FINAL REPORT

Shell Bank: An Oyster Shell Recycling, Habitat Selection, and Outreach Program for the Texas Coastal Bend

CMP Cycle 17 Final Report
GLO Contract No.: 13-041-000-6908

Jennifer B. Pollack, Ph.D.
Gail Sutton, M.S.

Department of Life Sciences and Harte Research Institute
Texas A&M University-Corpus Christi
6300 Ocean Drive
Corpus Christi, Texas 78412

Report Submitted to:
Texas General Land Office
Coastal Management Program

July 10, 2014

Table of Contents

List of Figures

ACKNOWLEDGEMENTS

We are grateful to the Port of Corpus Christi, Water Street Restaurants, and the many volunteers who have participated in activities related to oyster shell recycling and habitat conservation and restoration. The support of these partners has been essential to the growth and continuing evolution of the Shell Bank Program.

INTRODUCTION

Eastern oysters (Crassostrea virginica) are found in the Caribbean, Gulf of Mexico and Atlantic Ocean. These reef-building mollusks have great cultural, economic and ecological importance. Oysters provide a wide range of benefits to ecosystems and humans, including water filtration, nitrogen regulation, habitat and refuge for fish and invertebrates, shoreline protection, food for higher trophic levels, and resources for human consumption. Oysters are also indicator species that can be used to gather information on the overall health of an estuary.

Overharvesting of oysters and loss of reef habitat has caused a reduction in the benefits reefs provide. Oyster reefs are one of the most degraded marine habitats on earth, with estimates of only 15% remaining worldwide (Beck et al. 2011). Besides historical losses in reef size, in some Gulf of Mexico estuaries, loss of oyster biomass has also been significant (zu Ermgassen et al. 2012). When reefs are degraded through dredging or oysters are overharvested, future habitat is lost. Loss of oyster habitat is especially critical because the free-swimming larvae of oysters depend on the structural foundation of oyster reefs for recruitment and growth.

Oyster reef restoration efforts are ongoing across the United States by a variety of federal, state, private, and NGO groups to ameliorate oyster population declines. Oyster reef restoration efforts generally involve placing oyster shells or other hard substrates back into estuaries to provide attachment points for larval oysters and reef development. Shell is the natural substrate for restoring degraded oyster reefs—however, harvested oyster shells are often lost to landfills or competing uses such as road construction or as poultry feed additives (LDWF 2004). The limited availability and great expense of oyster shells is one of the major obstacles to oyster reef restoration on the large scale (LDWF 2004).

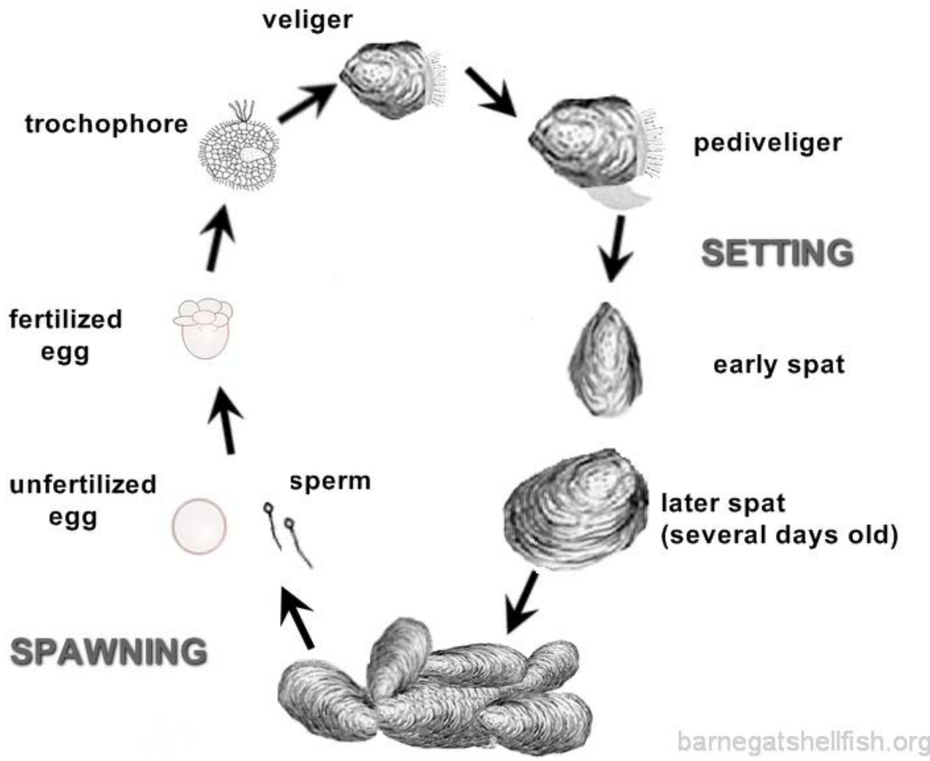

Figure 1. Oyster life cycle.

The Shell Bank Program was developed to reclaim shells from restaurants and seafood wholesalers for use in reef restoration. Shells reclaimed from this program have been used to restore 5.8 acres of oyster reef in Copano Bay and a 6.5 acres of oyster reef in in Aransas Bay with funding from the Coastal Conservation Association, Fish America Foundation, Gulf of Mexico Foundation, National Fish and Wildlife Foundation, Texas Parks and Wildlife Department, and the NOAA Community-Based Restoration Program.

Because demand for oyster shells often exceeds supply, many alternative substrates are being used to restore reefs, including crushed concrete, gravel, limestone, and river rock, as well as other mollusk shells. Despite studies that have examined specific substrate types in relation to oyster recruitment and growth, substrates for restoration are still often selected based on price and availability rather than their ability to mimic important ecological functions. Information is lacking on the relative habitat value for macrofauna of alternative substrates (French-McCay et al. 2003). As restoration efforts continue to increase, there is a critical need to understand the effectiveness of alternative substrates as replacements for natural oyster shell in reef building, not only for economic reasons but for both oyster recruitment and habitat creation for fish and macroinvertebrates.

Project Goals, and Partners

The Shell Bank Project was initially created as part of CMP Cycle #14 to be an innovative oyster shell reclamation, storage, and recycling program to for the Texas Coastal Bend. This project began as 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. For CMP Cycle 17, we expanded upon on these previous accomplishments to achieve several new goals: 1) expand the oyster shell collection efforts, 2) increase community involvement in oyster restoration, 3) develop an "Oysters in the Classroom" educational program in local schools, and 4) examine alternative reef building materials.

1. EXPAND OYSTER SHELL COLLECTION EFFORTS

Recycling oyster shells for use in oyster reef restoration is a four-step process (Fig 2). The process begins when oysters are harvested from bay waters, which in Texas is typically done using an oyster dredge. The majority of these oysters are then sold to restaurants, where oyster shuckers remove the top shell of each oyster and place it into a specially designated recycling bin. After patrons consume raw oysters or other types of oyster platters, the bottom shell of each raw oyster is collected by bussers, separated from restaurant trash and also placed in special collection bins. Once the collection bins are filled, they are brought outside and dumped into larger, customized collection bins that we use for shell transport. Twice weekly, we visit each restaurant, collect the bins—each with a capacity for 400 pounds of oyster shell—load them unto a flatbed trailer, and transport them to the Shell Bank Repository at the Port of Corpus Christi for at least 6 months of quarantine. This holding period is used to eliminate potential for disease or invasive organisms before the shells are used in oyster reef restoration projects. After a large quantity of shells has been reclaimed, they are used in oyster reef restoration projects in Texas Coastal Bend bays (using external funding).

In Corpus Christi, the largest majority of oyster shells are produced by Water Street Oyster Bar and Water Street Seafood Restaurant. These restaurants have been our long-term partners in the Shell Bank Program and contribute 100% of their oyster shells for reef restoration. We were happy to be able to add a new restaurant partner, Scuttlebutt's on Padre Island, to the Shell Bank family in early February, 2014. We had been consistently collecting shells from Scuttlebutts' in February and March but that the landlord of the building decided he does not want to allow oyster shell collection bins near the restaurant. We are continuing to pursue feasible solutions in cooperation with the restaurant manager, as they are excited to continue participating in the program.

Figure 2. The four steps of The Shell Bank oyster shell recycling process: harvest, consumption, reclamation, and recycling of shells. Image by Brittany Blomberg, Texas A&M University – Corpus Christi.

We reclaimed between 2,800 and 8,800 pounds of oyster shells per month during CMP Cycle 17, with an average of 6,190 pounds of oyster shells collected per month (Fig. 3). The total weight of oyster shells reclaimed from our restaurant partners during CMP Cycle 17 was 130,000 pounds, or approximately 99 cubic yards of shell.

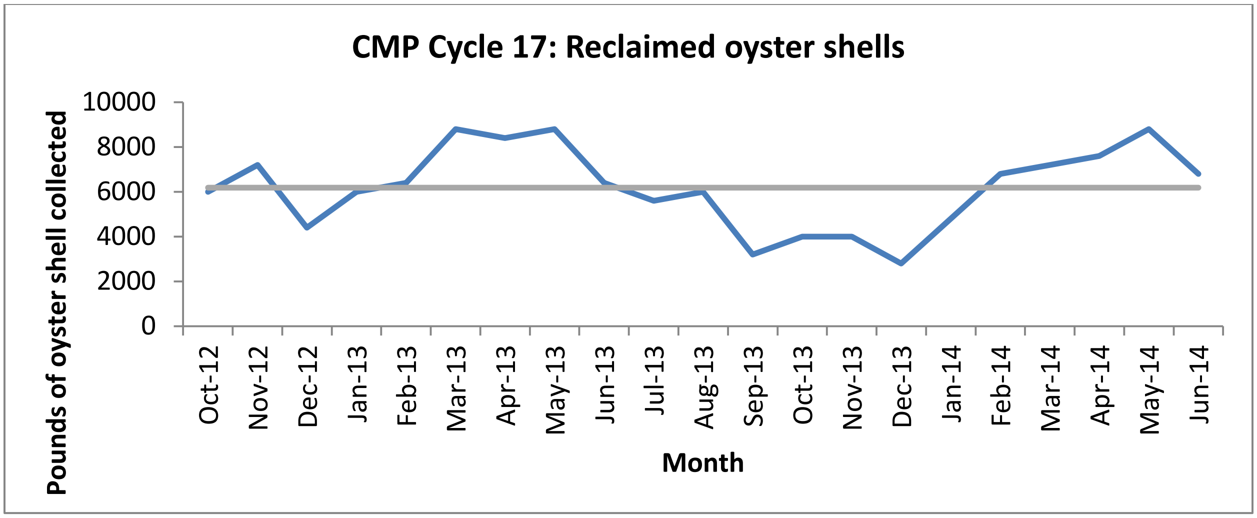

Figure 3. Pounds of oyster shell reclaimed (by month) as part of CMP Cycle 17 from October 2012-June 2014. The blue line illustrates monthly totals. The gray line illustrates the monthly average of 6,190 pounds.

In Texas, the public commercial and recreational oyster season runs from November 1-April 30 except for temporary closures issued by the Texas Parks and Wildlife Department. In August 2013, several areas of Galveston Bay were closed to the harvesting of oysters and other shellfish due to the presence of the red tide organism *Karenna brevis*. Red tide produces the toxin responsible for Neurotoxic Shellfish Poisoning (NSP), and there is a public health risk for people of consuming filter-feeding shellfish that may accumulate the toxin. The closed areas of Galveston Bay remained closed until October, 2013, and may have contributed to the decrease in oyster shells reclaimed during these months and in the wake of the red tide event. We were granted an extension to our project deadline, which allowed us to make up for the temporary reduction in shell volume by collecting for a longer period of time.

As part of CMP 17, we began collecting oyster shells at local and regional seafood festivals. We collected oyster shells produced from Fulton Oysterfest, which took place March 7-10 in Fulton, TX. We also partnered with Martin Middle School Science and Spanish Club, who had a booth at Oysterfest, to pass out our oyster shell recycling brochures to festivalgoers. The school also made an oyster reef float for the Oysterfest parade and carried our "Sink Your Shucks" oyster recycling banner—the students won first place in the parade (Figs 4-6)! In order to make collection efforts the easiest for festival organizers, we provided a roll off dumpster for collecting just the top shell off the oyster (the shell that is removed by shuckers in the raw bar area). We were unable to collect the bottom half of the shells, which go out to festivalgoers for oysters on the half shell, due to logistical problems with sorting those shells away from trash and other food scraps. We reclaimed about 2,000 pounds of shell from Oysterfest using this method.

Figure 4. Martin Middle school students ride on their oyster reef parade float in the Fulton Oysterfest parade (Photo: Richard Gonzalez)

Figure 5. Martin Middle School students carry the "Sink Your Shucks – Oyster Reef Under Construction" Banner in the Fulton Oysterfest parade (Photo: Richard Gonzalez)

Figure 6. First Place in the Fulton Oysterfest parade! (Photo: Richard Gonzalez)

We also partnered with St. Mary's University to reclaim oyster shells as part of Fiesta Oyster Bake, April 19-20, 2013 in San Antonio (Figs 7-10). The staff from St. Mary's who coordinated the event, in particular Steve Rosenauer, were extremely supportive of our program and they put forth a great effort to reclaim oyster shells from the event. By our estimates, we were able to reclaim approximately 40% of the oysters produced by the event, which was a great turnout for our first attempt at this partnership.

Figure 7. Entrance to 2013 St. Mary's Fiesta Oyster Bake

Figure 8. Some of our volunteers, Kevin De Santiago, Alex Austin, Jaimie Nevins, and Maria Gonzalez at 2013 Fiesta Oysterbake

Figure 9. St. Mary's staff at the "Pecan Grove" oyster station at 2013 Fiesta Oyster Bake

On April 11-12, 2014, we participated in Fiesta Oysterbake in San Antonio for the second year. Since the 2013 event, we have been in talks with Fiesta Oyster Bake staff about ways to increase our presence, reclaim more shell, and expand our educational and outreach efforts as part of the festival. Because many festival goers were interested in what we were doing, we pursued having a stand-alone booth at the 2014 festival in addition to walking around and speaking with people individually. Our booth was located directly across from the Pecan Grove area where buckets of raw oysters are served, which made it much easier for us to connect with festivalgoers to recycle their oyster shells. At the booth we passed out our Shell Bank brochures, handed out "Sink Your Shucks" pins, had a large container with oyster shells for people to guess the number and win a prize, gave shucking demonstrations, and talked to folks about oyster shell recycling and oyster reef restoration.

Figure 10. Volunteers man the Shell Bank booth at 2014 Fiesta Oysterbake

Figure 11. A bucket of reclaimed oyster shells bound for our collection bin at 2014 Fiesta Oysterbake

Figure 12. Reclaimed oyster shells from 2014 Fiesta Oysterbake

Figure 13. "Sink Your Shucks" pins from 2014 Fiesta Oysterbake

2. COMMUNITY INVOLVEMENT IN OYSTER REEF RESTORATION

We hosted two community shell bagging events in 2013 as part of CMP Cycle 17; all events were hosted at Goose Island State Park. Our volunteers come from a variety of backgrounds, including professionals, students (graduate, undergraduate, high school, middle school), youth groups, retirees, and winter Texas. On April 6, 2013, we had 169 volunteers come to Goose Island State Park and bag 17,224 pounds of reclaimed oyster shells. We partnered with Martin Middle School, Moody High School, and King High School to increase student involvement in the program. On May 4, 2013, we had 90 volunteers turn out to bag 28,820 pounds of oyster shell, more than 150% greater than the previous month, and with fewer volunteers!

In total, across both restoration events, volunteers filled 2,093 bags with 46,044 pounds of reclaimed oyster shells. Our restaurant partners continued to fund expansion of an educational oyster reef adjacent to Goose Island State Park in St. Charles Bay using these bags of oyster shell substrate.

Figure 14. Volunteers bagging recycled oyster shells at Goose Island State Park (Photo: Jeff Janko)

Figure 15. Martin Middle School students working together to bag recycled oyster shells (Photo: Jeff Janko)

Figure 16. Students work together to move bags of recycled oyster shells from the bagging area down to the restoration area (Photo: Jeff Janko)

We are particularly proud that the Shell Bank Program was a finalist for the Texas Environmental Excellence Award! Administered by the Texas Commission on Environmental Quality, this is the highest environmental honor in the state of Texas, and the award was signed by Governor Rick Perry.

3. OYSTERS IN THE CLASSROOM

The Oysters in the Classroom portion of the CMP 17 grant provided students with a unique view in to the life of Texas oysters and the role they play in the environment. Ten aquaria were set up at participating high schools and live oysters were collected from Goose Island State Park. The selected oysters (6-10 per tank) were then placed into the various aquaria at local schools. The participating classes were then responsible for maintaining water quality and feeding of their oysters. Special shellfish food was acquired for this project and daily feedings were necessary. The filter feeding and water quality benefits of oysters were easily observed during the feeding events with the oysters clarifying the food-rich waters in less than an hour. During the following months the students were able to observe and record their growth. One unintended benefit from this project was not only were the students watching the oysters grow, but they were also able to observe the numerous other organisms (barnacles, tunicates, mussels) that are associated with the oyster community and see the larger habitat that the oyster provides. Upon the completion of the school year, the oysters were returned to their natural environment. Curricula from CMP 16 were the cornerstone of the Oyster in the Classroom project by providing the corresponding materials to the live animals. Students progressed through the online teaching modules learning about bays, estuaries and keystone species, one of which is the oyster. Every teacher that participated responded favorably that they would like the aquaria set up next school year, Fall 2014, so they can continue the Oysters in the Classroom. In order to expand the project the teachers recommended a community bagging event in the fall so the animals can be collected then at the bagging event in the Spring of 2015 the animals will be returned to the educational reef at St. Charles Bay.

Dr. Jennifer Pollack met with TOTE members, Teachers on the Estuary because they are interested in participating in the Oysters in the Classroom. This group is supported by the National Estuarine Research Reserve System at the University of Texas Marine Science Institute in Port Aransas with funding provided by NOAA. Our goal is to request funding in CMP 20 to expand this project. The TOTE group is currently comprised of 18 teachers that are deeply involved in stewardship training and are excellent resource to expand this project that has received 100% approval by the teachers that participated. We are looking forward to continuing this project and making it available for more local schools.

Figure 17. Students test for water quality near an oyster reef in Aransas Bay

Figure 18. Students examine oyster shells and associated organisms in Aransas Bay

Figure 19. Collin Sherman collects oyster shells from St. Charles Bay for "Oysters in the Classroom"

Figure 20. Collin Sherman sets up an oyster aquarium in a Corpus Christi area high school for "Oysters in the Classroom"

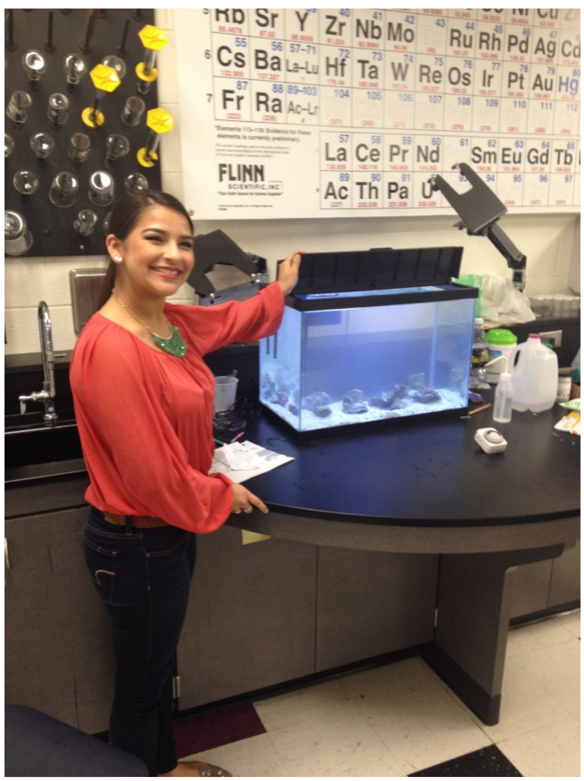

Figure 21. A Corpus Christi high school student monitors water quality in her classroom's oyster aquarium as part of "Oysters in the Classroom"

4. EXAMINE ALTERNATIVE REEF BUILDING MATERIALS

Field experiments were conducted in St. Charles Bay, Texas, part of the Mission-Aransas Estuary. Five substrate types used in the field experiments were acquired from a variety of sources. Oyster shell that had been sun-bleached for 6 months was obtained from the Shell Bank oyster shell recycling program. Concrete was reclaimed from the chutes and hoppers of concrete trucks after construction projects. Porcelain that had been sun-bleached for 12 months was reclaimed from the City of Corpus Christi's municipal waste stream. Both the concrete and porcelain were crushed and graded to approximately 8 cm size. River rock and limestone were purchased in ~8 cm pieces from a local plant nursery.

Ten shallow subtidal sites adjacent to natural oyster reef were selected throughout St. Charles Bay. Five 0.75-m^2 trays, each containing a different substrate type, were randomly distributed at each site in May 2013. Each tray was lined with 1 cm^2 mesh and filled with 38 L of substrate. Trays were anchored using steel reinforcing bar (rebar) to prevent movement or loss.

After four months (September 2013), the trays were sampled using 1 m^2 throw traps. At each site, six throw traps were deployed simultaneously, rapidly enclosing the area around each of the sampling trays and an area of bare sediment. The sampling tray was lifted from inside each throw trap and retained, while snug-fitting sweep nets (1.6 mm mesh) were passed through the enclosed area until all remaining organisms were collected. A 0.09 m^2 quadrat was placed randomly within each sampling tray for quantification of encrusting organisms such as oyster spat, barnacles, mussels, slipper shells, serpulid worms and algae. Substrates were retained in bags, placed on ice and brought back to the lab for processing. The shell height (from hinge to lip) of 20 randomly chosen spat from each tray (if available) were also measured. Organisms were placed in 10% formalin and brought to the lab for processing. In the laboratory, organisms were identified to the lowest practical level, enumerated, and measured for standard length (mm) using calipers.

The potential use of substrate type as prey refuge was evaluated using flow-through laboratory mesocosms at the Texas A&M AgriLife Mariculture Research Laboratory in Port Aransas, TX. A total of 28 110-L rectangular (76 x 30 x 46 cm) fiberglass mesocosms were each filled with one of five substrate types, oyster shell, concrete, porcelain, river rock, or limestone, or one of two control substrates, bare sand and no substrate. A total of 12 trials per predator treatment were completed for total of 24 experimental trials per substrate. Temperature and salinity were monitored daily to assure consistency between mesocosms.

Predator organisms used for these experiments were blue crabs (Callinectes sapidus; 12.5-14 cm carapace width) and pinfish (Lagodon rhomboides; 12-14 cm standard length). Panopeid mud crabs, which are highly abundant reef-residents, were used as prey organisms in all of the trials. All organisms were collected locally from the Mission-Aransas Estuary, TX.

Prior to the experiments, either two *C. sapidus* or two *L. rhomboides* were placed into the mesocosms for a 24 hour starvation period. Predator organisms were then corralled to one side of the mesocosm using plastic mesh to allow an acclimation area for the prey. Mud crabs were stocked at 10 individuals per mesocosm and allowed 30 minutes to acclimate. Trials began when the divider mesh was removed. Based on preliminary experiments to determine the time for 50% prey mortality to occur, for *C. sapidus* predators trials ran for 48 hours and for *L. rhomboides* predators 72 hours. At the conclusion of each trial, substrates were removed from each mesocosm to quantify prey mortality. All predators and surviving Xanthid crabs were released back into the field at the collection site.

Mean spat recruitment densities on the five substrate types ranged from 617 m^{-2} on shell to 1556 m^{-2} on river rock (Fig. 14A). No spat were observed from the bare sediment substrates. Spat recruitment densities were similar across all of the substrate types ($p \leq 0.11$). Mean spat shell heights ranged from 10.9 mm on porcelain to 16.7 mm on shell and were similar across all substrate types. Spat shell heights were significantly different among substrate types ($p < 0.0001$; Figure 14B). Spat on porcelain were significantly smaller than on all other substrate types except on limestone.

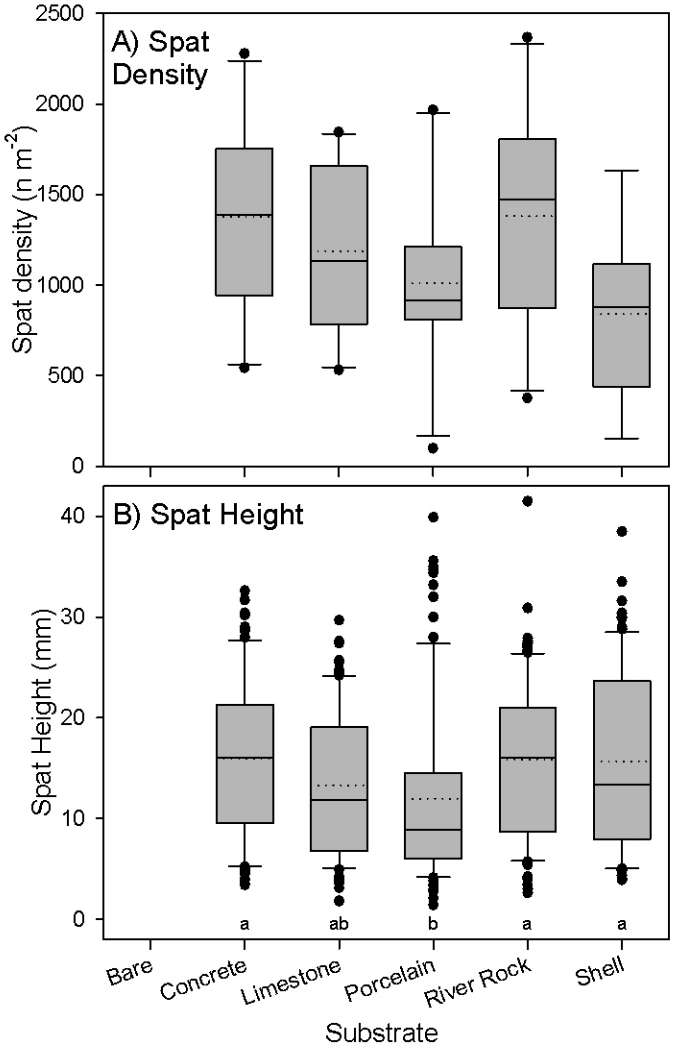

Figure 22. Box plots of spat density (A) and spat shell height (B) for each substrate type. Dotted line represents mean. No spat was found on bare substrate. Letters on spat shell height graph represent statistical significance.

A total of 16,069 epifaunal organisms were collected from the field experiments, representing 13 fish species and 9 macroinvertebrate taxa. Mean epifaunal densities ranged from 195 m^{-2} associated with shell to 775 m^{-2} associated with limestone (Fig 15A). Densities were similar among substrates ($p \leq 0.059$). Very low (2 – 15 m^{-2}) densities of epifauna occurred on the bare sand controls.

Species diversity (H') of epifauna ranged from 0.6 on river rock and limestone and 1.4 0.75-m^{-2} on shell. Epifauna diversity was significantly different among substrates (Fig 15B). Epifauna diversity on limestone and river rock was significantly lower than diversity on porcelain and shell.

The most abundant epifaunal macroinvertebrates included Porcelain crabs (family Porcellanidae), Xanthid crabs, snapping shrimp (Alpheus heterochaelis), and grass shrimp (Palaemonetes spp.). Numerically dominant fish species included naked goby (Gobiosoma bosc), Gulf toadfish (Opsanus beta), and Skilletfish (Gobiesox strumosus). Bay anchovy (Anchoa mitchilli) were also abundant around concrete substrate, but were likely collected from within the water column of the drop samplers rather than amongst the substrate itself.

Epifaunal communities from all substrate types except that occurring on limestone at site three were at least 70% similar to each other (Fig 16). The community on limestone at site 3 was only 43% similar to the other communities. All substrates were not significantly different from each other (ANOSIM: substrates $p \leq 0.78$).

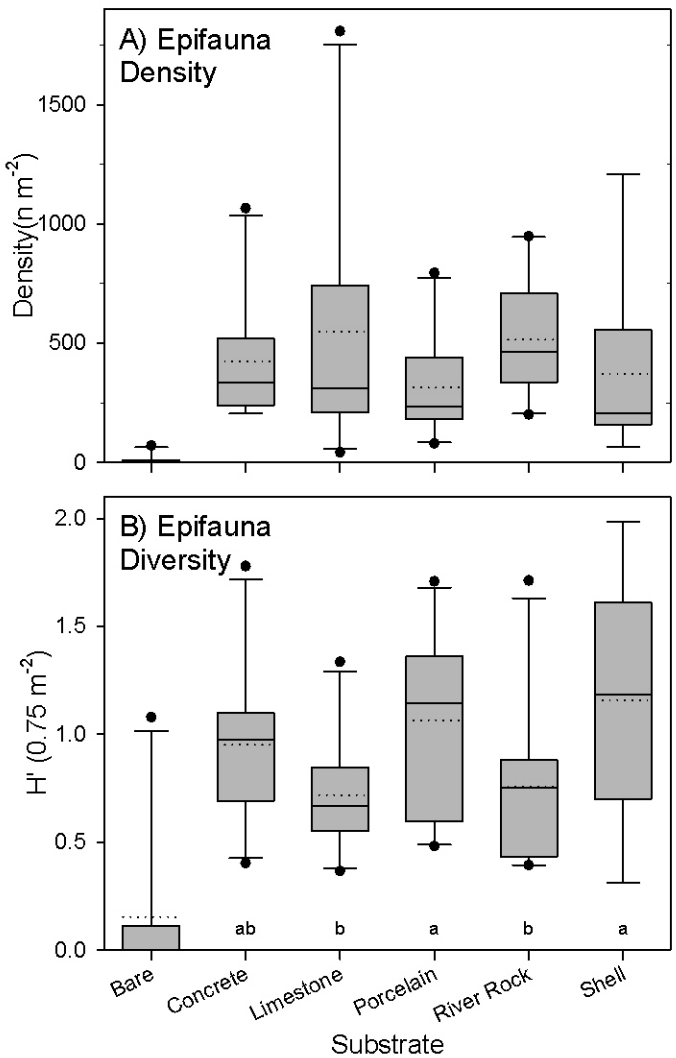

Figure 23. Box plots of epifauna density (A) and diversity (B) for each substrate type. Dotted line represents mean. Letters on epifauna diversity graph represent statistical significance.

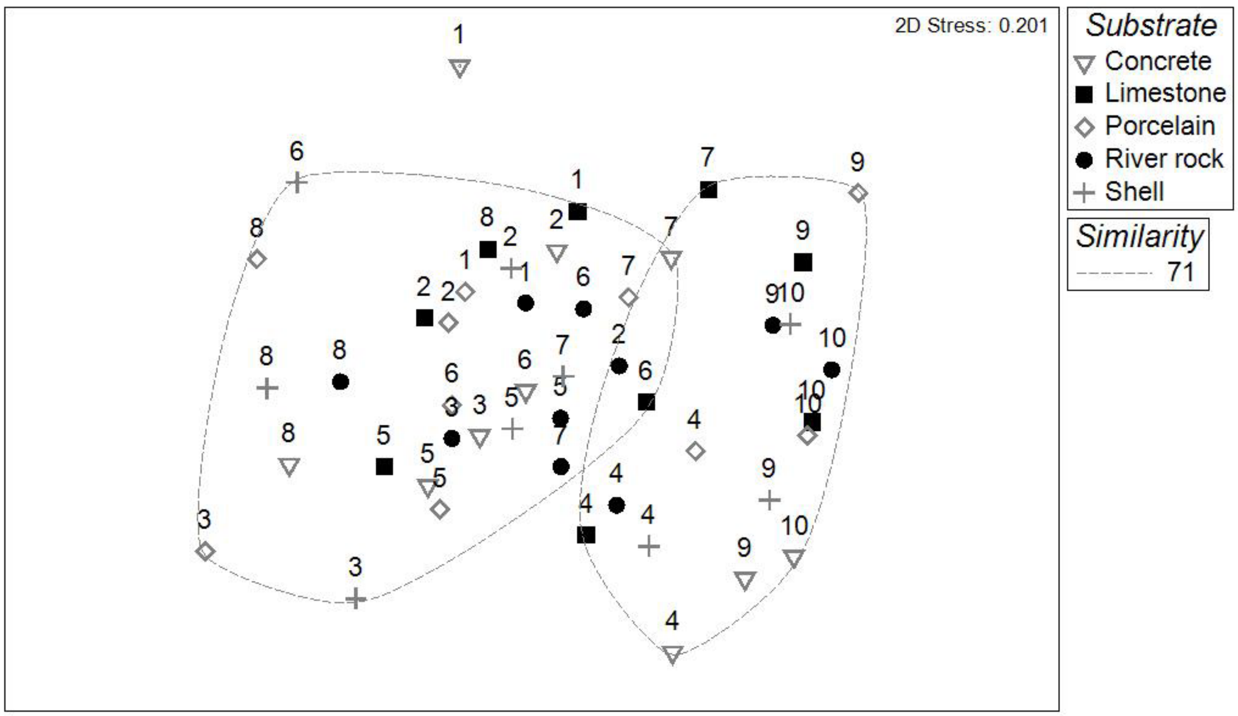

Figure 24. A) Multidimensional scaling plot of community structure for each substrate type at each site overlaid with similarity contour from cluster analysis.

Prey (Xanthid crab) mortality in the experimental mesocosms was highly variable, ranging from 4 -8% in the presence of *C. sapidus* predators and 4-11% in the presence of *L. rhomboides predators* (Figure 17). There were no significant differences among substrate treatments ($p \leq 0.74$) or predators ($p \leq 0.32$) when only the substrates were compared (Table 2, Figure 5). However, there was significantly higher prey mortality on the control substrates (no substrate and bare sand) than the treatment substrates ($p < 0.0001$) and predation by *C. sapidus* was significantly greater then predation by *L. rhomboides* when control substrates were included (p <

0.0001). Prey mortality from *C. sapidus* predation was significantly higher on bare bottom and sand substrates than on other substrates. Prey mortality from *L. rhomboides* predation was highest on bare bottom and sand substrates, but mortality on the no substrate control was significantly higher on all substrates except on limestone and the bare sand control was not significantly higher than the substrate treatments.

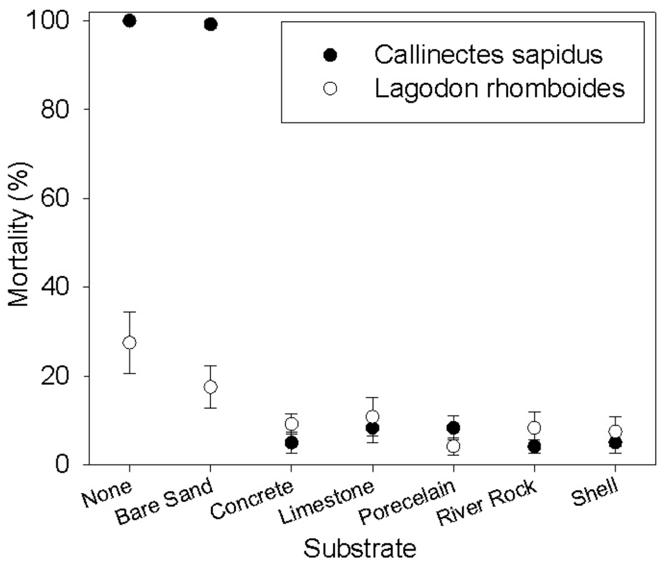

Figure 25. Mean (± Standard Error) mud crab mortality from blue crab or pinfish predators across each substrate type in mesocosm experiments.

The value of alternative substrates for sustaining oyster populations through time depends in part on the ability of oysters to recruit, grow, and survive a variety of stressors. Spat accumulation and growth are important for stabilizing reefs. It is also important for restored reefs to support valuable ecological functions provided by natural reefs, including habitat provisioning for reef-associated fauna (Rodney and Paynter 2006). In the present study, oyster recruitment was similar across all hard substrate types, and spat grew rapidly to near juvenile size (>25 mm) during the 4 month study period. Spat recruitment levels on river rock, limestone and concrete were similar to previous observations in the Gulf of Mexico (Soniat & Burton 2005). Epifaunal densities and community structure were similar across all hard substrate types, and were analogous to those on natural reefs, including gobies (*Gobiosoma* spp.), blennies (*Hypsoblennius* spp.), mud and stone crabs (*Menippe adina*) (Bahr & Lanier 1981). Gobies, toadfish and skilletfish in particular depend on hard substrates like oyster shell for spawning and foraging. The presence of these fishes in the field experiments suggests the alternative substrates provide at least some of the essential habitat functions required by these species.

Oyster reef restoration has traditionally placed dredged oyster shells on degraded reef areas to provide the foundation on which oysters recruit. Limited availability of oyster shell has presented an obstacle to large-scale reef restoration and has driven research on alternative substrates. This study provides important insight into the use of concrete, porcelain, limestone, and river rock as viable alternatives to oyster shell in their ability to recruit oyster spat, allow spat growth to juvenile size and provide refuge for epifauna. An understanding of the relative habitat value of alternative substrates for oyster reef restoration is important for quantifying ecosystem services of restored reefs, as well as promoting sustainable management of oyster resources through the use of suitable substrates.

CONCLUSION

The Shell Bank oyster shell reclamation and recycling program continues to grow and thrive, thanks to continued funding from the Texas Coastal Management Program. The program accomplished all of its stated goals as part of CMP Cycle 17: Expansion of shell collection efforts, increased community involvement in oyster reef restoration, implementation of an

“Oysters in the Classroom” program linked to the community based restoration events, and execution of laboratory and field experiments to better understand the effects of alternative reef building materials on oyster, fish, and crustacean populations. Of particular pride is the incredible community interest and support for participating in community restoration events. In response, with support from funds provided through CMP Cycle 18, these important events will continue to occur so that local volunteers from all backgrounds and ages. The Shell Bank Program will continue to educate the public, provide oyster shells for oyster reef restoration, and seek science-based solutions to improve the sustainability of oysters, an important coastal resource for Texas.

REFERENCES

Bahr, L. M. &W. P. Lanier (1981) The ecology of intertidal oyster reefs of the South Atlantic coast: a community profile. U.S. Fish and Wildlife Service Program FWS/OBS/-81/15.

Beck, M.W., R.D. Brumbaugh, L. Airoldi, A. Carranza, L.D. Coen, C. Crawford, O. Defeo, G.J. Edgar, B. Hancock, M.C. Kay, H.S. Lenihan, M.W. Luckenbach, C.L. Toropova, G. Zhang, and X. Guo. 2011. Oyster reefs at risk and recommendations for conservation, restoration, and management. Bioscience 61:107-116.

French-McCay, D.P., C.H. Peterson, J.T. DeAlteris, J. Catena (2003) Restoration that targets function as opposed to structure: replacing lost bivalve production and filtration. Marine Ecology Progress Series 264: 197-212.

LDWF: Louisiana Department of Wildlife and Fisheries (2004) Final report for Louisiana's Oyster Shell Recovery Pilot Project. Socioeconomics Research and Development Section and Marine Fisheries Division NOAA Award No. NA96FK0188.

Rodney, W.S., K.T. Paynter (2006) Comparisons of macrofaunal assemblages on restored and non-restored oyster reefs in mesohaline regions of Chesapeake Bay Maryland. Journal of Experimental Marine Biology and Ecology 355: 29-51.

Soniat, T.M., and G.M. Burton. 2005. A comparison of the effectiveness of sandstone and limestone as cultch for oysters, Crassostrea virginica. J Shellfish Research 24: 483–486.

Zu Ermgassen P.S., M.D. Spalding, B. Blake, L.D. Coen, B. Dumbauld, S. Geiger, J.H. Grabowski, R. Grizzle, M. Luckenbach, K. McGraw, W. Rodney, J.L. Ruesink, S.P. Powers, and R. Brumbaugh. 2012. Historical ecology with real numbers: past and present extent and biomass of an imperiled estuarine habitat. Proceedings of the Royal Society B: Biological Sciences 279: 3393-3400.