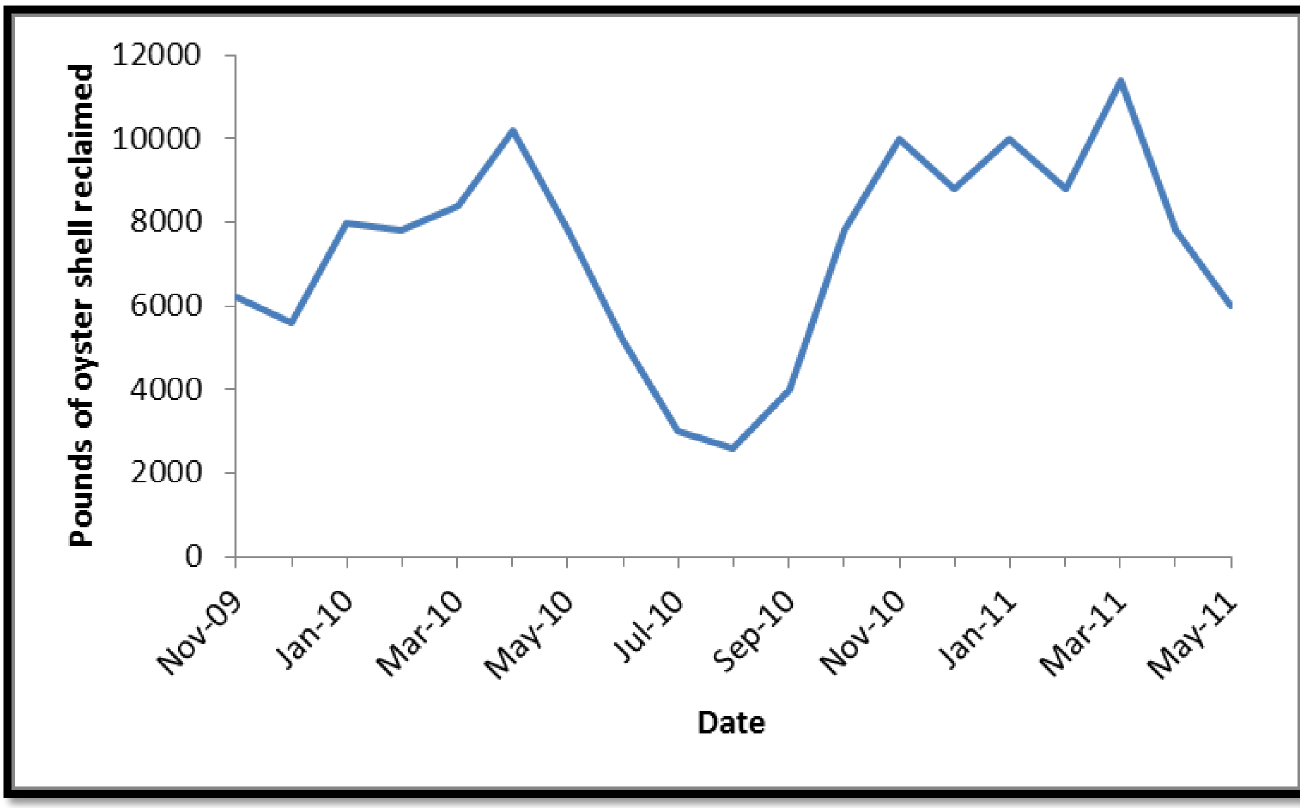


*Figure 12. Monthly weights of reclaimed oyster shells, November 2009-May 2011.*

After collecting the shells, they were deposited into different piles, depending on when they were collected from the restaurants. Therefore, we were able to utilize the piles of shell for restoration that were quarantined for the longest period of time. In determining the appropriate quarantine period, we first spoke with Drs. Dave Bushek, a parasitologist at Rutgers University, and Loren Coen, director of the Sanibel-Captiva Conservation Foundation Marine Laboratory. They were part of a group of authors of a 2004 paper in the Journal of Fisheries Research titled "Quarantine of oyster shell cultch reduces the abundance of *Perkinsus marinus*". As part of this research, they conducted experiments to follow changes in *P. marinus* disease abundance in shucked oysters in shell piles. They found that the amount of oyster tissue and parasite abundance declined sharply after one month and was "virtually eliminated" by three months. We also have been in communication with Lance Robinson and Karen Meador within the Texas Parks and Wildlife Department's Coastal Fisheries Division, and Ryan Fikes with the Gulf of Mexico Foundation, all of who requested a 6 month quarantine period before use in restoration, just to be on the conservative side. Because of these communications, we did not make any shell deposits into the shell pile that was designated for use in the oyster reef restoration project after November 2010. The reef is being constructed in June, 2011; therefore all of the shells in this pile are over 6 months old. When we moved the shells from the stockpile location at the Port of Corpus Christi to Cove Harbor for use in the restoration project, there was no tissue remaining on any of the shells. Therefore it was unnecessary (and impossible) to conduct any disease spot checks of oyster tissue on the clean, sun-baked shells in this pile.

## ASSESSMENT OF LOCATIONS FOR FUTURE OYSTER REEF RESTORATION

We analyzed examined long-term trends of water quality and oyster biology throughout the Mission-Aransas Estuary to identify and prioritize locations for future oyster reef restoration efforts. Long-term data on oyster populations and water quality have been collected by the Texas Parks and Wildlife Department Coastal Fisheries Division Resource Monitoring Program since 1986. We obtained these data for analysis as part of this project.

### Data Collection

Oysters were collected by oyster dredge (0.5 m wide, 5 cm diameter mesh) at 20 randomly selected locations on known reefs throughout the Mission-Aransas Estuary each month. Dredges were towed for 30 s in duration at a speed of 1.3 m $s^{-1}$ for approximately 40 m in distance. At each location, 19 live oysters were randomly selected and measured for shell length. A subset of 5 live oysters was also examined for spat (shell length $\leq$ 25 mm) settlement. The number of dead shells (> 25 mm) in each sample was counted and a subset of 5 shells was also examined for spat settlement. Water quality measurements of salinity, dissolved oxygen, temperature, and turbidity were collected throughout the bay system from January 1975 through April 2009.

Thanks to the efforts of Dr. Sammy Ray, oysters throughout the Mission-Aransas Estuary are examined on a quarterly basis for the presence of *Perkinsus marinus*, a parasite that causes severe oyster mortalities throughout the Gulf of Mexico (Ray 1996). From December 2004 through 2009, ten submarket (26-75 mm) and 10 market-size ($\geq$ 76 mm) oysters were collected from 8 fixed sampling locations on reefs in Copano Bay and Aransas Bay. A section of mantle tissue was removed and incubated in Ray's fluid thioglycollate medium for 2 weeks following the culture method of Ray (1966). Tissue cultures were stained with Lugol's solution and examined under the microscope. The percentage of oysters infected by P. marinus was calculated by dividing the number of oysters infected by the number of oysters tested. Data are available online at www.oystersentinel.org.

In selecting suitable locations for oyster reef restoration, we wanted to identify areas with historically favorable environmental conditions and healthy oyster populations (Table 1). We were interested in environmental factors because they can have strong effects on oyster reproduction, survival, and growth in estuarine ecosystems (Prytherch 1928; Butler 1949). In particular, the combination of high salinity and temperature increases oyster mortality due to disease (e.g., *Perkinsus marinus*) and predation (e.g., crabs, oyster drills) (Gunter 1955; Garton and Stickle 1980; Andrews and Ray 1988; Chu et al. 1993).

*Table 1. Principal oyster health and water quality metrics used to identify suitable locations for oyster reef restoration in the Mission-Aransas Estuary*

| Oyster health metric | Preferred level | Water quality metric | Preferred level |
|---|---|---|---|
| **Live oyster abundance** | High | Salinity | Moderate |
| **Disease** | Low | Temperature | Moderate |
| **Spat abundance** | High | Dissolved oxygen | High |

## Spatial Analysis

Environmental measurements were input into a Geographic Information System (GIS; ArcGIS 9.2, ESRI) and spatially interpolated over the area of the estuary using kriging. This method uses variable values in a spatially explicit sample to predict values at unobserved locations (Little et al. 1997). Map layers were created using a 2-minute cell size for mean and standard deviation of salinity, dissolved oxygen (mg/L), temperature (°C), and turbidity (NTU) (e.g. Figs 13-15).

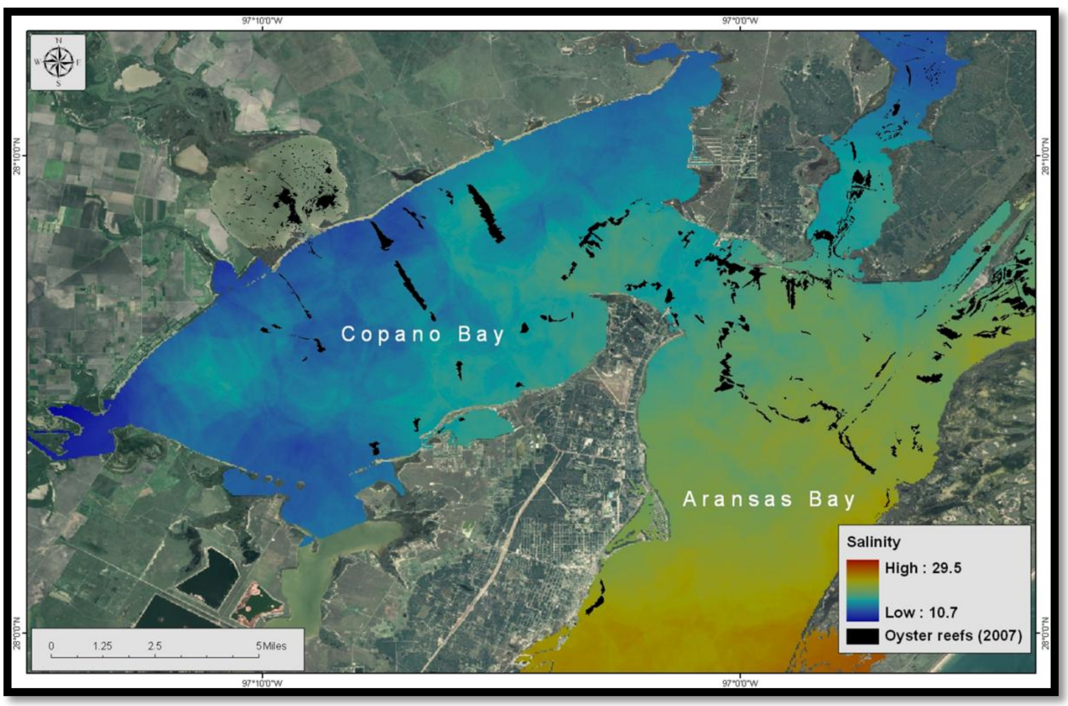


*Figure 13. Predicted mean salinity throughout the Mission-Aransas Estuary, TPWD data from 1975-2009.*

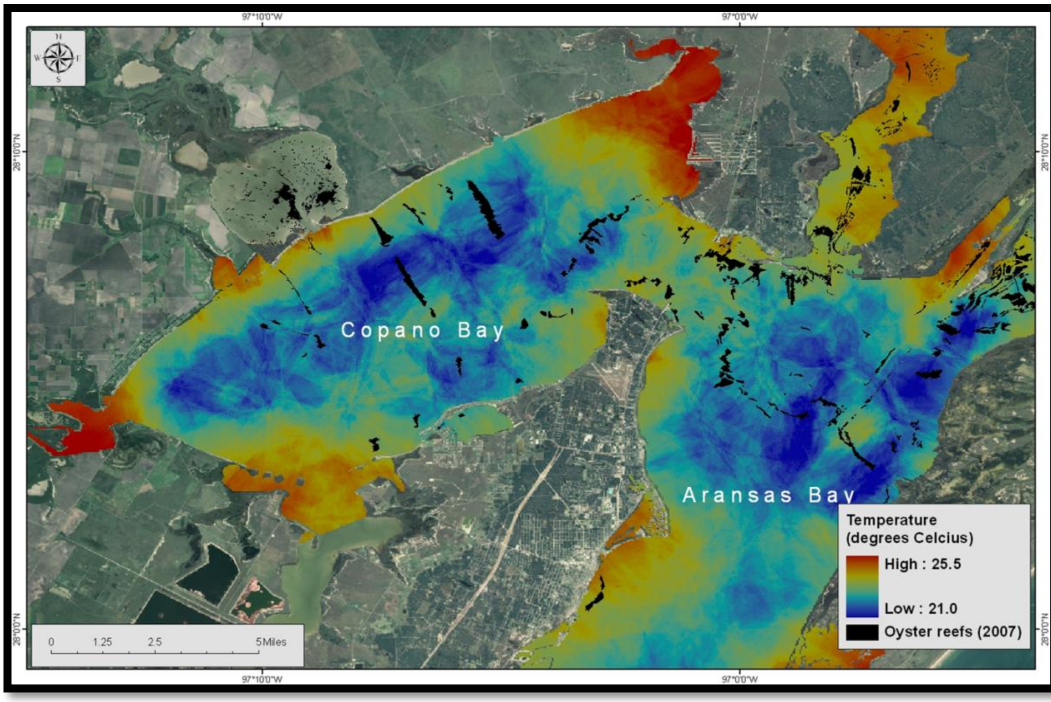


*Figure 14. Predicted mean temperature throughout the Mission-Aransas Estuary, TPWD data from 1975-2009.*

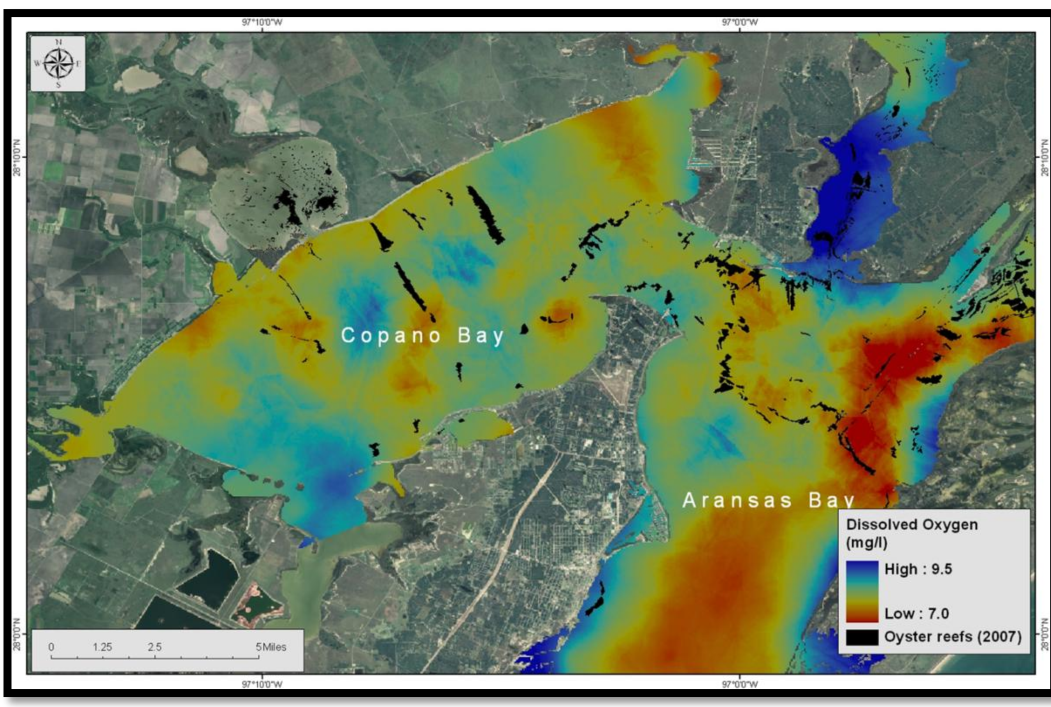


*Figure 15. Predicted mean dissolved oxygen throughout the Mission-Aransas Estuary, TPWD data from 1975-2009.*

Oyster data (except for disease) were also input into a GIS.  Each point was assigned to the closest reef polygon.  Map layers were created for mean and standard deviation of abundance of live oysters (> 25 mm shell length), dead shell (> 25 mm shell length), and spat (< 25 mm shell length) (e.g. Figs 16, 17).

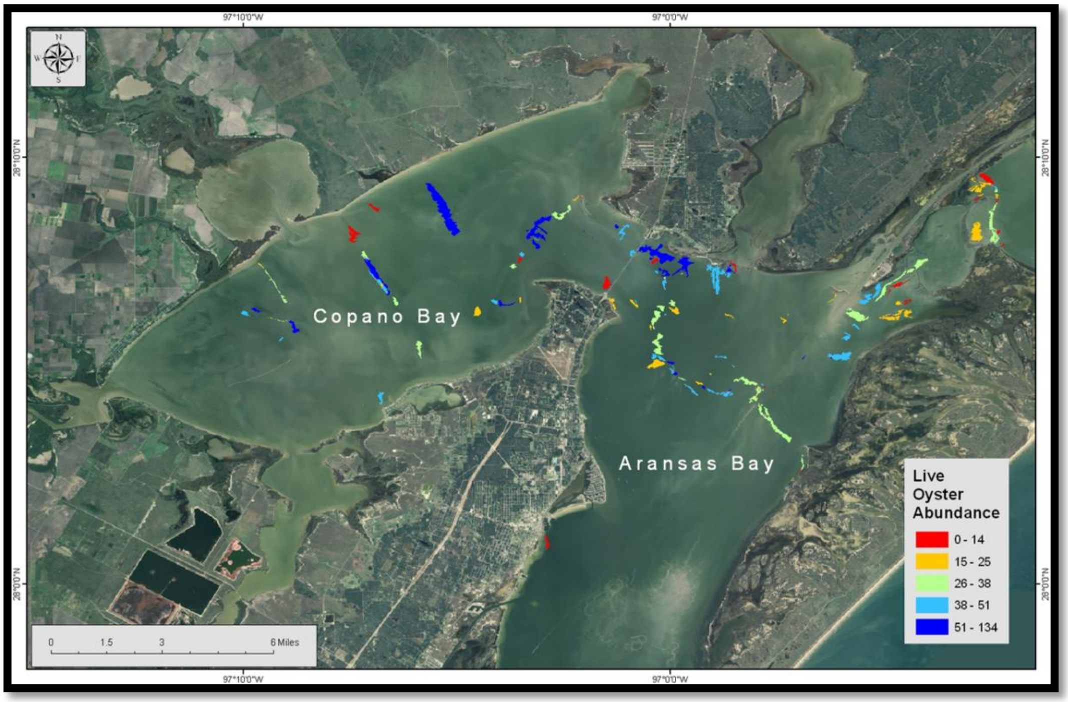


*Figure 16. Predicted live oyster abundance on oyster reefs throughout the Mission-Aransas Estuary, TPWD data from 1986-2009.*

Lastly, oyster disease data collected from fixed sampling locations throughout the Mission-Aransas Estuary were input into a GIS.  Data were displayed using a bubble plot where the relative size of the bubble indicates the mean percentage of oysters infected with *Perkinsus marinus* (Dermo) disease (Fig. 18).

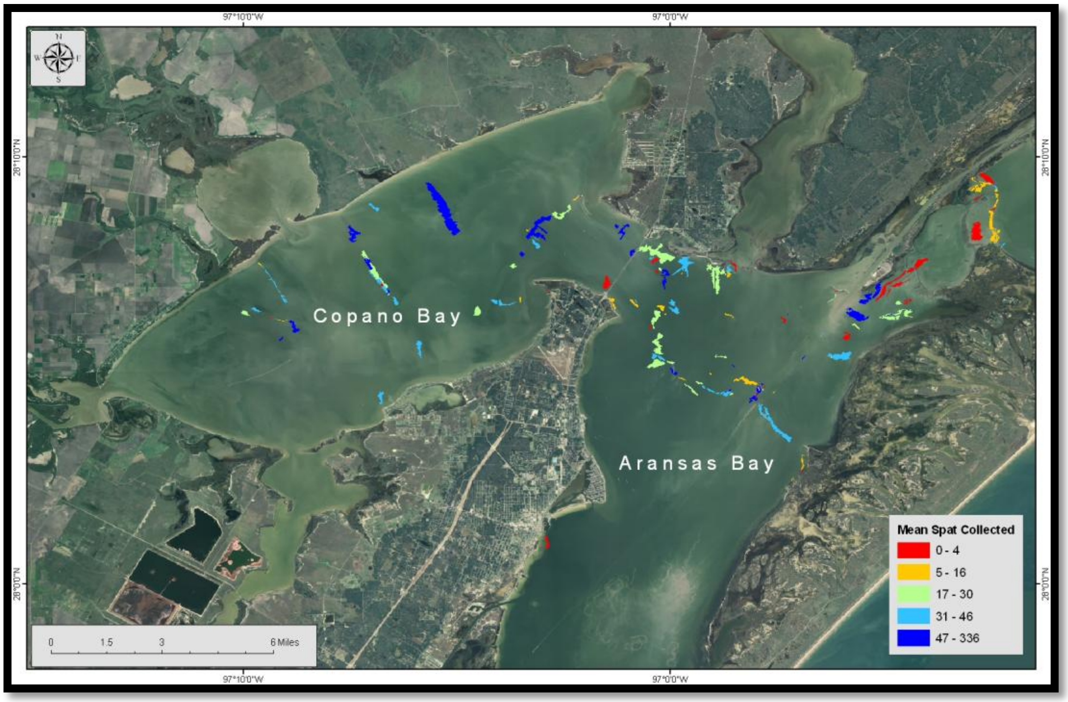


*Figure 17. Predicted mean number of spat (oysters <25 mm shell length) on oyster reefs throughout the Mission-Aransas Estuary, TPWD data 1986-2009.*

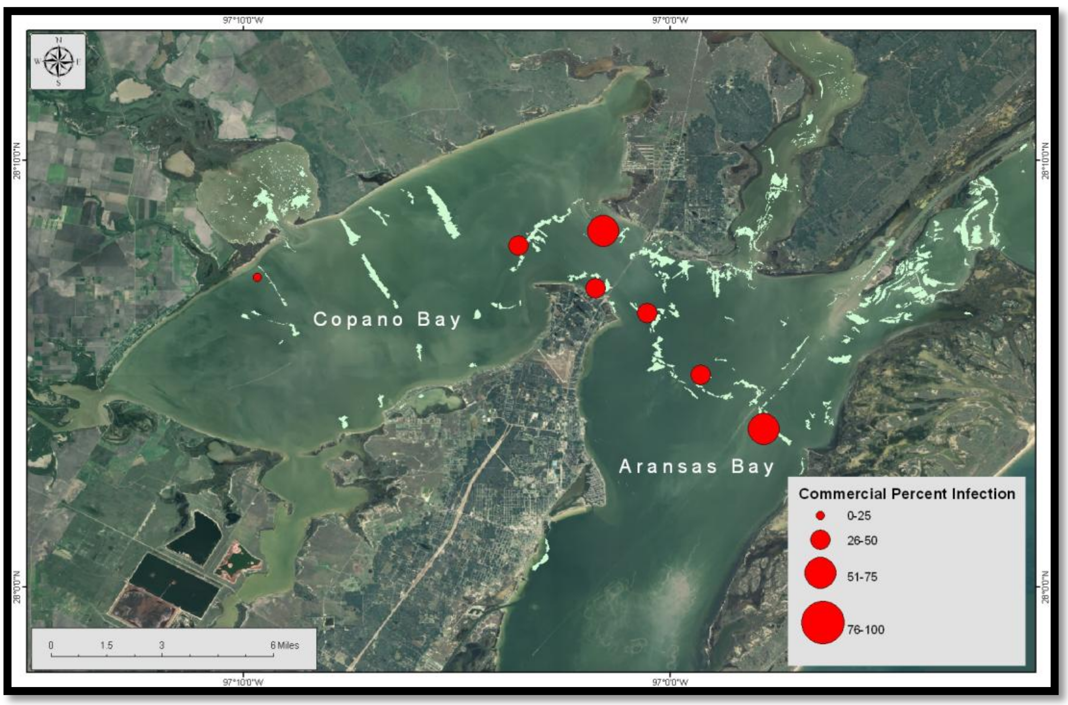


*Figure 18. Percent of commercial-sized (>75 mm shell length) oysters infected with Perkinsus marinus (Dermo disease), Oyster Sentinel data 2004-2009.*

Water quality data were reclassified from nominal to interval values because of the different units used to measure each parameter. The water quality map layers were then integrated using the weighted sum operation.

An index of oyster reef quality was derived using the following equation:

$$\frac{Mean\ \#\ live\ oysters}{Mean\ \#\ dead\ oysters} \times Mean\ \#\ spat$$

The resulting reef health map layer was then overlaid on the water quality map layer to create an integrated prediction map for prioritizing areas suitable for oyster reef restoration (Fig. 19). Based on this information, we selected Lap Reef in Copano Bay as our first location for an oyster reef restoration project using the reclaimed shells collected by this project (Fig. 20). The location was selected due to the optimal oyster reef quality and high water quality for oyster survival and growth.

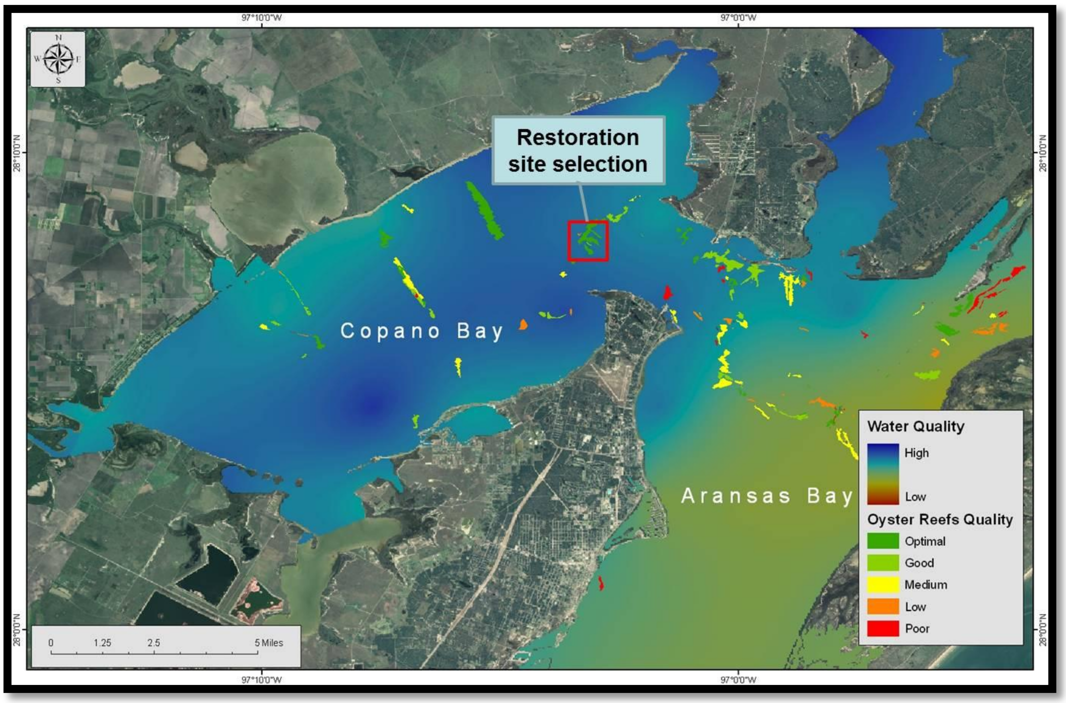


***Figure 19. Integrated prediction map illustrating a range of water quality values for oyster survival and growth and a range of oyster reef quality values. Also denoted is an area selected for future oyster reef restoration using reclaimed shells.***

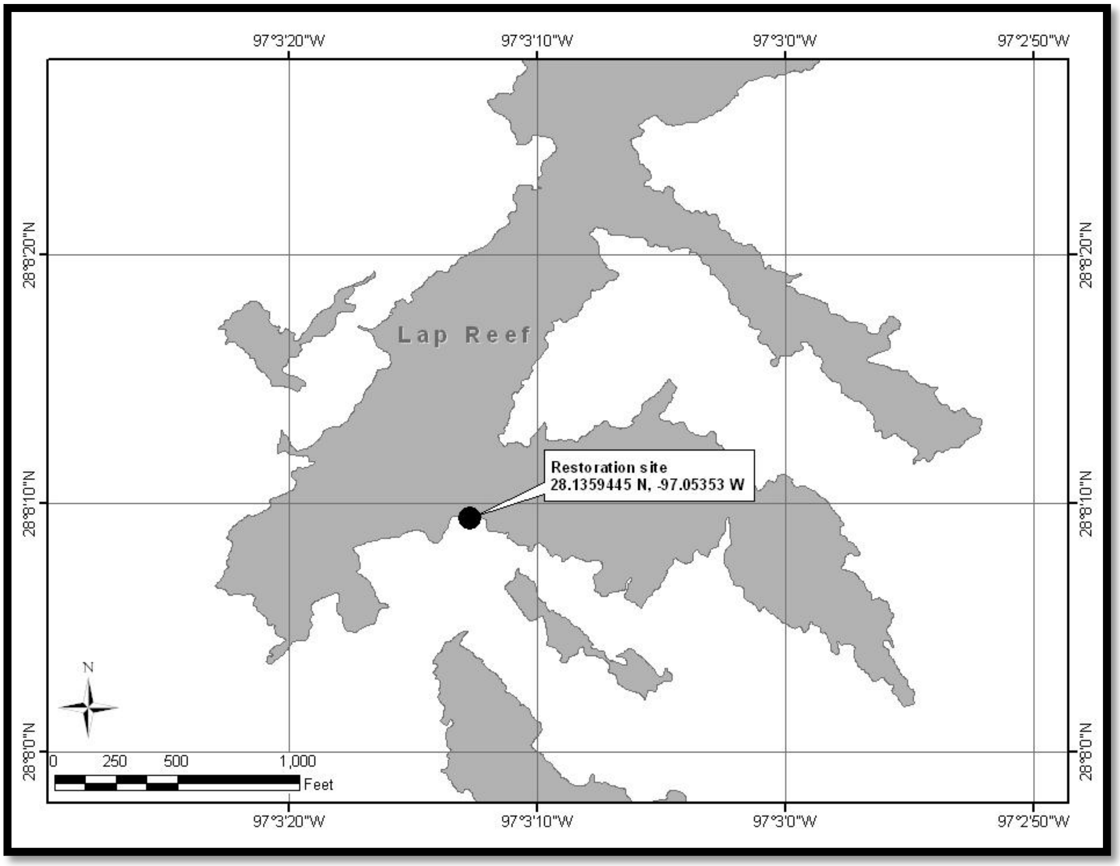


*Figure 20. Close up view of Lap Reef and the location selected for future oyster reef restoration using recycled oyster shells.*

## ECONOMIC ANALYSIS OF OYSTER SHELL RECYCLING

Due to the increase in knowledge regarding the role of oyster reefs in coastal ecosystems, world-wide restoration activities have escalated. In recent years, the NOAA Restoration Center has helped to restore more than 60 acres of actual oyster reef, accomplished through 75 projects in 15 states (NOAA 2009a). Oftentimes, restoration occurs simply by placing shucked oyster shell into an area known to have sufficient spat for successful colonization. Through monitoring, these projects have been found to be structurally and functionally successful in terms of biological integrity (NOAA 2009a); however, most projects are not economically assessed. It is often quite difficult to evaluate the economic impact of an oyster reef restoration project due to the non-quantifiable benefits (Thachappilly 2009).

Cost benefit analysis is a process designed to assist decision makers in weighing the benefits against the costs of different alternatives. This form of economic analysis was pioneered by the U.S. government to evaluate infrastructure projects that are public in nature and to determine if the government should intervene rather than allowing the status quo (Thachappilly 2009). Analysis begins with establishing objectives and identifying alternatives. Each alternative is evaluated on its individual merit. Finally, all alternatives are evaluated and compared to determine which alternative meets the objectives set forth at the onset of the project (Shively and Galopin 2009).

This study will focus on the economic implications of oyster shell reclamation and reef restoration by conducting a cost benefit analysis on the collection of shucked oyster shell from local restaurants and wholesalers.

### Objectives

The objectives of this study were: 1) to identify alternative uses of shucked oyster shells; 2) to determine the costs and benefits associated with the various alternatives; and 3) to prepare a cost-benefit analysis.

### Materials and Methods

#### *Study Locations and Logistics*

Studies were conducted at three locations: Texas A&M University-Corpus Christi (TAMUCC), Corpus Christi, Texas, Water Street Restaurants, Inc. (WSR), Corpus Christi, Texas, and the Port of Corpus Christi (POCC), Corpus Christi, Texas.

During the time period the oyster shells were collected and stored, an economic assessment of the program was begun. This assessment identified various alternatives of use for the collected shells and determines the cost benefit for each alternative.

#### *Analytical Methods*

To assess the economic viability of the reclamation and restoration of shucked oyster shells, a cost/benefit analysis was performed. In this study a matrix was developed to list all pertinent data: alternatives, costs, and benefits. The first step in the cost benefit analysis was to identify alternatives. Any recommended alternatives from this point were then evaluated from a technical and operational perspective. The following questions were explored with each alternative identified:

- What is the organization's objective?
- What would be operationally efficient?
- What would reduce operational costs?

After all feasible alternatives were determined, the costs and benefits associated with each alternative were calculated. Both quantifiable and non-quantifiable costs and benefits were assigned a value. If no direct dollar value could be assigned, value was assigned in terms of estimates and trade-offs. When a value assigned was based on a future date it was then discounted to find the present value. The assigned values of all costs and benefits were categorized in the matrix.

Major cost categories included the following: start-up costs (e.g., personnel, equipment, acquisition costs), operational costs (e.g., personnel, equipment, transportation, daily operating costs), non-recurring costs (e.g., one-time costs, attorneys, environmental studies) and capital investment costs (e.g. land, large equipment). The major benefits categories consisted of non-recurring benefits, cost reductions, value enhancement, other benefits, recurring benefits and non-quantifiable benefits.

The cost/benefit summary compares each alternative over the life of the program based on calculations derived from the matrix. This summary was used to determine the most efficient alternative use of shucked oyster shell. This information was used to provide recommendations to stakeholders to assist with the management of this resource and meet their objectives.

***Determining Alternatives***

The owner of WSR stated his primary reason for participation in this project was to identify an alternative to disposal of his shucked oyster shell in the municipal solid waste landfill while simultaneously lowering disposal costs. The premise adopted by the owner was that any savings, large or small, would add to the overall profit of the business. Historically, WSR oyster sales are the second largest selling food item in WSR restaurants producing 205,920 pounds of shucked shells in 2009 (Lomax, personal communication). The secondary incentive for participation was to eventually return oyster shells to native waters, essentially treating oyster them as a "resource out of place." The owner previously attempted to sustain a company-managed oyster shell recycling program, but discontinued it due to the excessive amount of time and effort required (Lomax, personal communication).

The alternatives available to the restaurant to dispose of the shucked shells included: 1) continued disposal of shucked shell in commercial waste, 2) stockpiling and resale of shell for alternative uses, or 3) reclamation of shell for reuse. WSR did not have the capacity or desire to stockpile shell for resale; therefore, alternative 2 was eliminated. This study evaluated the cost benefit of disposing of shucked shell from WSR via the current commercial waste system versus collection and relocation of shell by TAMUCC to a repository (Shell Bank).

***Determining Cost of Alternatives***

After all feasible alternatives were identified, costs associated with each were calculated for the period of 1 November, 2009, through 1 November, 2010, and are shown in Table 1. Costs of Alternative 1, commercial waste disposal of shell, were estimated using a cost structure provided by WSR and the number of live oysters sold during the study period (Table 1). WSR was unable

*Table 2. Total costs for project from 01/11/2009-01/11/2010.*

| Costs (USD) | Alternative1- Disposal | Alternative 2 - Reclaim |
|---|---|---|
| | | |
| **Start-up Costs** | | |
| **Labor Costs** | | |
| **TAMUCC** | 0 | 6,624 |
| **WSR** | 0 | 0 |
| **Website, Printed Materials** | 0 | 6,793 |
| **Supplies** | 0 | 210 |
| **Operational Costs** | | |
| **Labor & Benefit Costs** | | |
| **TAMUCC** | 0 | 5,642 |
| **Restaurants** | 1,100 | 1,100 |
| **Bins** | | |
| **TAMUCC** | 0 | 2,195 |
| **Restaurants** | 0 | 800 |
| **Mileage** | 0 | 2,365 |
| **Rental - Shell Repository** | 0 | 600 |
| **Supplies** | 0 | 75 |
| **Disposal Fees** | 1,814 | 0 |
| **Pick-up Fees** | 6,500 | 0 |
| **Non-recurring Costs** | 0 | 0 |
| **Capital Costs** | | |
| **TABLE 1 (cont.) Trailer** | 0 | 1,800 |
| | | |
| **Total Costs** | $9,414 | $28,204 |

to provide data regarding historical labor costs associated with direct disposal of shucked shell; therefore, the amount of $1,100 for labor costs was used, based on the cost estimated for separation of shucked shell (Lomax, personal communication). This was the cost estimated by WSR to separate oyster shells from other uneaten food items and is considered to be conservative. Waste disposal fee for WSR were based on gross weight at pickup, charged at a rate of $40.73 per ton (907.18 kilograms) and $125 for each pickup (Lomax, personal communication) (Table 2). The gross weight of shucked oyster shells was calculated by multiplying the number of live oysters sold during the period of the study by the mean weight of both valves of the eastern oyster shell (150 g) (Newell et al. 2005). To estimate mean weight of oyster shells, 100 shucked shells from WSR were weighed. This resulted in a mean weight of 149.68 g (5.28 oz). The number of disposal pickups used in this comparison was estimated by the shell owner based on the number of historical disposal pickups/week less the number occurring during the project time period.

Alternative 2, reclamation of shell, included actual expenses incurred by TAMUCC during the study period for collecting shucked oyster shell from WSR and depositing it in the Shell Bank (Table 1). Prior to shell collection, TAMUCC secured a five-year lease from the POCC at a rate of $50/month for quarantine and storage of shell. Additionally, a trailer was purchased for $1,800 for the hauling of the shucked shells in collection bins. TAMUCC already owned a vehicle; therefore, the only cost for the use of the vehicle was the federally-approved mileage rate, $0.50 per mile, during the study period (IRS 2011). After reviewing the shell owner's records, it was determined that four collection bins would be necessary for twice-weekly pickup at a cost of $2,196 (total). Covers were also purchased for the collection bins to control the odor and prevent insect infestations due to the proximity to the restaurants. This cost was included with cost of bins. WSR also purchased $800 of special bins for use within the restaurant to prevent accidental disposal of the shells. Miscellaneous supplies were purchased at a cost of $75.

Two undergraduate students were hired at $10/hour to drive the TAMUCC vehicle pulling the trailer for two pickups a week. Collection bins with oyster shell were transported approximately 3.1 miles (one way) to the repository and the shell dumped into mounds. The students would then return to the restaurant, unloaded the collection bins and washed the bins out. After being rinsed out, the bins were returned to the fenced area where they would be available for refilling by WSR. A total of $5,642 in wages and benefits was expended for the two students over the one-year period to collect, transport, and unload the shucked shell.

Start-up costs included salary and benefits for supervision of the students and development of the project. After initiation of the project, students were consistent with their collection schedule making changes to pickup times as needed to meet the restaurant owner’s production levels. In order to educate the public and shell owners about the project, a design company (Three Dimensional Development, L.L.C., Corpus Christi, TX) was hired to design a logo for the project and assist with the layout of a brochure. In December 2010, a website, www.oysterecycling.org, was published with information describing the recycling process for the oyster shells and how the shell would be used after reclamation. This website continues to be updated to include information and education materials for individuals of various age groups. Costs for these tasks have been included within Start-up Costs (Table 2).

After calculating the costs of each alternative, discussions with the shell owner resumed to determine the operational efficiency of the two alternatives and whether operational costs had decreased. WSR experienced some resistance with wait-staff due to additional effort needed to separate the shell and transporting this shell to the collection bins. Another issue involved keeping incidental trash out of the collection bins. Training of the wait-staff on the importance of the project assisted in elimination of trash and the disposing of shell into the commercial waste. On an economic, operational, and technical basis the reclamation of the shucked shells was a success for WSR. Management of this process was not substantially burdensome to daily operations and TAMUCC students and staff did not incur any technical issues with the reclamation of the shell. The shell owner saved money because the project was funded by the Texas General Land Office (TGLO); otherwise, it probably would not have been economically feasible to reclaim the shell (Table 3). To simply throw shucked shells in the trash cost approximately three times less than reclaiming the shell for later use.

*Table 3. Calculated cost to WSR for pick-up of shell and disposal for 2010.*

| Calculations (USD) | Value |
|---|---|
| | |
| **Total Number of Oysters Sold from 01/11/2009-01/11/2010** | 270,000 |
| **Weight of Shucked Oyster Shells in Pounds (# sold x 150 g x.0022)** | 89,100 |
| **Weight of Shucked Oyster Shells in Tons (pounds/2000)** | 44.55 |
| **Cost to Dispose of Shell ($40.73/ton x 44.55)** | $1,814 |
| **Cost of Pick-ups ($125/wk x 52 weeks)** | $6,500 |

Start-up expenses of $13,627 for labor and education related materials were incurred in the first year of the reclamation alternative. There would be no reason to incur those start-up expenses when disposing of the shell as commercial waste. During the one-year study, assets were purchased to move the shell to the shell repository. Normally, costs for the purchase of the trailer and bins would be depreciated over the assets' life expectancy (Lipton et al. 2006), which in this case was approximately five years. Due to the brief nature of the study period (one year), assets could not be depreciated for a longer period (LDWF 2004). Forecasting all expenses and oyster shell production over a five-year period would allow the study to include future periods to reflect the sustainability of the project. Additionally, any forecast of expenses for a longer period should include an inflation rate for wages, goods and services in order to determine any increase in existing costs and production related to the project (LDWF 2004).

Another issue experienced half-way through the collection period was the BP Deepwater Horizon Oil Spill, which occurred 20 April 2010 (OSC 2011). Immediately after the oil spill, WSR experienced several issues that caused their historical oyster sales, second only to shrimp in their restaurant, to fall from 624,000 live oysters in 2009 to 270,000 live oysters for the same period in 2010. WSR attributes this sharp decrease to three factors: limited supply of oysters available from the Gulf of Mexico, high cost to obtain oysters from other areas, and general resultant apprehension of consumers with respect to seafood from the Gulf of Mexico. The oil spill continued throughout the summer months of 2010 with the capping of the oil well occurring in September 2010 (OSC 2011). WSR had difficulty identifying suppliers to meet the remaining demand for oysters in their restaurants. Oysters had to be purchased as far north as Canada at a price three times higher than the normal market rates for oysters coming from Louisiana and Texas (Lomax, personal communication). The greatest amount of shell collected from WSR during the project period was 10,200 pounds in April, 2010, and the lowest was 2,600 in September, 2010, resulting in a 12-month total of 77,600 pounds of shucked shell collected by TAMUCC (Fig. 21). During the same 12-month period in 2009, WSR produced 205,902 pounds of shucked shells based on their purchases of 624,000 live oysters (Table 4).

***Five-year Forecast***

In order to accurately represent the true output of shucked shells by WSR and sustainability of the Shell Bank, a five-year forecast was prepared using the production totals from WSR from 1 November, 2008, to 1 November, 2009 (LDWF 2004). Additionally, the forecast included three scenarios: production and expenses for one restaurant, two restaurants, and three restaurants.

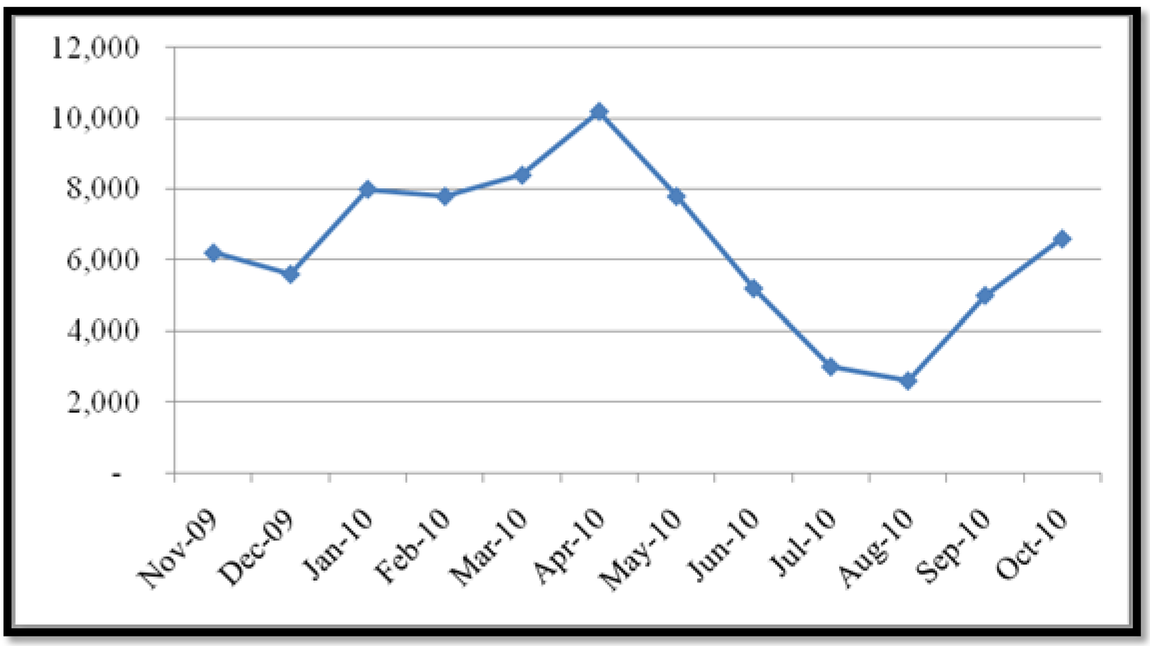


*Figure 21. Total pounds of shucked shell collected monthly from WSR during economic analysis study period.*

*Table 4. Calculations of total shucked shell weight from WSR for 2009.*

| Calculations | Value |
|---|---|
| | |
| **Total number of live oysters sold from 01/11/08-01/11/09** | 624,000 |
| **Weight of shucked oyster shells in Pounds (# sold x 150 g x.0022)** | 205,920 |

Three scenarios were investigated in order to reflect any economies of scale gained and in order to evaluate the long-term sustainability of the program (Willig and Panzar 1977). The analysis also included the non-tax depreciation of the trailer and bins, which spread the costs of these longer-termed assets over the useful life of the asset (Lipton et al. 2006). An inflation factor of 3.55% was used for all labor and benefit costs based on the mean consumer price index for the period of 1990-2010 for State Area and Employment, Hours and Earnings for Corpus Christi, Texas (USBL 2011b). Where appropriate, goods and services were forecasted with an inflation rate of 2.2% based on the mean consumer price index for the period of 1996–2010 for All Urban Consumers within Southern cities class size B/C (USBL 2011a). Appendices 1-2 include all production and expenses for both alternatives that will be discussed below.

Both Alternatives 1 and 2, utilized the figure of 624,000 live oysters sold in one year for one restaurant; hence, this amount doubled for two restaurants and tripled for three restaurants. In Years 2 - 5, the amount of live oysters sold was increased annually by 2.2% for inflation (USBL 2011a). Total labor and benefits for Alternative 1 was estimated at $2,530 for one restaurant, $5,060 for two restaurants, and $7,590 for three restaurants. These base figures were calculated from the labor and benefit values in Table 2, Alternative 1 ($1,100 × 2.3). This factor was derived by dividing the 2009 total of 624,000 live oysters sold by 270,000 in 2010. Labor and benefit costs for Years 2 - 5 were calculated incorporating an inflation rate of 3.55% (USBL 2011b). The labor and benefits for Alternative 1 (waste disposal) were estimated as the cost of WSR wait-staff to remove shucked shells from tables and shucking areas, followed by transport to the commercial waste receptacle. Disposal fees were calculated using the total pounds of shucked shells disposed of by a commercial vendor at a cost of $40.73 per ton (907.18 kg). An inflation rate of 2.2% was utilized in Years 2 - 5 (USBL 2011a). Pick-up fees were associated with cost of transporting the waste receptacle to the sanitary landfill. An average of one pick-up per week during the period in which WSR sold 270,000 live oysters was used to derive 120 pick-ups for 624,000 live oysters sold (Lomax, personal communication). Each pick-up cost $125, resulting in a first year cost for pick-ups of $14,950 for one restaurant, $29,900 for two restaurants, and $44,850 for three restaurants. An inflation rate factor of 2.2% was used for pick-up fees for Years 2 - 5 (USBL 2011a).

As stated above, the amount of live oysters sold and the total pounds of shucked oyster shell was the same for both alternatives in the five-year forecast. Start-up costs included labor for project initiation, hiring and training of students, and outreach. In future periods, labor costs related to project maintenance and supervision of students was included in Operational Costs. The amount of $6,624 for start-up labor and benefit costs was the same for one, two, and three restaurants because the cost was not affected by the number of participants in the program. The Shell Bank Project is the first of its kind in Corpus Christi so the need for a website and printed materials was deemed important in order to educate the public and potential shell donors. Total costs for the graphic design artist, website design and implementation, and the printing of 10,000 brochures was $6,793. A total of $210 of supplies was purchased to use with the printed materials. Labor and benefit costs for TAMUCC for the collection of shucked shells and the supervision of the collectors, totaled $5,642 for one restaurant, $11,284 for two restaurants, and $16,926 for three. Labor and benefits for Years 2 - 5 included a 3.55% inflation factor (USBL 2011b). As stated previously, labor and benefit costs for the restaurants to handle the shucked shells, based on 624,000 live oysters sold, would be $2,530 for one restaurant, $5,060 for two, and $7,590 for three. TAMUCC purchased four collection bins with lids, per restaurant to collect and store the shucked shells until they were deposited at the shell repository. The cost of four bins was $2,196 with a life expectancy of five years. To depreciate the bins over five years the total cost was divided by five and that amount, $439 per restaurant, was expensed to spread the cost of the asset over its life expectancy (Lipton et al. 2006). In Year 3, the amount expensed was increased by 50% to cover any damage or loss and an inflation rate of 2.2% was included to cover any increase in costs (USBL 2011a). The restaurants also purchased bins to collect shucked shells within the restaurant. The cost of $800 per restaurant was similarly depreciated over five years with the third year including a 50% increase to cover damage or loss plus an inflation rate of 2.2% (USBL 2011a). Mileage to pick-up shucked shells at participating restaurants was based on traveling to the center of downtown Corpus Christi where WSR is located. The budget for one restaurant was 45 miles for roundtrip travel from duty point to the restaurant and then to the shell repository. Two restaurants increased the mileage by 25%, therefore the second restaurant was added to the roundtrip. Addition of a third restaurant increased mileage by 50% to reflect the mileage necessary to collect shell at three stops. During the study period the federal approved mileage rate was $0.50 (IRS 2011); however, an inflation rate of 2.2% was also included in Years 2 - 5 (USBL 2011a). In order to stockpile shucked shell for future use it was necessary to find a location in which he shucked shells could cure and not represent a nuisance due to odor and possible insect infestations. As stated above, the POCC leased TAMUCC land to use as a shell repository for $50 per month for five years (fixed rate contract without inflation). The final operating cost was $75 for straps and small containers to store the straps. This cost was not increased by number of restaurants. In Years 3 and 5, additional straps were budgeted for damage or loss with a 2.2% inflation rate (USBL 2011a). The only capital cost incurred was the $1,800 trailer to haul loaded collection bins to the shell repository. For the purpose of this study, the trailer was depreciated in a straight-line manner cost basis method for a period of five years. This trailer could have qualified for a longer life expectancy than five years; however, due to the nominal purchase price five years was considered reasonable (Willig and Panzar 1977). In Year 3, the amount expensed was increased by 50% to cover normal maintenance and repair to the trailer plus an inflation rate of 2.2% (USBL 2011a).

***Determining Benefits for Alternatives***

In order to compare both the quantifiable and non-quantifiable benefits of both alternatives, economic values were assigned and benefits categorized (NOAA 2011b). Benefits of the two previously determined alternatives were separated into the following major categories: non-recurring, cost reduction, value enhancement, other, recurring, and non-quantifiable. As mentioned, Alternative 1 calls for disposal of the shucked shell via a commercial waste vendor. After the oysters are served in the restaurants, the shells would be disposed in a commercial receptacle and hauled to the local landfill. This method of disposing of shucked shells does not provide any definitive non-recurring benefits, whereas reclamation of oyster shell has the potential of non-recurring benefits via the sale of the shell for reuse for road building, construction, chemical production, soil conditioning, and poultry grit (Hargis and Haven 1999). The sale of the oyster shell would be an immediate, non-recurring benefit that could be realized if funding did not come to fruition to reuse the shell. Within the Corpus Christi Gulf coast area, oyster shell sells for $25 per cubic yard before transportation costs (A. Godinch, personal communication). In the Galveston Bay area, the price decreases to $15 per cubic yard before transportation costs (G. Meener, personal communication). Reclaiming the shell from three restaurants over five years and depositing it in the repository would provide an immediate value of $61,175, as shown in Table 5, for three restaurants based on local prices in Corpus Christi Gulf Coast area.

Cost reduction was one of the shell owner's primary purposes for volunteering for this project. In Table 2, the one year assessment of the project did reveal the easiest, most cost effective method for disposing of the shell was to continue putting the oyster shell in the commercial waste system. In 2010, restaurants nationally averaged a pre-tax profit margin of only 3.5% making cost savings very important to the bottom line profit of restaurants (Deloitte and Touche 2010).

The first year of the five year forecast the commercial disposal method was more cost effective than the reclamation method, $21,674 and $25,798 respectively (Appendix 1 and 2). This was primarily due to the start- up costs for the reclamation project, which included graphic design and printing costs for education and outreach (Appendix 2). Over the five year period the total cost for commercially disposing of the shell totaled $341,980 versus $191,682 to reclaim the shell at a repository (Tables 6-8). Therefore, the cost reduction benefit for commercial disposal of shell begins with a savings, but from one year to the next the budget grows at a mean rate of 2.5% per year (Appendix 1). Whereas the reclamation alternative realized economies of scale (Willig and Panzar 1977); as more restaurants were added to the forecast the costs slightly dropped in year two, were stable in years three and four, and were slightly higher in year five for an mean growth rate of -2.6% (Appendix 2). Commercial disposal of the oyster shell does not translate into a cost reduction benefit unlike the process of reclaiming the shell. The value of the cost reduction benefit for reclaiming the shell is the cost differential between disposing of the shell versus reclaiming the shell ($341,980 - $191,682 = $150,298)

***Table 5. Calculations for the value of all shell collected over five years for one, two, and three restaurants.***

| Values | 1 Restaurant | 2 Restaurants | 3 Restaurants |
|---|---|---|---|
| | | | |
| **Year 1- Pounds of Shell Collected** | 205,920 | 411,840 | 617,760 |
| **Year 2- Pounds of Shell Collected** | 210,450 | 420,900 | 631,351 |
| **Year 3- Pounds of Shell Collected** | 215,080 | 430,160 | 645,240 |
| **Year 4- Pounds of Shell Collected** | 219,812 | 439,624 | 659,436 |
| **Year 5- Pounds of Shell Collected** | 224,648 | 449,296 | 673,943 |
| **Total Shell Collected** | 1,075,910 | 2,151,820 | 3,227,730 |
| | | | |
| **Total Cubic Yards (lbs/1,319)** | 816 | 1,631 | 2,447 |
| | | | |
| **Total Value Shell (cu yd x $25 USD)** | $20,400 | $40,775 | $61,175 |

*Table 6. Cost benefits analysis for disposing of the shucked shell via commercial waste for three restaurants over five year period.*

| Costs (USD) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| **START-UP COSTS:** | | | | | |
| **Labor Costs** | | | | | |
| **TAMUCC** | 0 | 0 | 0 | 0 | 0 |
| **Restaurants** | 0 | 0 | 0 | 0 | 0 |
| **Website, Printed Materials** | 0 | 0 | 0 | 0 | 0 |
| **Supplies** | 0 | 0 | 0 | 0 | 0 |
| **OPERATIONAL COSTS:** | | | | | |
| **Labor & Benefit Costs** | | | | | |
| **TAMUCC** | 0 | 0 | 0 | 0 | 0 |
| **Restaurants** | 7,590 | 7,859 | 8,138 | 8,427 | 8,727 |
| **Bins Depreciated** | | | | | |
| **TAMUCC** | 0 | 0 | 0 | 0 | 0 |
| **Restaurants** | 0 | 0 | 0 | 0 | 0 |
| **Mileage** | 0 | 0 | 0 | 0 | 0 |
| **Rental - Shell Repository** | 0 | 0 | 0 | 0 | 0 |
| **Supplies** | 12,581 | 13,140 | 13,429 | 13,725 | 14,027 |
| **Disposal Fees** | 44,850 | 45,837 | 46,845 | 47,876 | 48,929 |
| **Pick-up Fees** | 0 | 0 | 0 | 0 | 0 |
| **Non-recurring Costs** | 0 | 0 | 0 | 0 | 0 |
| **CAPITAL COSTS:** | 0 | 0 | 0 | 0 | 0 |
| **Trailer Depreciated** | 0 | 0 | 0 | 0 | 0 |
| **Total Costs Future Value** | 65,021 | 66,836 | 68,413 | 70,028 | 71,682 |
| **Total Costs Present Value** | 65,021 | 65,526 | 65,756 | 65,989 | 66,223 |
| **BENEFITS:** | | | | | |
| **Non-recurring** | 0 | 0 | 0 | 0 | 0 |
| **Cost Reduction** | 0 | 0 | 0 | 0 | 0 |
| **Value Enhancement** | 0 | 0 | 0 | 0 | 0 |
| **Other Benefits** | 0 | 0 | 0 | 0 | 0 |
| **Recurring** | 0 | 0 | 0 | 0 | 0 |
| **Total Benefits Future Value** | 0 | 0 | 0 | 0 | 0 |
| **Total Benefits Present Value** | 0 | 0 | 0 | 0 | 0 |
| **Present Value Discount Rate** | 2% | | | | |
| **Present Value Denominator** | 1.00 | 1.02 | 1.04 | 1.06 | 1.08 |
| **COMMERCIALLY DISPOSED SHELL:** | | | | | |
| **Total Present Value Benefits** | $0 | | | | |
| **Total Present Value Costs** | -$328,515 | | | | |
| **Net Benefit** | -$328,515 | | | | |

*Table 7. Cost benefits analysis for reclaiming and reselling the shucked shell from three restaurants over five year period.*

| Costs (USD) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| START-UP COSTS: | | | | | |
| Labor Costs | | | | | |
| TAMUCC | 6,624 | 0 | 0 | 0 | 0 |
| Restaurants | 0 | 0 | 0 | 0 | 0 |
| Website, Printed Materials | 6,793 | 0 | 0 | 0 | 0 |
| Supplies | 210 | 0 | 0 | 0 | 0 |
| OPERATIONAL COSTS: | | | | | |
| Labor & Benefit Costs | | | | | |
| TAMUCC | 16,926 | 20,403 | 21,128 | 21,878 | 22,654 |
| Restaurants | 7,590 | 7,859 | 8,138 | 8,427 | 8,727 |
| Bins Depreciated | | | | | |
| TAMUCC | 1,318 | 1,318 | 2,005 | 1,318 | 1,318 |
| Restaurants | 480 | 480 | 731 | 480 | 480 |
| Mileage | 3,547 | 3,625 | 3,705 | 3,787 | 4,515 |
| Rental - Shell Repository | 600 | 600 | 600 | 600 | 600 |
| Supplies | 75 | 75 | 75 | 75 | 75 |
| Disposal Fees | 0 | 0 | 0 | 0 | 0 |
| Pick-up Fees | 0 | 0 | 0 | 0 | 0 |
| Non-recurring Costs | 0 | 0 | 0 | 0 | 0 |
| CAPITAL COSTS: | 0 | 0 | 0 | 0 | 0 |
| Trailer Depreciated | 360 | 360 | 360 | 360 | 360 |
| Total Costs Future Value | 44,523 | 34,646 | 36,932 | 36,849 | 38,732 |
| Total Costs Present Value | 44,523 | 33,966 | 35,498 | 34,724 | 35,783 |
| BENEFITS: | | | | | |
| Non-recurring | 11,709 | 11,966 | 12,229 | 12,498 | 12,773 |
| Cost Reduction | 20,497 | 32,190 | 31,481 | 33,179 | 32,650 |
| Value Enhancement | 37,066 | 38,714 | 39,566 | 40,437 | 41,326 |
| Other Benefits | 0 | 0 | 0 | 0 | 0 |
| Recurring | 0 | 0 | 0 | 0 | 0 |
| Total Benefits Future Value | 69,272 | 82,870 | 83,376 | 86,114 | 86,749 |
| Total Benefits Present Value | 69,272 | 81,245 | 80,042 | 81,147 | 80,143 |
| Present Value Discount Rate | 2% | | | | |
| Present Value Denominator | 1.00 | 1.02 | 1.04 | 1.06 | 1.08 |
| SOLD RECLAIMED SHELL: | | | | | |
| Total Present Value Benefits | $391,849 | | | | |
| Total Present Value Costs | $184,494 | | | | |
| Net Benefit | $207,355 | | | | |

*Table 8. Cost benefits analysis for reclaiming and reusing the shucked shell from three restaurants over five year period.*

| Costs (USD) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| **START-UP COSTS:** | | | | | |
| **Labor Costs** | | | | | |
| **TAMUCC** | 6,624 | 0 | 0 | 0 | 0 |
| **Restaurants** | 0 | 0 | 0 | 0 | 0 |
| **Website, Printed Materials** | 6,793 | 0 | 0 | 0 | 0 |
| **Supplies** | 210 | 0 | 0 | 0 | 0 |
| **OPERATIONAL COSTS:** | | | | | |
| **Labor & Benefit Costs** | | | | | |
| **TAMUCC** | 16,926 | 20,403 | 21,128 | 21,878 | 22,654 |
| **Restaurants** | 7,590 | 7,859 | 8,138 | 8,427 | 8,727 |
| **Bins Depreciated** | | | | | |
| **TAMUCC** | 1,318 | 1,318 | 2,005 | 1,318 | 1,318 |
| **Restaurants** | 480 | 480 | 731 | 480 | 480 |
| **Mileage** | 3,547 | 3,625 | 3,705 | 3,787 | 4,515 |
| **Rental - Shell Repository** | 600 | 600 | 600 | 600 | 600 |
| **Supplies** | 75 | 75 | 75 | 75 | 75 |
| **Disposal Fees** | 0 | 0 | 0 | 0 | 0 |
| **Pick-up Fees** | 0 | 0 | 0 | 0 | 0 |
| **Non-recurring Costs** | 0 | 0 | 0 | 0 | 0 |
| **CAPITAL COSTS:** | 0 | 0 | 0 | 0 | 0 |
| **Trailer Depreciated** | 360 | 360 | 360 | 360 | 360 |
| **Total Costs Future Value** | 44,523 | 34,646 | 36,932 | 36,849 | 38,732 |
| **Total Costs Present Value** | 44,523 | 33,966 | 35,498 | 34,724 | 35,783 |
| **BENEFITS:** | | | | | |
| **Non-recurring** | 0 | 0 | 0 | 0 | 0 |
| **Cost Reduction** | 20,497 | 32,190 | 31,481 | 33,179 | 32,650 |
| **Value Enhancement** | 37,066 | 38,714 | 39,566 | 40,437 | 41,326 |
| **Other Benefits** | 0 | 0 | 0 | 0 | 0 |
| **Recurring** | 0 | 0 | 0 | 0 | 0 |
| **Total Benefits Future Value** | 57,563 | 70,904 | 71,047 | 73,616 | 73,976 |
| **Total Benefits Present Value** | 57,563 | 69,514 | 68,288 | 69,370 | 68,343 |
| **Present Value Discount Rate** | 2% | | | | |
| **Present Value Denominator** | 1.00 | 1.02 | 1.04 | 1.06 | 1.08 |
| **REUSED RECLAIMED SHELL:** | | | | | |
| **Total Present Value Benefits** | $333,077 | | | | |
| **Total Present Value Costs** | $184,494 | | | | |
| **Net Benefit** | $148,583 | | | | |

***Cost/Benefit Analysis***

Throughout Asia, the vast quantity of shucked oyster shell has caused these countries to look at various methods of disposal to the point of valorization of prices in order to control the illegal dumping of oyster shell (Barros et al. 2009). Many studies look at the benefits of using shucked oyster shell for composting, liming, and neutralizing phosphates and heavy metals (Jung et al. 2007; Ok et al. 2010).

Oyster shells are 95-99% calcium carbonate by weight making the shell sought after for various applications (Barros et al. 2009; Nakasaki et al. 2007). Oyster shell, like limestone, has been used to control pH and promote microbial activity to assist with organic decay (Nakasaki et al. 2007). Most applications grind oyster shell into pieces or powder for use in composting or soil conditioning (Nakasaki et al. 1993); however, studies indicate the ability of intact oyster shell to biodegrade over time in addition to the microbial activity the shell generates (Islam et al. 2010; Lee et al. 2010). These studies also indicate that shucked oyster shell has a synergistic effect when discarded with other waste byproducts, which has been proven to assist with composting (Nakasaki et al. 1993). This value-enhanced benefit has no quantifiable value; therefore, would be considered a trade-off between adding more waste to the landfill versus potential increased buffering capacity and organic degradation (Lautenbach et al. 2010; Yu et al. 2010). The reverse argument can be made that reclaiming the shell to prevent increased waste at the landfill should also be considered a value-enhanced benefit. Nationally, the amount of waste put into municipal solid waste landfills has grown from 88.1 million tons in 1960 to 243 million tons in 2009 (EPA 2011), of which food scraps comprised 14%.

Public participation in recycling has grown from 5.6 million tons of waste recovered in 1960 to 82.0 million tons in 2009 (EPA 2011). The National Restaurant Association found in a 2010 survey that over half of the adults surveyed were more likely to eat at a restaurant employing green initiatives (Deloitte and Touche 2010). This survey also indicated that green initiatives and the topic of sustainability were not simply a fad, but a long-term trend among restaurant patrons (Deloitte and Touche 2010) and (Obeide et al. 2010). Additionally, 44.7% of those surveyed responded they would pay more for menu items in green restaurants and drive further to patronize a green restaurant (Obeide et al. 2010).

In order to assign a direct dollar value due to oyster shell reclamation being perceived as a green initiative, a value-enhanced benefit, a restaurant owner would need to monitor sales prior to implementation and after the program had been in place for an extended period of time (Obeide et al. 2010). In this case, WSR was unable to assign a value due to the dramatic decrease in sales after the BP Deepwater Horizon Oil Spill (Lomax, personal communication). Assessment of the savings related to shell deposition in the City of Corpus Christi landfill required inspection of the city's annual budget for fiscal year 2009 (CCC 2009). In 2009, the total tonnage deposited at the Cefe Valenzuela landfill was 142,460 tons, resulting in revenue of $16,985,429 ($0.06 per pound of waste). For the purpose of this study, we will assume that the $0.06 per pound for waste deposited at the landfill in Corpus Christi would not decrease from 2009 to 2010. An inflation factor of 2.2% was added to each year thereafter based on the consumer price index (USBL 2011a). If 3,227,730 pounds of shell (Table 4) was not discarded at the landfill, savings to vendors would equate to $197,109 based on the $0.06 per pound figure (Tables 6, 7).

Another important reason WSR participated in the oyster shell reclamation program was their opinion that the shucked shells transported to the landfill represented a resource out of place and could have a positive impact on the environment by being reused in oyster reef restoration (Lomax, personal communication). This study was unable to determine other benefits of discarding the shucked oyster shells at the landfill other than those discussed within non-recurring, cost reduction, value enhanced, or recurring benefits.

Many other benefits of reuse of shucked oyster shell without processing costs exist (Hargis and Haven 1999). The reclamation project associated with this study focuses on reuse of shucked shell for oyster reef restoration. Studies have cited the benefits of oyster reef restoration for water quality, nursery habitat, commercial harvest, recreation, and shoreline stabilization to name a few (Hargis and Haven 1999; Henderson and O'Neil 2003). To derive the economic benefits from an oyster reef and assess a direct dollar value to those benefits is difficult due to the large number of variables within the reef's environment (Beck et al. 2011). The viability of the reef is dependent on many factors including salinity, water temperature, and dissolved oxygen (Hargis and Haven 1999). Until the shucked shell from this study is actually placed in the water, and the reef is monitored to determine the environmental and economic benefits, findings from previous studies must be utilized to forecast any recurring benefits. The U.S. Army Corps of Engineers (USACE) compiled a study in 2003 to quantify the ecological and economic benefits of oyster reef restoration. One primary value that is easily assessed is the oyster production from the restored reef (Henderson and O'Neil 2003). The amount of shell amassed over the five years from three restaurants would total ~3,227,730 pounds (Table 4) and could be used to build a reef approximating 1.5 acres. Using the USACE Virginia Method, which does not provide any costs for maintenance to the reef, the study site might expect to produce 20 bushels per acre per year (Henderson and O'Neil 2003). This amount is insignificant in comparison to the increased biodiversity expected from the restoration project. The USACE study suggests that the restoration of oyster reefs is economically more beneficial to the fish and crab fisheries than to the oyster fishery (Henderson and O'Neil 2003). In 2004, the U.S. National Marine Fisheries Service (NMFS) determined that the value of commercial fisheries was greater in areas with well-established oyster reefs (Haby et al. 2009). The NMFS study determined that 10 $m^2$ of oyster reef that lasts 50 years would increase value of local fisheries of thirteen species by $98.06 per year per 10 square meters (Haby et al. 2009). Restoring 1.5 acres (6,070 $m^2$) would then add $59,522 in value to local fisheries per year once the reef is established. The present study was unable to determine increased value to local fisheries as no reef of this type (i.e., artificial) presently exists.

As stated previously, one of the primary reasons WSR wanted to reclaim the shell was to reduce operating expenses within restaurants (Lomax, personal communication). By discarding the shucked shell in the landfill all expenses cease upon disposal and no future expenses are incurred. Thus, the direct value assigned would be zero because the recurring benefit gained by disposing of the shell is cessation of expenses and liability. Placing the shucked shells in the shell repository also constitutes a liability and resulting in an expense should the shell not be reused or sold (Jung et al. 2007). The profuse odors emitted by the oyster shells during the period the organics are degrading would also limit the shell owners' options for stockpiling shucked shell (Jung et al. 2007). Consequently the recurring benefit for reclaiming the shell, excluding reuse or sale of the shell, is a negative number due to the storage and maintenance costs for the shell repository. In this study those costs are already accounted for in the annual cost structure; thus, the direct value assigned is zero (Table 7).

There are many non-quantifiable benefits related to the reclamation of oyster shell used for reef restoration (Beck et al. 2011). Oyster reef restoration has positive effects on water quality, fishing, recreational activities, and shoreline stabilization (Henderson and O'Neil 2003; Hicks et al. 2004). Direct users of bay waters can benefit from cleaner water due to the ability of oysters to filter large quantities of water, which in turn may improve property values, tourism, and the recreational experience (Henderson and O'Neil 2003; Hicks et al. 2004). The NMFS has stated that fisheries landings are increased by having healthy, productive oyster reefs in the same area (Haby et al. 2009). Anglers in Louisiana took part in a Marine Recreational Fish Statistics Survey by NMF to determine their willingness to pay to maintain the right to fish over oyster reefs (LDWF 2004). The study concluded the anglers would pay $13.21 annually for this right and that 23% of annual marine fishing days occurred over these reefs (Henderson and O'Neil 2003). Another survey performed in 12 counties around Chesapeake Bay found that improved water quality equates to a 20% increase in dollars to the area related to visiting boaters and to the intrinsic value of boat itself (Hicks et al. 2004). Water quality and shoreline erosion can affect the value of property that many communities are utilizing oyster reefs to maintain shoreline stabilization by promoting sedimentation, growth of vegetation, and deflecting waves (Henderson and O'Neil 2003). Prior to starting reef restoration all of these factors must be considered and documented in order to assess and assign a value to the benefits derived (Coen and Luckenbach 2000; Peterson et al. 2003).

The purpose of a cost benefit analysis is to compare all of the anticipated costs and value all of the expected benefits for a proposed project in order to evaluate whether a particular project is worthwhile (Nas 1996). After meeting with WSR, the feasibility of alternatives was first determined after which costs and benefits associated with each alternative were evaluated and direct dollar values assigned. The first issue encountered during the study period was the BP Deepwater Horizon Oil Spill causing oyster sales to drop from the 2009 level of 624,000 live oyster sales to 270,000 live oyster sales in 2010 (OSC 2011). Based on this unexpected drop in sales, all calculations for the cost benefit analysis were based on WSR 2009 oyster sales.

Costs and benefits for both alternatives were entered into the cost benefit spreadsheet allowing values to be totaled and discounted to a present value. Discounting was done in order to assess future cash flows (costs and benefits) in present day values (current dollars) (NOAA 2011b). Limited information was available on what discount rate was most appropriate for this project. A discount factor of 2% was decided upon based on other studies utilizing this factor and the amount being relatively close to the inflation factor for goods and services used for the study area (Nas 1996). Some environmental economists argue that discounting is not applicable to environmental issues because its purpose is to bring costs and benefits back in time similar to a reverse interest rate (Hawkins and Salverda 2011) and that this function can reduce the value of an environmental project very quickly over time if a higher discount rate is used (Heinzerling and Ackerman 2002). The calculation used in this study to discount rates was:

$$d = \frac{F \times n - P}{F \times n}$$

where F is equal to the future value of the cost or benefit, n is equal to the number of year, and P is equal to the present value of cash.

All costs and benefits for the two alternatives identified were discounted to present values so the net benefit of each could be compared. Three values were determined: disposal of shell, reclamation and resale of shell, and reclamation and reuse of shell. The net benefit for the disposal of the shell was a negative amount, -$328,515 (Table 5) and was associated with no quantifiable benefits for disposing of the shell. To quantify any disposal benefits of the shell would require a study to determine the true value of the composting abilities of the shell being discarded at the landfill (Kwon et al. 2004). However, the quantity of shell calculated in one year of this study, 309 tons, was negligible compared to the total volume of waste the City of Corpus Christi places in the landfill: 142,459.5 tons in 2009 (CCC 2009). This would indicate a limited ability to compost the shell.

The second alternative, to reclaim the shell, was divided into two cost benefit options. Option one was to reclaim the shell and then sell it to an end user for road building, construction, chemical production, soil conditioning, and poultry grit (Hargis and Haven 1999). During this study, contact was made with two of the largest producers of shucked oyster shell in the area: Alby's Seafood (Fulton, TX) and Casterlines Seafood Market (Fulton, TX). Bid requests for the purchase of 600 cubic yards shucked oyster shell were obtained from Alby's Seafood and Casterlines Seafood Market as well as Hillman's Shrimp & Oyster Co. (Port Lavaca, TX). Bids from Alby's Seafood and Casterlines Seafood Market were given to the TAMUCC Purchasing Department at $25 per cubic yard and Hillman's Shrimp & Oyster Co., bid was $15 per cubic yard. All three bids stated that the transportation costs to move the shell was an additional charge. Quotes for transporting shell from the purchase site to the Shell Bank ranged from $6.50 to $33 per cubic yard. The higher quotes were for the movement of the shell from Port Lavaca to the repository, thus making the lower purchase price of shucked shell at $15 per cubic yard higher due to the relocation costs. A price of $25 per cubic yard was used in the cost benefit analysis for selling the reclaimed shell. The category for "other" benefits included the net benefit calculation for the sale of reclaimed shell (Table 4), value for not placing the shell in the landfill, and the cost reduction savings for reclaiming the shell rather than disposing of it. The net benefit for reclaiming and selling the shell was $207,355, making this a viable option for the project (Table 6). Oyster shells are one of the few recyclable commodities that do not require any modification in order to reuse so the risk is inherently low to the entity or individual reclaiming and stockpiling the shell. This is another reason why the discount rate was lower in the study (Heinzerling and Ackerman 2002). Discount rates should be reflective of the risk the project is possibly assuming (Hawkins and Salverda 2011). More shell owners would assume this risk and stockpile their shell like larger wholesalers; however, their ability to secure a location to stockpile the shell is the biggest issue due to odor and infestation of insects (Jung et al. 2007).

The second option for reclaiming the shucked shell was reuse in oyster reef restoration (LDWF 2004). Only two benefits were assigned a direct dollar value for this option due to the large number of environmental variables related to the ecosystem services restored reefs provide (Beck et al. 2011). Several studies evaluated water quality, recreational, and shoreline stabilization benefits then assigned values for those benefits (Henderson and O'Neill 2003). These benefits should be evaluated if the reclaimed shell from WSR and other restaurants is eventually reused for oyster reef restoration. Enough data should then be available to quantify and assign value to many other benefits (Beck et al. 2011). The net benefit for reusing reclaimed shell for oyster reef restoration was $148,153, based on two benefits: not putting the shell in the landfill and the cost reduction savings between disposal and reclaiming the shell (Table 7).

This scenario represents an interesting paradox wherein one shell owner is paying a company to haul away and dispose of a good and another company is selling a similar good but requiring the buyer pay to haul it away. In contrast, Korean shellfish consumers generate such a quantity of spent shell that the government has implemented valorization in order to prevent illegal dumping and to give value to the spent shell (Barros et al. 2009). The state of North Carolina has also attempted to prevent spent oyster shell from being placed in the landfill by offering tax credits for shell donors and passing house bill 1465 banning the dumping of shell at landfills (Buehlmann et al. 2009; NCDENR 2009). Tax credits and banning the dumping of the shell are two methods the state of Texas could employ to offer the small shell owners an incentive to stop disposing of the shell and redirect it for reuse (Buehlmann et al. 2009; NCDENR 2009).

As was found in the present study, prices for shucked shell in the Corpus Christi Gulf Coast area hamper restoration efforts. The shell bank project is currently funded by the Texas General Land Office to determine the feasibility of shucked shell reclamation and reuse for reef restoration. Discussions were held with the City of Corpus Christi Solid Waste Division staff in hopes of continuing this recycling program within the city. Recently the city started a new recycling program in hopes of reducing the amount of waste entering the landfill. In 2007, the City closed the J.C. Elliot landfill, which averaged 468,391 tons of waste per year over a 36 year period at a mean rate of $0.024 per pound of waste (2007 value). By 2009, the mean cost per pound had increased to $0.06 (CCC 2009). At this time, the city feels they do not have the staff available to startup or continue the oyster shell recycling program. These discussions will be re-initiated once the net benefits to the program have been calculated and shared with the city staff.

Due to the high cost of shucked shell, which was acerbated by the recent lack of availability related to the oil spill, this study investigated other materials that could be used in tandem with shucked oyster shell or in lieu of shucked oyster shell. As a result of similar issues with cost of shucked oyster shell, prior oyster reef restoration projects resorted to considering other materials, in particular limestone, concrete rubble, river rock, and other types of shell (LDWF 2004; NOAA 2011a). NOAA field tests indicated that the oyster spat will settle on any hard surface that is porous and not smooth. These surfaces included clam shells and coal fly ash due to the smooth surfaces and the lack of crevices (NOAA 2011a). In the Corpus Christi Gulf coast area, the most suitable substitute material found is clean concrete rubble at a cost of $16 per cubic yard. A local recycling firm currently offers to crush concrete into three to four inch pieces for use in oyster reef restoration projects. This is a particularly good option for creating a base for the reef in that it is closest to the sediment allowing for the more expensive oyster shell to rest on the upper portion of the reef (LDWF 2004, Nestlerode et al. 2007).

Oyster reefs provide a wide-range of ecosystem services from providing unique, three dimensional structures that can act as a sanctuary to small fish to erosion control for housing located near beaches (Henderson and O'Neil 2006). Fishermen have long contended that oyster reefs are desirable fishing grounds (LDWF 2004). Many studies have already concluded that restoring oyster reefs is an ecologically important practice (Lipton et al. 2006); however, more studies are required to document the benefits of restoration to the coastal ecosystems and communities they serve (Beck et al. 2011; Jin et al. 2003). As communities seek means whereby they might reduce costs and improve the local standard of living, the recycling of oyster shell could be a start. This simple commodity has great capacity in its raw form to transform the declining health of bays and estuaries if properly located.

Oyster reef restoration would become more prevalent if federal, state, and local governments considered implementation of bans on the discarding of shell and offered tax credits to the donors of shell. Smaller shell owners that are incapable of stockpiling shell for resale or reuse may seek alternatives when incentives are offered. A natural partner for these concepts would be the City of Corpus Christi or waste management companies because they already have the infrastructure to collect and stockpile the shucked shell. Discussions will continue with the City of Corpus Christi in order to expand the oyster shell recycling program and ensure its sustainability.

### Conclusions for economic analysis

Oyster shell reclamation is a feasible alternative to disposal of shucked shells via the commercial waste system due to the alternatives to resell or reuse the shell. In this study, deposition of shucked oyster shells in the local landfill resulted in a large negative net benefit to the project suggesting disposal of spent shell at the landfill should be reevaluated by other restaurants because the reuse of spent shell is economically viable.

## PUBLIC EDUCATION

### Oyster Shell Recycling Program Logos

We worked with Debbie Lindsey-Opel and Matt Opel of 3DD results and Opel Creative to design a set of recognizable oyster shell recycling program logos that could be used by participating restaurants on their menus and promotional materials (Fig. 19).


*Figure 22. Oyster Shell Recycling Program logos.*

## Website

We developed a project website, http://oysterrecycling.org for posting project updates, media coverage, and other information (Fig. 20). We will continue to develop and update this page as we continue our oyster shell recycling efforts as part of CMP cycle 15.


*Figure 23. Screenshot of project website, www.oysterrecycling.org.*

## Coastal Issues Forum

Project results were presented to stakeholders and the public at the Coastal Bend Bays Foundation's Coastal Issues Forum on October 11, 2010. Speakers included project manager Dr. Jennifer Pollack, graduate student and Harte Research Institute Assistant Director Gail Sutton, who conducted the economic analysis of oyster shell recycling, and owner of Water Street Restaurants, Brad Lomax. Presentation slides from the event are available on our project website at: http://www.oysterecycling.org/CBBFcoastalforum.pdf.

## Videos

We created a 6 ½ minute informational video about the process of oyster shell recycling using the audio from our live interview on November 18, 2009 with Jim Lago, host of "Lago in the Morning", a popular talk radio show on 1360 News Radio KKTX. The video is available on our website at: http://www.oysterecycling.org/videos.html.

### Brochure

Debbie Lindsey-Opel and Matt Opel of 3DD results and Opel Creative worked with us to design an informational brochure on the process of oyster shell recycling (Appendix 3). This brochure was provided to Water Street Restaurants for the purpose of public education. They provide a brochure with each plate of oysters to educate consumers about oyster shell recycling and the efforts this program is making to reclaim oyster shells for restoration of degraded reefs.

## CONCLUSION

The Shell Bank oyster shell reclamation and recycling program is continuing on, thanks to continued funding from the Coastal Management Program. In summary of our accomplishments as part of CMP Cycle 14, we accomplished all of our stated goals: We first developed a partnership with Water Street Seafood Restaurants to reclaim all of their shucked oyster shells. We then developed a partnership with the Port of Corpus Christi to establish the Shell Bank shell repository for stockpiling reclaimed oyster shells. These partnerships allowed us to reclaim over 139,400 pounds, or 69.7 tons of oyster shells since November, 2009. We then collected and integrated data on oyster health and water quality to create maps that identify suitable areas for future oyster reef restoration within the Mission-Aransas Estuary. We conducted an economic analysis, concluding that oyster shell reclamation is a feasible alternative to disposal of shucked shells via the commercial waste system due to the alternatives of shell reuse or resale. Lastly, we have increased public awareness of oyster shell recycling and oyster reef restoration and will build on that momentum in the future. With support from funds provided through CMP Cycle 15, we plan to add additional restaurant partners, purchase shell from seafood wholesalers, and continue our public education efforts. Using funds provided by a NOAA-Gulf of Mexico Foundation Community-based Restoration Partnership grant, we will construct our first oyster reef restoration project in June 2011 using oyster shells reclaimed by this project. We will provide ongoing project updates as part of CMP Cycle 15.

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## *APPENDICES*

### *Appendix 1. Five year forecast of costs for disposal of oyster shells.*

**Five-year Forecast Disposal**

| | **YR 1** | | | **YR 2** | | | **YR 3** | | | **YR 4** | | | **YR 5** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 Rest. | 2 Rest. | 3 Rest. | 1 Rest. | 2 Rest. | 3 Rest. | 1 Rest. | 2 Rest. | 3 Rest. | 1 Rest. | 2 Rest. | 3 Rest. | 1 Rest. | 2 Rest. | 3 Rest. |
| **Volume of Shell** | | | | | | | | | | | | | | | |
| Live Oysters Sold - # | $624,000 | $1,248,000 | $1,872,000 | $637,728 | $1,275,456 | $1,913,184 | $651,758 | $1,303,516 | $1,955,274 | $666,097 | $1,332,193 | $1,998,290 | $680,751 | $1,361,502 | $2,042,252 |
| Spent Weight in Pounds | $205,920 | $411,840 | $617,760 | $210,450 | $420,900 | $631,351 | $215,080 | $430,160 | $645,240 | $219,812 | $439,624 | $659,436 | $224,648 | $449,296 | $673,943 |
| **Waste Disposal** | | | | | | | | | | | | | | | |
| **Development Costs:** | | | | | | | | | | | | | | | |
| Labor Costs | | | | | | | | | | | | | | | |
| TAMUCC | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Restaurants | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Printed Materials | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplies | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Operational Costs:** | | | | | | | | | | | | | | | |
| Labor & Benefit Costs | | | | | | | | | | | | | | | |
| TAMUCC | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Restaurants | $2,530 | $5,060 | $7,590 | $2,620 | $5,240 | $7,859 | $2,713 | $5,426 | $8,138 | $2,809 | $5,618 | $8,427 | $2,909 | $5,818 | $8,727 |
| Bins Depreciated | | | | | | | | | | | | | | | |
| TAMUCC | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Restaurants | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Mileage | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Rental - Shell Repository | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplies | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Disposal Fees | $4,194 | $8,387 | $12,581 | $4,380 | $8,760 | $13,140 | $4,476 | $8,953 | $13,429 | $4,575 | $9,150 | $13,725 | $4,676 | $9,351 | $14,027 |
| Pick-up Fees | $14,950 | $29,900 | $44,850 | $15,279 | $30,558 | $45,837 | $15,615 | $31,230 | $46,845 | $15,959 | $31,917 | $47,876 | $16,310 | $32,619 | $48,929 |
| **Non-reoccuring Costs** | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Captial Costs:** | | | | | | | | | | | | | | | |
| Trailer Depreciated | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Total Disposal Costs** | $ 21,674 | $ 43,347 | $ 65,021 | $ 22,279 | $ 44,558 | $ 66,836 | $ 22,804 | $ 45,609 | $ 68,413 | $ 23,343 | $ 46,685 | $ 70,028 | $ 23,894 | $ 47,788 | $ 71,682 |

*Appendix 2. Five year forecast of costs for reclamation of oyster shells.*

**Five-year Forecast of Reclamation of Shell**

| | YR 1 | | | YR 2 | | | YR 3 | | | YR 4 | | | YR 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 Rest. | 2 Rest. | 3 Rest. | 1 Rest. | 2 Rest. | 3 Rest. | 1 Rest. | 2 Rest. | 3 Rest. | 1 Rest. | 2 Rest. | 3 Rest. | 1 Rest. | 2 Rest. | 3 Rest. |
| **Volume of Shell** | | | | | | | | | | | | | | | |
| Live Oysters Sold - # | $624,000 | $1,248,000 | $1,872,000 | $637,728 | $1,275,456 | $1,913,184 | $651,758 | $1,303,516 | $1,955,274 | $666,097 | $1,332,193 | $1,998,290 | $680,751 | $1,361,502 | $2,042,252 |
| Spent Weight in Pounds | $205,920 | $411,840 | $617,760 | $210,450 | $420,900 | $631,351 | $215,080 | $430,160 | $645,240 | $219,812 | $439,624 | $659,436 | $224,648 | $449,296 | $673,943 |
| **Reclamation of Shell** | | | | | | | | | | | | | | | |
| **Development Costs:** | | | | | | | | | | | | | | | |
| Labor Costs | | | | | | | | | | | | | | | |
| TAMUCC | $6,624 | $6,624 | $6,624 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Restaurants | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Website, Printed Materials | $6,793 | $6,793 | $6,793 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplies | $210 | $210 | $210 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Operational Costs:** | | | | | | | | | | | | | | | |
| Labor & Benefit Costs | | | | | | | | | | | | | | | |
| TAMUCC | $5,642 | $11,284 | $16,926 | $8,719 | $14,561 | $20,403 | $9,028 | $15,078 | $21,128 | $9,349 | $15,613 | $21,878 | $9,681 | $16,167 | $22,654 |
| Restaurants | $2,530 | $5,060 | $7,590 | $2,620 | $5,240 | $7,859 | $2,713 | $5,426 | $8,138 | $2,809 | $5,618 | $8,427 | $2,909 | $5,818 | $8,727 |
| Bins Depreciated | | | | | | | | | | | | | | | |
| TAMUCC | $439 | $878 | $1,318 | $439 | $878 | $1,318 | $668 | $1,337 | $2,005 | $439 | $878 | $1,318 | $439 | $878 | $1,318 |
| Restaurants | $160 | $320 | $480 | $160 | $320 | $480 | $244 | $487 | $731 | $160 | $320 | $480 | $160 | $320 | $480 |
| Mileage | $2,365 | $2,956 | $3,547 | $2,417 | $3,021 | $3,625 | $2,470 | $3,088 | $3,705 | $2,525 | $3,156 | $3,787 | $2,580 | $3,870 | $4,515 |
| Rental - Shell Repository | $600 | $600 | $600 | $600 | $600 | $600 | $600 | $600 | $600 | $600 | $600 | $600 | $600 | $600 | $600 |
| Supplies | $75 | $75 | $75 | $0 | $0 | $0 | $77 | $77 | $77 | $0 | $0 | $0 | $79 | $79 | $79 |
| Disposal Fees | | | | | | | | | | | | | | | |
| Pick-up Fees | | | | | | | | | | | | | | | |
| **Non-reoccuring Costs** | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Captial Costs:** | | | | | | | | | | | | | | | |
| Trailer Depreciated | $360 | $360 | $360 | $360 | $360 | $360 | $548 | $548 | $548 | $360 | $360 | $360 | $360 | $360 | $360 |
| **Total Reclamation Costs** | $ 25,798 | $ 35,161 | $ 44,523 | $ 15,315 | $ 24,980 | $ 34,646 | $ 16,348 | $ 26,640 | $ 36,932 | $ 16,242 | $ 26,545 | $ 36,849 | $ 16,807 | $ 28,092 | $ 38,732 |

## IMPORTANCE

### ECOLOGY

Oyster reefs provide habitat for a diverse group of animals including fish, shrimp, worms and crabs. Oysters are food for larger fish, rays and crabs that are capable of crushing their shells.

### ECONOMY

Oysters are big business – Texas is the 2nd largest oyster producer in the U.S. The oysters also provide "ecosystem services": they improve water quality by filtering phytoplankton and excess nutrients, and the oyster reefs can form a protective breakwater that stabilizes the shoreline and protects against erosion.

## CONTACT


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# OYSTER RECYCLING

## IT'S HABITAT FORMING

## HOW DOES THIS PROCESS WORK?

Oysters spawn from Spring through Fall, releasing sperm and eggs into bay waters. Young larval oysters have no shell. They swim freely for about 3 weeks and then seek a hard surface upon which to attach and begin building their shells.

Oysters prefer to settle on the shells of other oysters. However, as oysters are harvested, their associated shell habitat is also removed.

Our oyster shell recycling program reclaims oyster shells, or "shucks," from restaurants and seafood wholesalers so that they can be used in future oyster reef restoration projects. Without oyster shell recycling, this important coastal resource would be lost to the landfill, which disrupts the process of natural reef regeneration.

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