

Trabue Harborwalk Oyster Habitat Restoration Project: Overview and One-Year Monitoring Results



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The Nature
Conservancy 

Acknowledgements

The Nature Conservancy thanks our many partners for making the Trabue Harborwalk Oyster Habitat Restoration Project possible and successful. The City of Punta Gorda, Florida Department of Environmental Protection-Charlotte Harbor Aquatic Preserves & Charlotte Harbor Preserve State Park, Charlotte Harbor National Estuary Program, Florida Fish & Wildlife Conservation Commission, Friends of the Charlotte Harbor Aquatic Preserves, Peace River Audubon Society, and the State and Federal permitting agencies contributed their amazing support through staff and volunteer time, resources, and expertise since the project's inception. Additionally, the project was supported by the following businesses and individuals and we greatly appreciate their involvement: Clamtastic Seafood Inc., Carlton Ward Jr., Ernesto Lasso de la Vega, Home Depot-Punta Gorda, Jaime Boswell MC, LLC., Keesling Construction, Laishley Park Municipal Marina, Reef Innovations, and Tara Landscaping. Thank you to The Mosaic Company Foundation, Sally Mead Hands Foundation, and other private donors for funding the project. We also greatly appreciate the many citizen volunteers, too numerous to mention here, who donated their time to assemble the reef materials, construct the reefs, and assist with the project monitoring before and after installation. The dedication and enthusiastic participation of everyone involved transformed this project from a vision to reality. The Nature Conservancy is honored to be a part of this community.

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This report is also available on the Charlotte Harbor Water Atlas site, which is managed by the Charlotte Harbor National Estuary Program and can be accessed at this web link: <http://www.chnep.wateratlas.usf.edu/oyster-habitat-restoration/>.

Executive Summary

In 2012, The Nature Conservancy (TNC) funded and worked with the Charlotte Harbor National Estuary Program (CHNEP) and the Southwest Florida Oyster Working Group (SWFOWG) – made up of local partners with experience and knowledge in various aspects of oyster reef restoration – to develop Florida’s first estuary-wide, science-based oyster habitat restoration plan. In December 2012, the CHNEP Management Conference approved the Charlotte Harbor Oyster Habitat Restoration Plan (Boswell et al. 2012). The plan contains a Restoration Suitability Model (RSM) that spatially defines potentially suitable areas in Charlotte Harbor for oyster reef restoration based on 5 criteria: bathymetry, tidal river salinity isohalines, seagrass persistence, proximity to boat channels, and presence of aquaculture lease areas. Output from the RSM indicates that there is over 40,000 acres of highly suitable area for oyster restoration within the Charlotte Harbor System. The plan’s long-term project objectives include establishing vibrant and growing oyster reef habitat in the Charlotte Harbor with a restoration goal of 1,000-6,000 acres of oyster habitat.

With private funding in hand from The Mosaic Company Foundation to implement a pilot oyster reef restoration project in the Charlotte Harbor System, TNC worked with the CHNEP and Florida Department of Environmental Protection - Charlotte Harbor Aquatic Preserves (FDEP-CHAP) to identify an appropriate location for the project. The project location ultimately selected was the shallow intertidal area off Trabue Harborwalk, a linear walking trail and park located in the City of Punta Gorda along tidal portions of the Peace River. Selection of the project location was based on the highly suitable areas identified in the Charlotte Harbor Oyster Habitat Restoration Plan, presence of an oyster larvae source, accessibility for volunteers and adjacency to publicly owned property.

Since no known oyster habitat restoration projects had been conducted in the northern portion of Charlotte Harbor, TNC designed a pilot project to test methods that might typically be used for larger restoration projects in the region. Three methods were selected: loose fossil shell, bags of loose fossil shell, and oyster mats using recycled shell. Fossil shell was selected as a material for the loose and bagged shell reefs due to the limited availability of recycled oyster shell. Both the bag and mat materials used in reef construction are aquaculture grade plastic. As the reefs grow, all artificial materials are expected to be covered with natural oyster growth and fully incorporated into the reefs.

The pilot project was designed to facilitate comparison of how well the three approaches perform. Three reefs of each material approximately 4 m by 9 m in size were constructed and one control site was established. A reference site could not be found near the project area as the previously observed natural reefs no longer exist. A monitoring plan based on the Oyster Habitat Restoration Monitoring and Assessment Handbook Guidelines (Baggett et al, 2014) was developed and implemented to assess reef performance and effect on adjacent habitats and native species. Monitoring plan elements included: project footprint and reef area; reef height; live oyster density and size frequency; water temperature, salinity, dissolved oxygen and clarity/turbidity; oyster recruitment and cluster formation; macroinvertebrate use of the reef; waterbird utilization of the reefs; habitat stability (accretion/erosion between reef and mangrove shoreline) and submerged aquatic vegetation.

Community volunteers assisted with all aspects of project implementation including construction of reef materials, monitoring, seagrass transplanting and reef construction. As of April 2017, more than 1,300 volunteers from area schools, fishing clubs, agencies and other community organizations have contributed approximately 2,950 hours to the project.

Key Results One Year after Reef Installation:

- All reefs combined produced an estimated 364,490 live oysters (> 10 mm in shell length). The bagged shell reefs produced 260,134 new oysters, followed by the loose shell reefs with 87,108 oysters, and the mat reefs with 17,248 oysters. Bagged shell reefs also showed the greatest positive change in reef height and concentration of oysters in smaller size classes.
- Macroinvertebrates (excluding oysters) on all the reefs increased from sparse tubeworms to an estimated nearly 1 million individuals representing 33 species, primarily barnacles, polychaete worms and the flat mud crab, *Eurypanopeus depressus*. *E. depressus* is a predator on oyster spat and an important prey item for the commercially valuable blue crab, *Callinectes sapidus*.
- More individual waterbirds were observed during the post-installation monitoring (465) compared to the pre-installation monitoring (245) yet the species composition was similar pre- and post-monitoring (17 versus 16 species, respectively).
- There were no statistically significant changes in submerged aquatic vegetation (SAV) shoot density, abundance or blade length at the control or reefs sites from the post-installation monitoring to 1 year post-installation monitoring.
- There were no observed entanglements on the projects reefs. Observations were conducted monthly by the Peace River Audubon Society.
- Juvenile smalltooth sawfish, *Pristis pectinate*, utilized the Lower Peace River near the Trabue project site both before and after reef installation. While the juveniles tracked by Florida Fish and Wildlife Conservation Commission staff did not exhibit a statistically significant preference for the restored reefs as compared to the surrounding sandy-mud flats with sparse seagrass (Poulakis et al. 2017), two of the acoustically tagged juveniles demonstrated activity around and on top of the restored reefs.

Summary and Conclusions

The Trabue Harborwalk Project demonstrated how to successfully pilot a small-scale project to test different restoration methods and involve the community in all aspects of the project.

The short-term project objectives were achieved including:

- Permitting a restoration project in this region of the Charlotte Harbor Estuary,
- Involving community volunteers to assist with construction of reef materials, reef deployment and reef monitoring,
- Deploying reef materials and conducting pre- and post-installation monitoring,
- Improving knowledge about how different reef materials perform and function,
- Improving knowledge about the extent to which juvenile smalltooth sawfish utilize the restoration area and oyster reef habitat.

Much of what was learned will be useful as TNC and partners move forward with implementation of other oyster reef restoration projects in the Charlotte Harbor region.

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Abbreviations Used in this Document

Charlotte Harbor National Estuary Program (CHNEP)

Florida Department of Environmental Protection – Charlotte Harbor Aquatic Preserves (FDEP-CHAP)

Florida Fish and Wildlife Conservation Commission (FWC)

National Marine Fisheries Services (NMFS)

Sanibel-Captiva Conservation Foundation (SCCF)

Southwest Florida Oyster Working Group (SWFOWG)

Submerged Aquatic Vegetation (SAV)

The Nature Conservancy (TNC)

Background and Objectives

Over the past century, the health of the natural resources in the Gulf of Mexico and its bays and estuaries have dramatically declined. Yet, these systems remain the foundation of life in the Gulf and form the backbone of the region's economy. Places like Charlotte Harbor are important refuges for the Gulf's many plants and animals – from the Florida manatee and American oystercatcher, to redfish and shrimp – and it is critical that this estuary's habitat remain healthy if the Gulf is to recover from threats like the Deepwater Horizon oil spill or the damaging effects of climate change.

Charlotte Harbor has, in fact, long been recognized by The Nature Conservancy (TNC) as an exceptionally important Florida estuary. Well before the oil spill, TNC identified it as a key contributor to the health of the Gulf and protected over 18,800 acres within the watershed. The area is rich in biological diversity – 86 of Florida's endangered and threatened species, and numerous recreational and commercial species reside there – and, perhaps most importantly, it is largely restorable. A biodiversity study, conducted by TNC in 2005 (Geselbracht *et al.*), combined with a feasibility study and sea level rise modeling completed in 2013 (Geselbracht *et al.*) demonstrated that, while many habitat types had declined significantly, there were several opportunities for effective restoration, particularly oyster reef restoration.

Led by TNC, a scientific analysis of oyster reefs globally (Beck *et al.* 2009) revealed that oyster reefs are likely the most degraded and most imperiled type of marine ecosystem on Earth. Every area that historically had oyster reef habitat within Charlotte Harbor has experienced substantial losses of oyster reef habitat since 1982. However, oyster reefs can be recovered and restoring the reefs back to the functioning ecosystems they once were will not only help improve water quality and species productivity, but will also help protect against the effects of sea level rise.

Oyster reefs are known to provide habitat to numerous species of fish and invertebrates. Many of these species are in turn eaten by, or grow to become, recreationally or commercially harvested species. In some cases, the species inhabiting oyster reefs are food sources for species valued for recreational enjoyment such as blue crab, sheepshead, spot and wading birds. It is currently unknown if oyster reefs are utilized by the federally endangered smalltooth sawfish, *Pristis pectinata*, and to what extent.

TNC's Florida Chapter identified Charlotte Harbor as a Florida marine priority area in TNC's larger strategy to restore the Gulf of Mexico. The need for restoration has since been driven by the effects of the oil spill, as well as a strong local interest and the high potential for collaboration. Following a lead gift by The Mosaic Company Foundation to fund a pilot oyster reef restoration project in the northern portion of the estuary, TNC funded and worked with the Charlotte Harbor National Estuary Program (CHNEP) and the Southwest Florida Oyster Restoration Working Group (SWFOWG) – made up of local partners with experience and knowledge in various aspects of oyster reef restoration – to develop the first estuary-wide, science-based oyster habitat restoration plan in Florida.

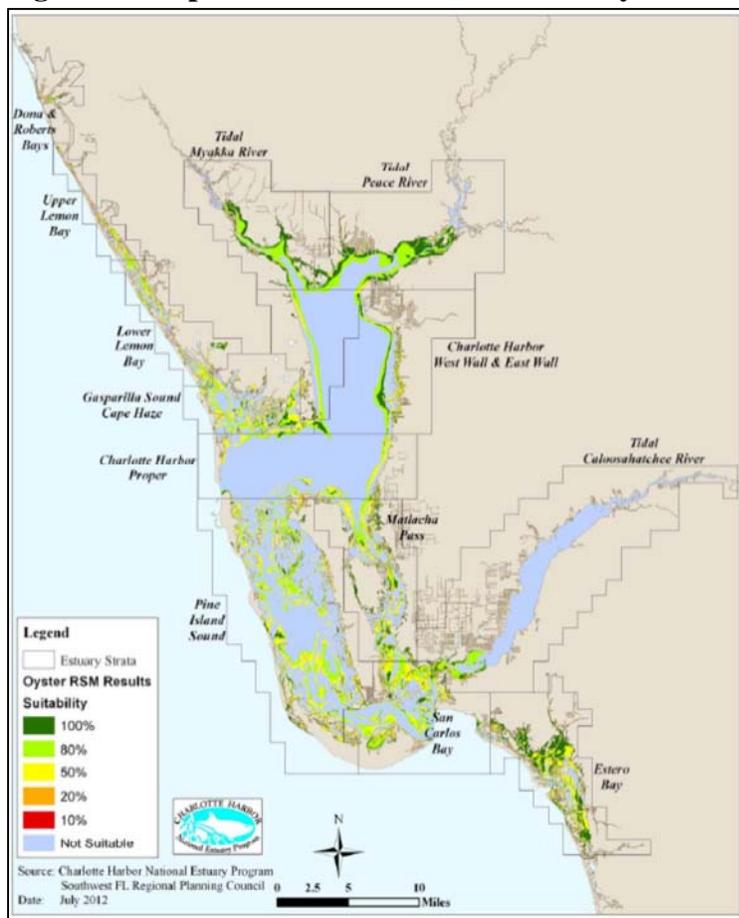
In December 2012, the CHNEP Management Conference approved the Charlotte Harbor Oyster Habitat Restoration Plan (Boswell *et al.* 2012). The plan contains a Restoration Suitability Model that spatially defines potentially suitable areas in Charlotte Harbor for oyster reef restoration

based on 5 criteria: bathymetry, tidal river salinity isohalines, seagrass persistence, proximity to boat channels, and presence of aquaculture lease areas. Output from the Restoration Suitability Model indicated that there is over 40,000 acres of highly suitable area for oyster restoration within the Charlotte Harbor System (Figure 1).

The plan’s long-term project objectives include establishing vibrant and growing oyster reef habitat in the Charlotte Harbor System with a restoration goal of 1,000-6,000 acres of oyster habitat.

The following sections describe how the pilot project helps meet the plan’s objectives. The project design, materials, and construction methods are described in detail to document the project as a reference guide for TNC and others who may want to apply the same methodologies.

Figure 1. Output of the Restoration Suitability Model (from Boswell *et al.* 2012).



Project Design

Site Selection

In 2013, using the Restoration Suitability Model from the oyster habitat restoration plan, TNC considered sites for a pilot project that fell within the 80-100% suitability range in the northern region of the Charlotte Harbor estuary. There was no known oyster restoration activity in this region yet there were large areas ranked in the 80-100% suitability range. Around the same time, TNC held a workshop in the City of Punta Gorda on ways to improve coastal resilience in the Charlotte Harbor area in the face of accelerating sea level rise and provided hands-on training using the suite of spatially explicit, web-based tools that TNC has made available on the CoastalResilience.org website. As

part of this workshop, we discussed how to improve the resilience of shorelines with natural habitats and used oyster reef restoration or construction as an example. Participants were asked to place colored dots on a map of Charlotte Harbor indicating good places to put oyster reefs to support shoreline resilience. The Trabue Harborwalk area was identified by multiple people as a suitable site.

TNC's project team (Anne Birch, Laura Geselbracht and Andrea Graves) in collaboration with other members of the SWFOWG visited several potential project sites in Charlotte Harbor including those recommended as part of the Coastal Resilience workshop. In addition to being in an 80-100% high suitability area, project collaborators looked for sites with a likely source of oyster larvae (e.g., nearby live oysters), good access to accommodate project construction, adjacent to public land, good public visibility, and supportive local government partners. The Trabue Harborwalk site fit all these criteria and TNC, with help from partners, pursued permitting at this site.

Site Design and Restoration Methods

The Trabue Harborwalk was designed as a pilot project to test 3 different intertidal oyster habitat restoration methods: oyster bags, oyster mats and loose shell enclosed by oyster bags. These methods have been used for oyster restoration projects in other estuaries and shown to be successful in providing substrate where oyster larvae can attach and grow. Oyster bags and loose shell have been used in many locations throughout Florida and beyond. This is not the case for oyster mats, which is a method that had only been used in one location prior to the Trabue project. TNC partnered with the University of Central Florida and others to successfully restore oyster reefs using oyster mats in the Mosquito Lagoon located on the central east coast of Florida. At the time of project development, the Trabue site was the first location outside of the Mosquito Lagoon to test the suitability of this method.

A total of nine (9) small intertidal reefs were planned (3 reefs of each method). The original reef layout was modified prior to deployment due to the presence of low density seagrass at the site. A much larger area than was needed was permitted to allow for maximum flexibility in project design and future expansion of the project. Within this larger permit area, specific reef locations were chosen to avoid and minimize impacts on the seagrass as illustrated in Figure 2. One of the planned reefs was inadvertently located outside of the permit area boundaries (see far left of map at Site C). This small deviation in reef placement was accepted by the permitting agencies. All seagrass present within the reef footprints at Sites B and C were transplanted to the seagrass receiving areas identified in Figure 2. At Site D, under the pier at the end of Adrienne Street, no seagrass was present at the time of reef materials deployment.

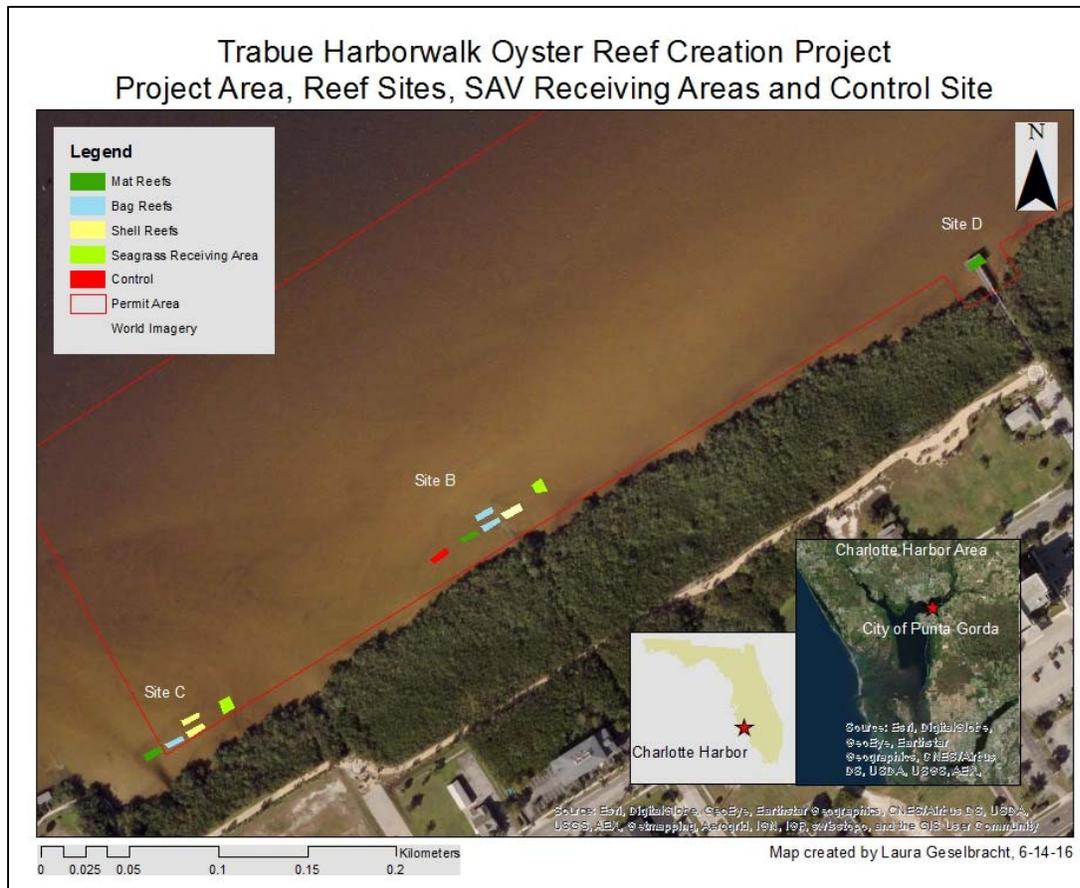


Figure 2. Location of constructed reefs, control area and seagrass receiving sites at Trabue Harborwalk oyster reef restoration site, Punta Gorda, Florida

To measure the success of the 3 different restoration methods, a monitoring plan was developed for the project that included pre- and post-installation monitoring of the reefs. To accurately assess the live oyster recruitment on each reef type, sampling trays that could be easily removed during the monitoring events were installed at each reef site. The monitoring is described in more detail later in this report.

Reef Materials Selection, Preparation and Deployment

Reef Materials Selected for Testing

Loose Shell and Oyster Bags

Due to limitations on the availability of recycled oyster shell, fossilized shell was identified as a suitable alternative for the oyster bags and loose shell reefs. The fossilized shell was sourced from SMR Aggregates, a sand mining operation in Sarasota, FL where shell is a byproduct; and provides a clean cultch material (Figures 3 and 4B). More than 45 tons of fossilized shell was used to create the reefs. The shell material was ordered in two different grades, medium and large washed shell, to test which worked best for creating the shell-filled bags used to create the reefs. The large shell size was preferable because it allowed for “nooks and crannies” within the bags for recruitment and resulted in a lighter overall bag weight. The oyster bag material (bag mesh) is a flexible ¾ inch plastic diamond mesh material (Naltex DuroNet, Item 1142, by DelStar

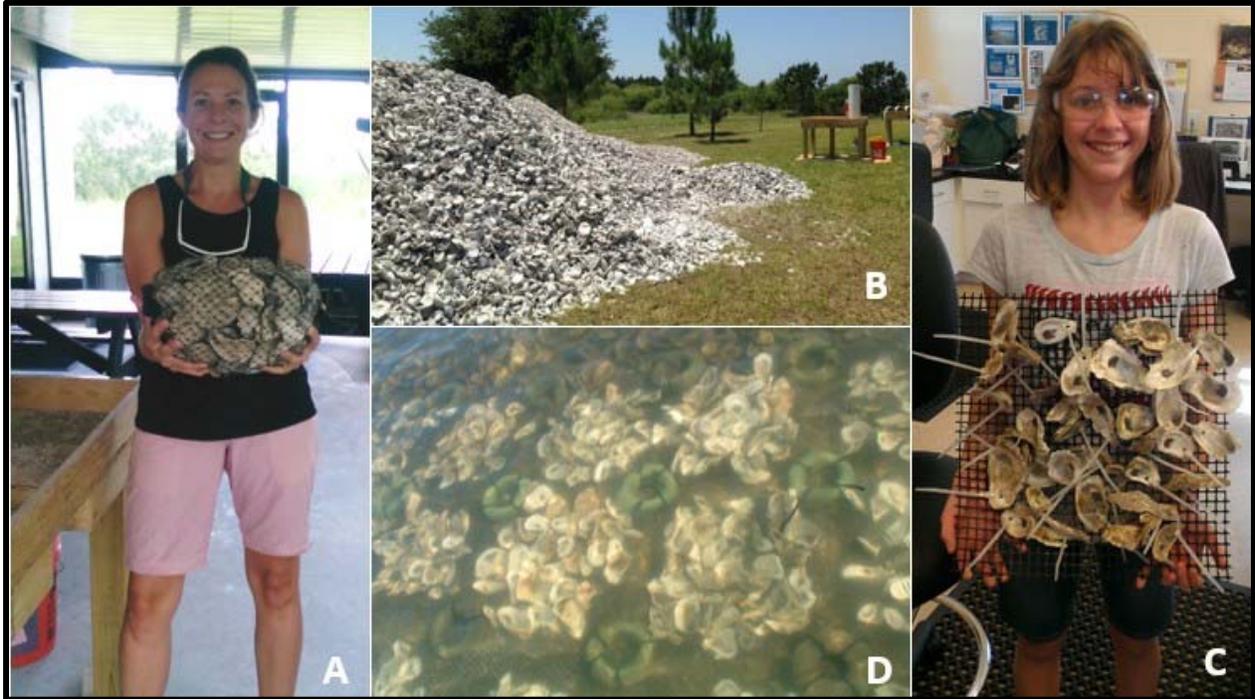
Technologies Inc.), which comes in a continuous roll or “sleeve”. Two different size bags were constructed, a larger size used to construct the bagged reefs and a smaller size used as a border around the loose shell reefs. The filled larger bags were approximately 60 cm long, and 15-25 cm in diameter and the filled smaller bags were approximately 25 cm long, and 15 cm in diameter (Figure 4A). This commonly used bagged shell method keeps the shell material together allowing time for new oyster recruitment to settle on and encase the mesh material.



Figure 3. Sample large washed shell from SMR Aggregates.

Oyster Mats

Recycled oyster shell donated by Clamtastic Seafood, Inc., a shucking house in Cedar Key, Florida, was used to construct the oyster mats. The shell was quarantined for six months to prevent the spread of oyster pathogens between areas. The mat material used was Vexar, an aquaculture grade plastic material on which recycled oyster shells were attached using 7-inch length, 50 lb clear cable ties (Figure 4C). Approximately 1,400 “donut weights”, typically used in irrigation to protect sprinkler heads, were used to secure the mats to each other. These weights are composed of cement and circular in shape with an open middle (Figure 4D). The donut weight dimensions are approximately 15 cm in diameter and 2 cm high and weigh approximately 1 kg each.



© (a) FDEP; (b & c) Kate Aug; (d) Anne Birch

Figure 4. Material formats used for Trabue Harborwalk oyster reef restoration project: bagged fossil shell (A), loose fossil shell (B), mats with recycled shell attached (C) and mats with donut weights attached in water (D).

Materials Preparation

TNC contracted with the FDEP-CHAP to coordinate community volunteers to assemble the oyster bags and mats. The FDEP-CHAP hired a part-time Volunteer Coordinator, Kate Aug, in January 2016 for a 7-month period. All the materials needed for assembly were stored at a vacant lot in the City of Punta Gorda. The City donated use of the lot for this project. The assembled materials were also stored at this location prior to deployment. The FDEP-CHAP provided office space for the Coordinator and space for material storage and hosting volunteers to help with assembly of bags and mats. Volunteer events to assemble the mats and bags were held at the FDEP-CHAP Burnt Store Road location. Kate also held events at schools and other locations around the City.

Oyster Mat Assembly

The oyster restoration mats used in the project were created by attaching 36 oyster shells of various sizes to a 40 cm by 40 cm sheet (0.16 m²) of the mesh material. This design was originally developed and tested by Dr. Linda Walters, University of Central Florida. A hole was first drilled in each shell to accommodate the cable ties. The shells were attached to the mat material in the same orientation as live oysters on reefs (perpendicular to the substrate, not lying flat on the mesh) using cables ties as noted above. The ends of the cable ties were trimmed close to the shell to reduce the amount of plastic in the



environment and prevent an unnatural appearance to the reef from cable tie ends sticking out of the water. Volunteers assisted with all aspects of mat making, including drilling shells, cutting mesh and attaching shells to the mats.

Oyster Bag Assembly

Prior to bag assembly custom “bagging tables” were designed and built by a project volunteer. The method for bag construction is shown in Figure 5. The process consisted of shoveling fossilized shell into 5-gallon buckets, which were then emptied on the table and pushed into holes that fed into PVC tubes (approximately 20 cm in diameter). The tubes were pre-covered with bag mesh cut from rolls with the bottom end tightly knotted. Once the bags were filled the PVC tube was removed, the top end of the bag was tied and the knot ends were trimmed. The shell bags were stacked and later transported by truck to the storage site, with help from volunteers in loading and unloading the bags.

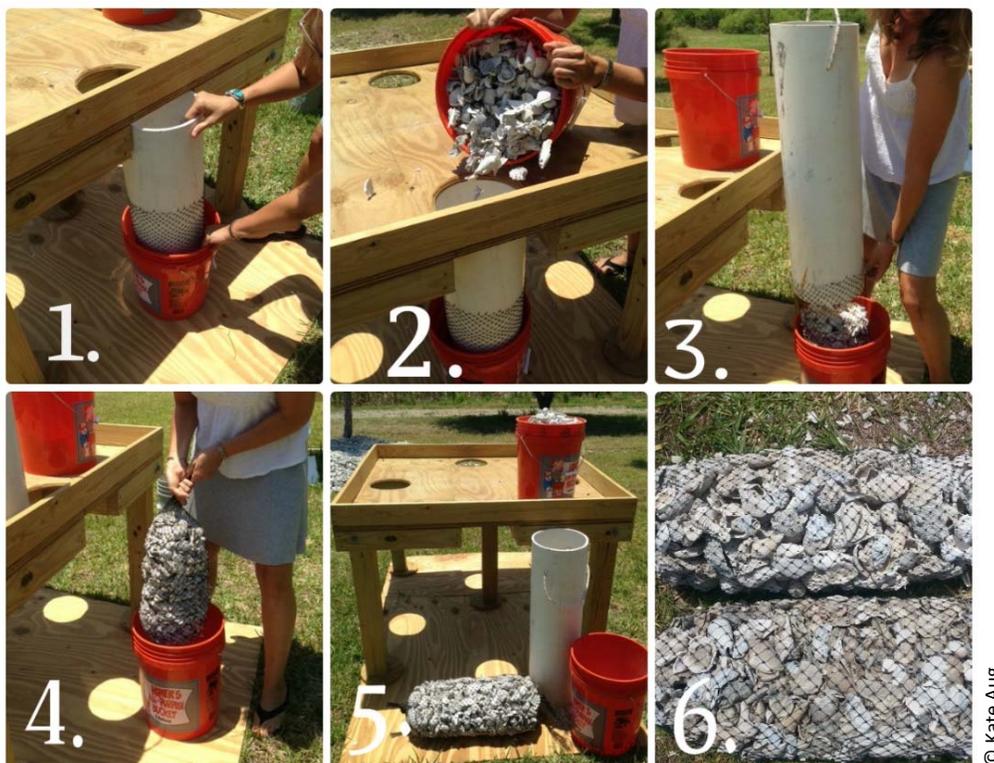


Figure 5. Steps to making an oyster bag.

Materials Deployment

Deployment Contractor

Reef Innovations, Inc. was contracted by TNC to deploy all reef materials to the reef sites. Volunteers were on site throughout the deployment to unload materials from the barge and place them into the pre-marked reef footprints.

Timing

Originally, the project team had planned to initiate reef deployment in late spring/early summer of 2015 to get the reef materials in the water prior to likely peak larval presence. While no oyster larvae surveys have been collected in the Lower Peace River, Volety *et al.* (2010) conducted larval surveys in the Lower Caloosahatchee River and found peak presence began to build in spring, peaked in August and declined until bottoming out in December. The period of December through March was found to have little to no oyster larvae present. Just prior to conducting the pre-deployment survey required by the permit, seagrass presence was noted in the project area. Deployment was delayed hoping the transient species observed, *Ruppia maritima* (common name widgeon grass), would subside during the colder winter months. When this did not happen, the project team talked to the permitting agencies and developed a mitigation strategy. The reef design was modified to avoid as much seagrass impact as possible and any existing seagrass in the reef footprints was transplanted by volunteers prior to installing the reef materials. After the new/revised permits were approved and issued in the fall, the project moved forward. In late August 2015, reef materials were deployed with the assistance of volunteers as described in the next section. Materials deployment, including placing sampling trays to be used in the post construction monitoring, was completed on October 16, 2015.

Reef Construction

During reef installation, the oyster mats were laid side by side in a grid system and a cement “donut” weight was placed at all corner intersections of the mats and along the outer edges to connect the mats with each other and ensure they stayed in place. A donut weight was attached to each mat corner using a 36 cm long, 54 kg test weight black cable tie. The final step was to trim the ends of the black cable ties close to the weight to reduce the amount of plastic in the environment and prevent an unnatural appearance to the reef from cable tie ends sticking out of the water. To create the oyster bag reefs, the larger size bags were unloaded from the barge, passed by a line of volunteers, then carefully placed side-by-side in a single layer within the reef footprint.

For the loose shell reefs, the perimeter was created by laying the smaller size oyster bags end-to-end to prevent the loose shell from spreading. This method has been successfully implemented by the Sarasota Bay Estuary Program. Bags were placed along the edge of the reef footprint with the deep side of the area left open. Loose shell was then shoveled from a barge and raked into place to form a consistent base with a depth of approximately 30 cm. The final step was to close the remaining reef edge with oyster bags.

Sampling Trays

After reef construction was completed, sampling trays were installed at each of the 9 reefs. These trays served as fixed quadrats to assess live oyster and macro-invertebrate density at each reef type. Nine trays were placed around the perimeter of each reef using a random number generator and then anchored to the bottom sediment. Each tray contained a sample of the material of the reef type it was deployed on: loose shell, bagged shell, or oyster mat. The trays and contents were collected during each monitoring event. Following monitoring events, the oysters collected from the reef were returned to the tray and reef to minimize impacts to the reef and future sampling efforts.

Monitoring Plan Overview

In 2014, in collaboration with partners, TNC developed the “Oyster Habitat Restoration Monitoring and Assessment Handbook” (Baggett et al. 2014). The purpose of this document is to provide guidance for assessing the condition of restored oyster reefs to standardize the metrics collected and their method of collection. Both universal and other optional metrics are identified in the handbook to accommodate the various levels of project resources available for monitoring. A monitoring plan (Appendix A) was prepared for the Trabue Harborwalk Project based on the metrics recommended in the above described handbook. The monitoring plan was updated as the project evolved. The selected metrics were collected at the reef sites and a control site. A control site mimics the pre-restoration conditions at the project site. No reference oyster reef could be identified near the project site (Lower Peace River) although considerable effort was put into locating one. A reference site is one that has the characteristics of a healthy reef that is desired post-restoration. All the universal metrics recommended in the Handbook were included in the Trabue Harborwalk Monitoring Plan as well as several additional metrics as described below. The specific methods employed are contained in Appendix A.

Universal Metrics Included in the Trabue Harborwalk Oyster Reef Restoration Monitoring Plan

- Project footprint and reef area
- Reef height
- Live oyster density
- Oyster size frequency

Universal Environmental Variables

- Water temperature
- Salinity
- Dissolved oxygen

Selected Additional Metrics Contained in the Project Monitoring Plan

- Water clarity/turbidity
- Oyster cluster formation
- Invertebrate use of the reef
- Macroinvertebrate infauna
- Waterbird utilization of the reefs
- Habitat stability, accretion/erosion between reef and mangrove shoreline
- Submerged aquatic vegetation
- Entanglement monitoring

To assist with the monitoring, TNC contracted with Friends of the Charlotte Harbor Aquatic Preserves who in turn contracted with Ford Walton a recently retired, longtime Florida Department of Environmental Protection employee with decades of field experience working in bays and estuaries.

*Selected Additional Monitoring Conducted by FWC
(This metric is not included in the Project Monitoring Plan)*

- Presence/absence of juvenile smalltooth sawfish

The federally endangered smalltooth sawfish, *Pristis pectinata*, resides and reproduces in Charlotte Harbor, Florida, which has been designated as critical habitat for this species. This fish, once ubiquitous throughout southeast U.S. estuarine and nearshore waters, is now mostly limited to Charlotte Harbor and Florida Bay. Sawfish are known to pup in Charlotte Harbor and juveniles are regularly found near the north shore of the Lower Peace River across the river from the project area. It is currently unknown if oyster reefs enhance the survival of sawfish by providing food or other services, or reduce the availability of the ecosystems they prefer. It is also unknown the extent to which juvenile sawfish utilize the project area. The Florida Fish and Wildlife Conservation Commission (FWC) has been studying sawfish in the Charlotte Harbor area for several years using a variety of approaches including tagging and tracking using acoustic transmitters and receivers. To better understand whether juvenile sawfish utilized the project area prior to installation of reef materials and the extent to which oyster reefs might influence their behavior, TNC contracted with FWC to conduct a tracking survey of juvenile sawfish in the project area. The first year of monitoring (2014) focused on whether the juvenile sawfish utilize the project area. The sawfish were both passively tracked via stationary listening stations and actively tracked over a 24-hour period to better understand their diel movements. The second year of monitoring focused on whether and how the presence of the constructed reefs influenced their behavior.

Results One-Year Post Installation

Monitoring Results

At the time of this report, pre-installation, post-installation (immediately following reef construction) 6-months post-installation and 1-year post-installation monitoring have taken place. The dates that these monitoring events took place are as follows: pre-installation monitoring, August 17 – 18, 2015; post-installation monitoring, September 28-29; 6-months post-installation monitoring, May 3-5 and May 13, 2016; and 1-year post-installation monitoring November 14-16, and November 29, 2016. The results of these monitoring efforts are described below:

Universal Metrics Included in the Trabue Harborwalk Oyster Reef Restoration Monitoring Plan

- Project footprint and reef area – These metrics were collected during the post-installation monitoring (soon after installation) and at the 6-months and 1-year post-installation monitoring events. Due to the design of the reef layout, project footprint and reef area are one in the same. No significant changes were anticipated and none were observed. Coordinates and measurements from these monitoring events are included in Appendix B (Tables B-1 through B-3) and are summarized in Table 1 below.

Table 1. Reef area at post-installation, 6-months post-installation and 1-year post-installation using a tape measure (and ultrasonic device on the 1-year monitoring).

	Post-Installation with Tape Measure (m²+/- 25 cm²)	6-Months Post-Installation with Tape Measure (m²+/- 25 cm²)	1-Year Post-Installation with Tape Measure (m²+/- 25 cm²)	1-Year Post-Installation with Ultrasonic Device (m²+/- 25 cm²)
Reef Area	356	353	353	353

- Reef Height - These metrics were collected during the post-installation monitoring and at the 6-months and 1-year post-installation monitoring. Some changes from the post-installation monitoring were observed and are summarized in Table 2 below (see also Figure 6). Averaged height measurements for each reef during each sampling event are included in Appendix B (Tables B-4 – B-6). Conditions during collection of the 6-months post-installation data were windy causing wave chop that made collection of reef height data during high tide challenging. Consequently, the measurement procedures for reef height were modified by collecting the data at low tide. Wave chop is now less of a concern and increased confidence in the revised methodology. At the time of the 1-year post-installation monitoring, mat reefs and bagged shell reefs lost height (-3.7 cm and -5.4 cm, respectively) due to settlement into the underlying sediments. We know the result of lost reef height was primarily due to settling versus sedimentation because trays with reef materials placed in the same areas remained mostly on top of the sediments (see discussion of sampling methods changes under oyster density below). The measured difference in the loose shell reefs from installation to approximately 1 year later was 1.7 cm, likely falling within the range of sampling error. Additional, years of monitoring will clarify whether the changes observed in reef height are a trend.

Table 2. Reef Height at post-installation and 6-months and 1-year post-installation of reef materials (SD = standard deviation)

Station	Type	Average Height at Installation (cm)	Average Height After 1 Year(cm)	Difference	Average Difference by Type (cm)	Percent Change
C1	Mat	9.9	5.7	-4.2		
B5	Mat	7.9	5.4	-2.5		
D9	Mat	8.0	3.6	-4.4	-3.7	-45%
	SD:	0.9	0.9			
B8	Shell	14.7	13.4	-1.3		
C3	Shell	10.5	14.3	3.9		
C4	Shell	12.6	15.2	2.5	1.7	+13%
	SD:	1.7	0.7			
C2	Bag	16.9	11.3	-5.6		
B6	Bag	16.8	12.7	-4.2		
B7	Bag	19.8	13.4	-6.4	-5.4	-31%
	SD:	1.4	0.9			

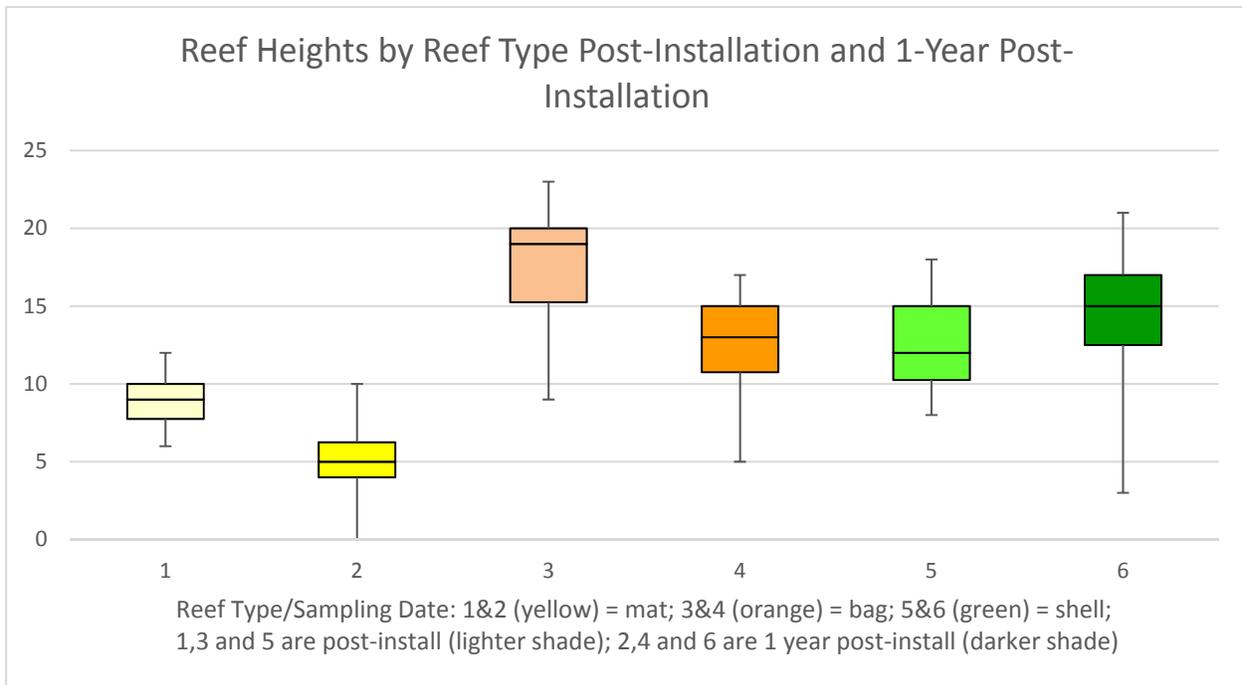


Figure 6. Change in reef height at installation and after 1 year.

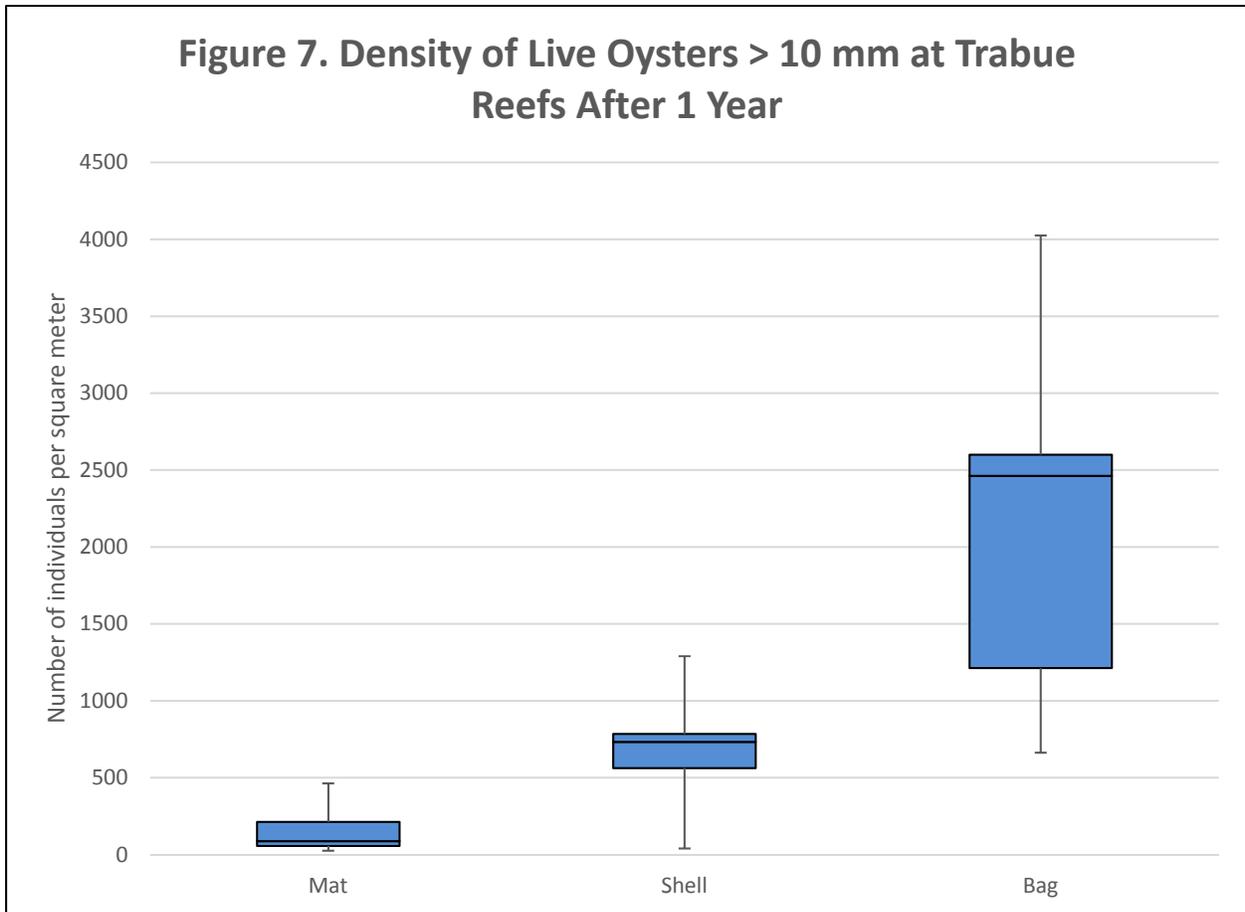
- Live oyster density - Our initial sampling method employed a sampling tray filled with the reef material. Trays were pre-placed randomly along the perimeter of the reef and randomly selected for processing at the time of sampling. Sample trays were only processed once during either the 6-months or 1-year sampling events. As a means of testing whether sampling trays were influencing recruitment results (i.e., reducing the settling of materials into the sediments), sampling during the 1 year sampling event was also conducted on randomly selected reef material removed directly from the reefs (i.e., no sampling tray). The results indicate that the sampling trays did have an impact on results. Sampling tray impacts were most notable on the mat reefs where 348 recruits/m² were observed with the sampling trays versus 154 recruits/m² without sampling trays (Table 3). The sampling trays also had a large effect on bagged shell results (4,494 recruits/m² with the trays versus 2,186 recruits/m² without the trays). The sampling trays had less effect on the loose shell reef results (950 recruits/m² with the sampling trays and 714 recruits/m² without the trays). Below, we use the “no sampling tray” results to evaluate reef success. Overall, the bagged shell reef performed the best on a per area basis (Table 3; Figure 7).

The CHNEP Oyster Restoration Plan (Boswell et al. 2012) identifies three levels of goal-specific success criteria for oyster reef restoration in Charlotte Harbor based on live oyster density: Level I, 0-200 live oysters per m², Level II, 200 – 800 live oysters per m² and Level III, 800 – 4000 oysters per m². Based on these success criteria, the mat reefs achieved Level I success (149 live oysters/m²), bagged shell reefs achieved Level II success (714 live oysters/m²) and the loose shell reefs achieved Level III success (2,186 live oysters/m²) (Table 3). This rating scheme was not, however, intended to measure levels of success, but rather serve as tool to communicate basic information on a system’s ecological health (Volety *et al.*, 2009).

We suggest establishing a restoration target, as recommended by Dr. Loren Coen (pers. comm. on 1/24/17), based on observations of oyster densities on natural reefs located nearby the restoration project. As no reference reef could be identified near the Trabue reef restoration area (i.e., the Lower Peace River), we used the densities found on reference reefs at three sites further south in the Charlotte Harbor system as observed by the Sanibel Captiva Conservation Foundation (SCCF). The average density of live oysters at the three reference reefs in the southern portion of Charlotte Harbor (Matlacha Pass, San Carlos Bay and Tarpon Bay) prior to restoration taking place in these areas ranged from 413 to 1488 oysters/m² (Mark Thompson, SCCF, pers. comm.) Given these results, we set our success target at the lowest of these measured reference densities, 413 oyster/m². Recruitment (live oysters > 10 mm) exceeded this restoration target on the bagged shell and loose shell reefs (2,186 recruits/m² and 714 recruits/m², respectively) and fell short on the mat reefs (154 recruits/m²; Table 3; Figure 7). Detailed results are presented in Appendix B, Table B-7.

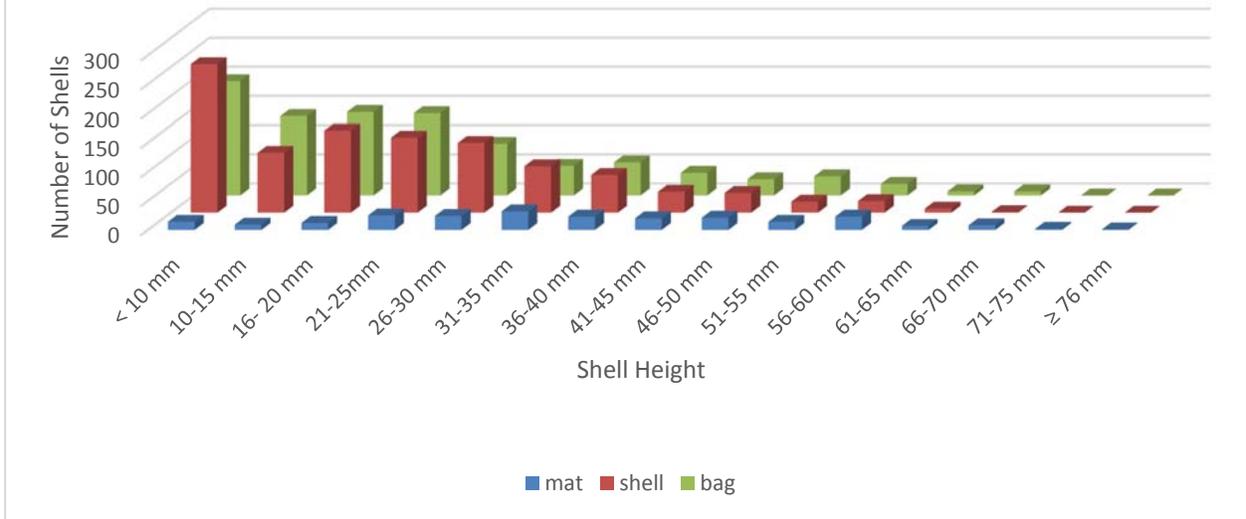
Table 3. Average density of oyster recruits (live oysters > 10 mm in length) by reef type. Standard deviations (SD) are included.

Reef Type	6 months with sampling tray (recruits/m²)	SD	1 year with sampling tray (recruits/m²)	SD	1 year no sampling tray (recruits/m²)	SD
Mat Reefs	307	90	348	211	154	149
Loose Shell	482	216	950	309	714	364
Bagged Shell	1,760	990	4,494	2,055	2,186	1,040



- Oyster size frequency – Recruit (>10 mm) shell height was measured for up to 84 oysters per sample. Samples randomly collected directly from the reef were used (i.e., not in sampling trays). Oysters with a height less than 10 mm were recorded as “spat”. Shell heights of live oysters for each reef type were placed into the size classes recommended in the Monitoring Handbook and included in the Monitoring Plan (<10 mm (spat); 11-15 mm; 16- 20 mm; 21-25mm; 26-30 mm; 31-35 mm; 36-40 mm; 41-45 mm; 46-50 mm; 51-55 mm; 56-60 mm; 61-65 mm; 66-70 mm; 71-75 mm; and, ≥ 76 mm; See detailed results in Appendix B, Table B-10). A histogram of the results is illustrated in Figure 8). The 3 reef types all showed the presence of multiple size classes. The bagged shell and loose shell reefs, however, had a greater concentration of oysters in smaller size classes which indicates strong, continuing recruitment and actively growing reefs.

Figure 8. Year 1 Size Frequency Distribution of Live Oysters by Reef Type (no tray samples)



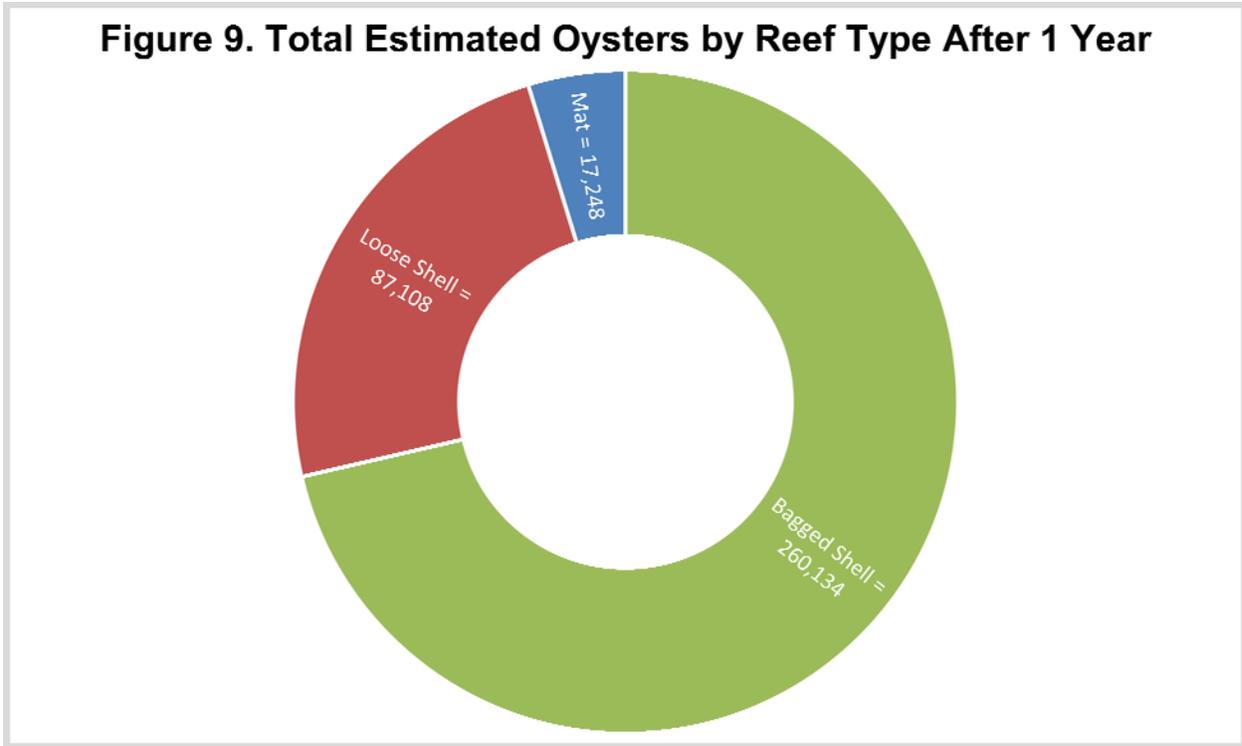
- Total estimated live oyster recruits by reef type – The number of live oyster recruits (>10 mm) from the samples randomly collected directly from the reef (i.e., no sampling tray) varied by reef type (Table 4; Figure 9). In general, the mat reefs had the fewest recruits and the bagged shell reefs had the most recruits. The number of recruits on the loose shell reefs fell in between the other two reef types. Total live oyster recruits by reef type were estimated at 17,248 for the mat reefs, 87,108 for the loose shell reefs and 260,134 for the bagged shell reefs (See Appendix, Table B-11 for more detailed results). Total estimated oysters produced at reefs at the 1 year mark were estimated to be 364,490 (Table 4). The range in the number of oysters generated by each reef type is likely mostly due to two factors: surface area available for larval settlement and propensity of the material to settle into the sandy-mud substrate.

Table 4. Total estimated live oyster recruits by reef type*

Reef Type	Total Estimated Recruits
Mat	17,248
Loose Shell	87,108
Bagged Shell	260,134
TOTAL:	364,490

*Data are from samples collected directly from the reef (i.e., not from sampling trays)

Figure 9. Total Estimated Oysters by Reef Type After 1 Year

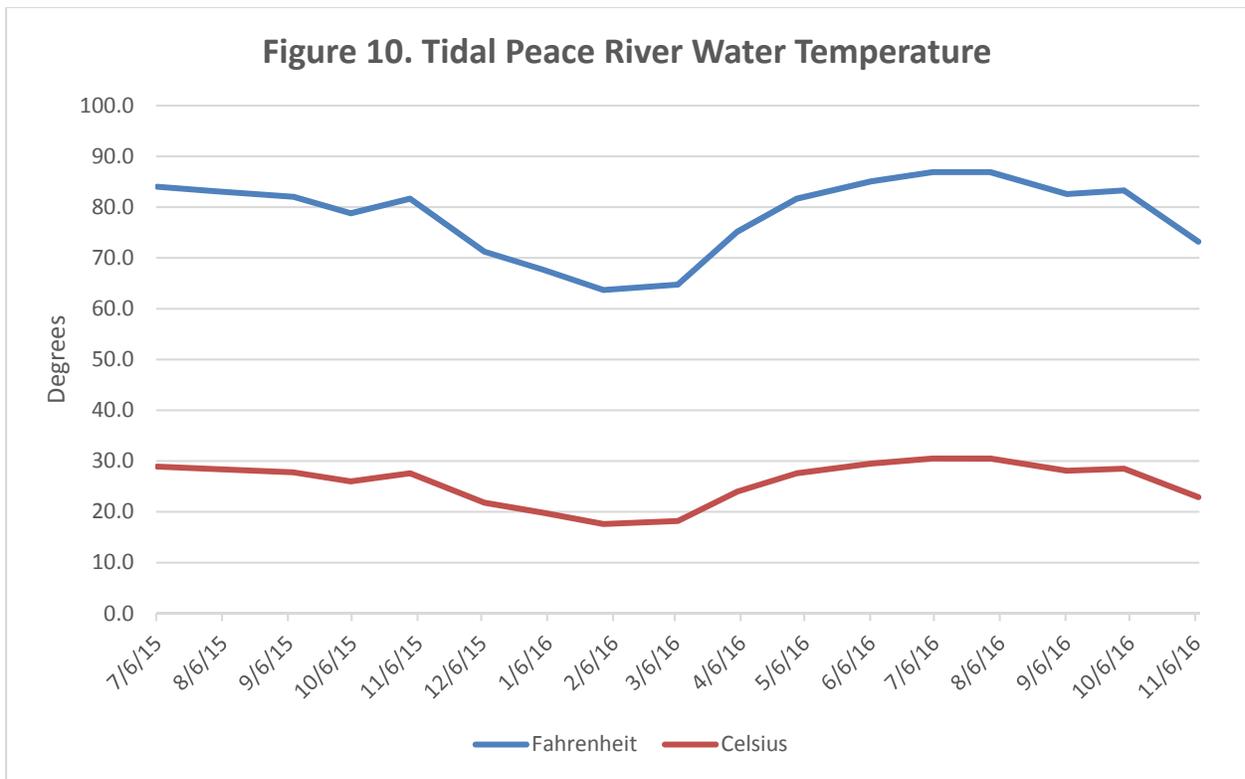


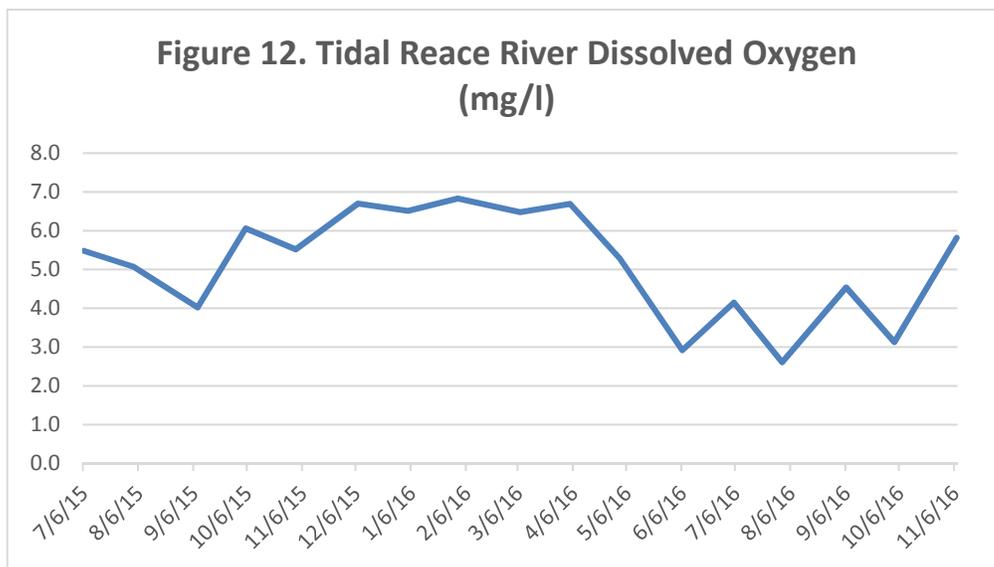
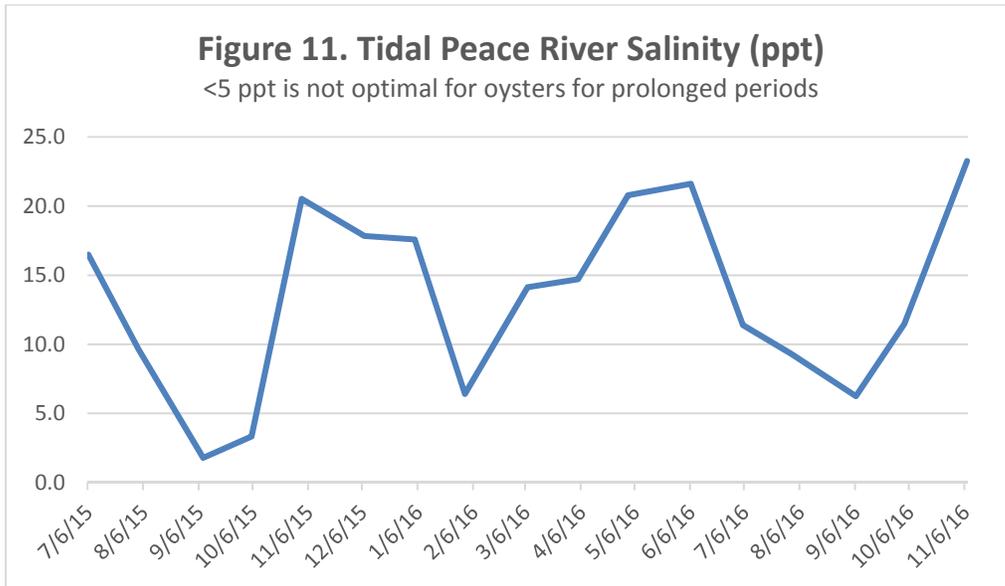
Universal Environmental Variables

- Water Temperature, salinity and dissolved oxygen – Water temperature, salinity and dissolved oxygen vary seasonally in the Lower Peace River. Data on these parameters are collected by Florida Department of Environmental Protection’s Charlotte Harbor Aquatic Preserves as part of the Charlotte Harbor Estuaries Volunteer Water Quality Monitoring Network. All Network data is collected at sunrise. The Network’s regular monitoring site in the Tidal Peace River at Gilchrist Park (site CHV006) is approximately 1.5 kilometers downstream of the Trabue Harborwalk reefs. A comparison of monitoring data taken at both the Trabue Harborwalk reefs and Gilchrist Park showed no appreciable difference so water quality sampling at the Trabue Harborwalk restoration site was discontinued.

Over the approximately one year deployment period, September 2015 to November 2016, water temperature at Gilchrist Park ranged from a low of 18°C in the winter/early spring months to a high of nearly 31°C in the summer and early fall months (Figure 10; see also Appendix B, Table B-13). Salinity in the Lower Peace River is most directly affected by rainfall in the Peace River watershed. Over the 1 year period following deployment, salinity ranged from 1.8 ppt to 21.6 ppt (Figure 11). Salinities below 5 ppt are not optimal for oysters and may explain the reduced numbers of live oysters that we observed at the project site in the summer of 2015 prior to reef installation. Dissolved oxygen (DO) ranged from 2.6 to 6.8 mg/l (Figure 12). A DO level <2 mg/l is known to adversely impact the settlement, growth, and survival of oysters (e.g., Baker and Mann 1992; Johnson et al. 2009) when these levels are sustained. High sustained salinities can also

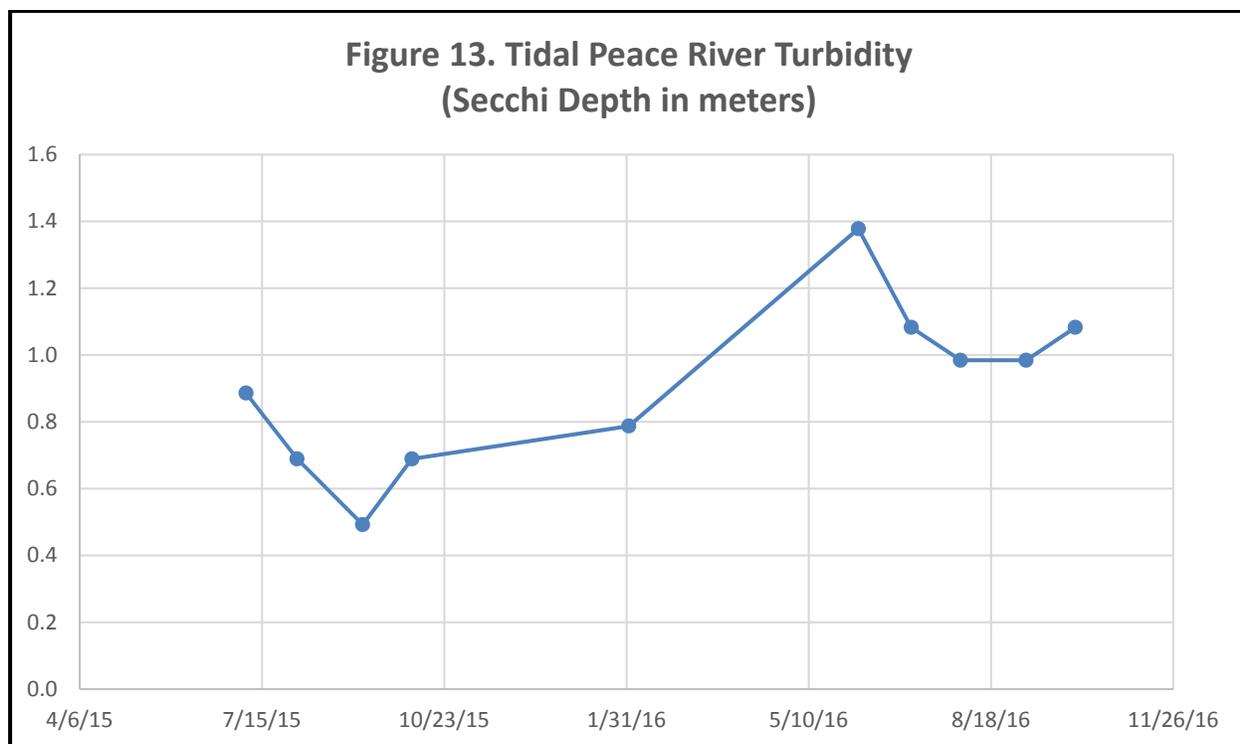
result in greater instances of disease and predation as found by Ewart and Ford (1993), Shumway (1996) and Bobo et al. (1997).





Selected Additional Metrics

- **Turbidity** - One other water quality parameter was measured near the project site, turbidity. This metric is also collected regularly by FDEP-CHAP’s Charlotte Harbor Estuaries Volunteer Water Quality Monitoring Network at their Tidal Peace River site at Gilchrist Park (site CHV006). Turbidity varies seasonally as well with the lowest value of 0.5 m and the highest value of 1.4 m recorded over the study period (Figure 13). Turbidity is not likely to adversely affect oysters, but by reducing turbidity locally, oysters can enhance SAV growth nearby.



- Live oyster cluster formation, no tray samples - A sign that the oyster mats are forming a reef structure are the number of bridges formed between shells attached to the mats. Five out of nine samples had bridge formations (see Table 5). Average bridge formation across all the mat samples was 1 which indicates that the reef formation is in its early stages.

Table 5. Oyster cluster formation on mat reefs at Year 1.

Reef ID/ Sample #:	D9-1	D9-2	D9-3	C1-1	C1-2	C1-3	B5-1	B5-2	B5-3	Average
Mat Bridge Count:	1	0	2	1	0	0	0	3	2	1

- Invertebrate use of the reef, tray samples - Invertebrates were monitored using two metrics: macroinvertebrate epifauna presence and macroinvertebrate infauna presence. Invertebrate epifauna presence was monitored at the reef sites during the reef monitoring events and at the control site concurrently with the SAV surveys. Invertebrate infauna presence was monitored at the reef and control sites during all reef monitoring events. Results of the pre-installation, 6-months post-installation and 1-year post-installation surveys are presented below and in Tables 6 - 8.

Only qualitative epifauna surveys of the reefs were conducted prior to reef installation. The areas were comprised of mostly bare sediments with sparse SAV and tubeworms. During the pre-installation monitoring of SAV in areas adjacent to the reef sites (out to 50 feet, <15.24 m>), macroinvertebrate presence was recorded at 32 out of 74 transect stations or approximately 42%. Only tubeworms were recorded. Post-installation of the reef materials at the reef sites, invertebrate epifauna samples were collected from the same randomly selected trays as the oyster samples. Results are summarized in Table 6.

Observation of the sampling trays at the control site during the post-installation sampling events also revealed few macroinvertebrates except for some barnacles attached to the sampling trays.

Table 6. Summarized epifauna results (reef sites only).

Presence	6 mo.	6 mo.	1 year	1 year
Taxonomic Group/Number	Taxa	Individuals	Taxa	Individuals
Sipunculida	0	0	0	0
Nemertea	1	129	1	59
Polyclada	2	27	1	43
Oligochaeta	1	9	1	34
Polychaeta	8	754	8	698
Mollusca				
Bivalvia	8	180	5	137
Gastropoda	2	21	1	6
Crustacea				
Amphipoda	6	557	5	146
Isopoda	3	23	2	21
Tanadacea	1	23	1	43
Cirripedia	1	common	2	common
Decapoda	8	2776	5	2085
Sample Total:	41	4499	33	3136
Total Reef Estimate:				907,966

UA = unavailable. Species within the taxa were recorded as unidentified. No information was provided on the number of species. Common = Too numerous to count.

At approximately 6 months following reef installation, the number of macroinvertebrate epifauna taxa (excluding oysters) expanded at the reef sites from 1 to 41. The number of individual macro-invertebrates also expanded during this first post-installation survey. While we cannot quantify this change we can qualitatively describe it as a large increase in macroinvertebrate fauna taxa and individuals. Prior to reef installation, tubeworms were sparse. Six months after reef installation, the reef materials that were devoid of macroinvertebrate life upon installation became populated with a diversity and large number of invertebrates as reflected in Table 6. At 1-year post-installation, taxa and individual numbers were down as compared to observations recorded during the 6-months post-installation monitoring, but still well above the pre-installation observations. Barnacles, polychaete worms and the flat mud crab, *Eurypanopeus depressus*, made up most of the new macroinvertebrate epifauna present on the reefs. *E. depressus* is commonly found on oyster reefs in Florida (Boudreax *et al.* 2006) with oyster spat being an important food source (Kulp and Peterson 2013). On South Carolina oyster reefs, Grant and McDonald (1979) found that the population of *E. depressus* varies seasonally, recording up to 55 individuals/m² during their peak summer season falling to as little as 6 individuals/m² in the winter. Average density of *E. depressus* at the Trabue reef sites was 709 individuals/m² during the summer sampling (6-months post installation) and 534 individuals/m² during the winter sampling (1-year post-installation). While this is substantially higher density than what Grant and McDonald (1979) recorded, the mud

crabs at the Trabue reefs sites were still quite small (< 20 mm length), but can reach up to 130 mm in size (Boudreax et al. 2006). *E. depressus* is one of the most common species of mud crab present in areas frequented by redfish (Fernandez 2015), is an important food source for blue crabs, *Callinectes sapidus* (Kulp and Peterson 2013) and preys on barnacles (Meyer and Townshend 2000). See Table 7 for a summary of total numbers by reef type and for all the reefs as recorded during the 1 year monitoring event.

Table 7. Invertebrate epifauna summary by reef type and for all reefs after 1 year

Sample Results	MAT	BAG	SHELL	
Sample Number of Taxa, mean	15.3	9.8	8.6	
Sample Individuals, mean	108.4	133.1	106.9	
Sample Weight (gms), mean	24.0	68.7	32.4	
Sample Size (m ²)	0.16	0.18	0.08	
Portion of Reef Represented by Sample	0.00399	0.00439	0.00199	All Reefs
Total Estimated Number by Reef Type	27,199	30,351	53,618	111,168
Total Estimated Weight by Reef Type (gms)	6,028	15,668	16,253	37,949*

*Approximately 84 pounds.

In the pre-installation infauna surveys at the reef sites, a total of 22 taxa and 279 individuals were found (Table 8). Three reef sites had only 3 taxa, while Site C Bags (Site C2) had the greatest number of taxa at 11. Total number of individuals by site ranged from 3 at Site B Control to 104 at Site B Shell (Site B8). Most of the invertebrates found at Site B Shell (95 of 104) were the barnacle, *Balanus cf. improvises*, on a large dead *Crassostrea* shell. Taxa present in at least 5 of the 10 reef or control sites included *Melongena corona* (Crown conch), *Nassarius vibex* (Bruised nassa), *Amygdalum papyrium* (Paper mussel), *Macoma tenta* (clam), *Diopatra cuprea* (polychaete worm), *Neanthes succinea* (polychaete worm), *Cyathura polita* (isopod), and *B. cf. Improvisus*. Approximately six months after reef installation, the number of species observed was similar (22 in the pre-survey versus 24 in the 6-months post-installation survey), but the number of individuals observed declined by approximately 25% at the reef sites (279 individuals just prior to reef installation versus 208 individuals at 6-months post-installation). During the 1-year post reef installation sampling, the number of taxa remained consistent with 22 taxa observed, while the number of individuals present declined as compared to the preceding surveys with 123 individuals observed (a 56% decline from baseline conditions). The reduction in invertebrate infauna numbers at the reef sites post-installation as compared to pre-installation may be a result of anoxic conditions expanding under the reef materials, which would be expected.

Table 8. Invertebrate infauna survey results (reef and control sites).

	Pre-survey	Pre-survey	6 mo.	6 mo.	1 year	1 year
Taxon	Taxa	Individuals	Taxa	Individuals	Taxa	Individuals
REEF SITES						
Marine Worms	8	41	8	68	9	52
Molluscs	6	53	7	30	4	14
Crustaceans	8	185	9	110	9	57
TOTAL:	22	279	24	208	22	123
Reef total/9*:	2	31	3	23	2.4	13.6
CONTROL SITE						
Marine Worms	0	0	4	10	1	1
Molluscs	2	2	5	15	0	0
Crustaceans	1	1	6	10	0	0
TOTAL:	3	3	15	35	1	1

*Reef results are divided by 9 to be comparable to the control results (27 reef samples vs. 3 control samples)

Three species of macroinvertebrate infauna were observed at the control site during the pre-installation survey whereas 15 species were observed after 6 months and only 1 after 1 year. The number of infauna individuals seemed to follow a similar pattern with 3 individuals observed during the pre-installation monitoring, 35 observed after 6-months and 1 observed after 1 year. The greater number of species and individuals observed at the 6-months post-installation timeframe versus at the pre-installation monitoring and after 1 year, may reflect seasonal variations, environmental changes, or differences in sampling methods. A comparison of the control site with the reef sites also reveals fewer taxa and individuals at the reef sites, which as noted above may reflect the increasing anoxic conditions beneath the reef materials. A complete report on the macroinvertebrate surveys is available as Appendix C.

- Waterbird utilization of the reefs - Birds have been monitored 1-2 times per month since April 2014 by volunteers of the Peace River Audubon Society. Originally, the reefs were to be located just off the pier at Site D so bird surveys began from this pier. Due to a higher density of seagrass in this area at the time the reef materials were to be installed, the reef sites were moved further downstream to accommodate permit requirements. Once the reef materials were installed, a new bird observation area was established on the boardwalk overlooking Site C (Figure 14). Although pre-installation monitoring of the reef sites did not take place at the exact location of where the reefs were ultimately placed, the pre-installation observation area is similar in depth, sediment and proximity to mangroves and the restoration area. The pre-installation observations are useful for comparisons with the post-installation observations. Only half of the original pre-installation monitoring area is included to ensure that observation areas are comparable.

Location of Pre- and Post-Installation Monitoring of Bird Utilization of Reef Areas



Figure 14. Waterbird monitoring locations.

More individual birds were observed during the 1 year post-installation monitoring as compared to the pre-installation monitoring during the same timeframe one year apart, 465 versus 245 respectively (a difference of approximately 90%). However, a similar number of species were observed during both monitoring periods, 17 species during the pre-installation monitoring and 16 species during post-installation monitoring (Table 9). This relationship could change as post-installation monitoring continues. Of the 20 species of birds observed near the reefs sites over the 2 years of monitoring, 14 increased in number after 1 year of reef installation. A new control area is now being monitored to compare near reef observations with areas by no reefs.

Table 9. Comparison of pre- and post-installation bird observations at the restoration area over the same period (Nov – Nov) 1 year apart. Species highlighted in green increased in number.

Species/Observed Number of Individuals	Pre-Installation	Post-Installation
American oystercatcher, <i>Haematopus palliatus</i>		3
Brown pelican, <i>Pelecanus occidentalis</i>	1	6
Double-breasted cormorant, <i>Phalacrocorax auritus</i>		3
Boat-tailed grackle, <i>Quiscalus major</i>	1	
Great blue heron, <i>Ardea herodias</i>	1	13
Great egret, <i>A. alba</i>	3	21
Killdeer, <i>Charadrius vociferus</i>	6	
Belted kingfisher, <i>Megasceryle alcyon</i>	1	
Laughing gull, <i>Leucophaeus atricilla</i>	26	16
Lesser scaup, <i>Aythya affinis</i>	144	
Little blue heron, <i>Egretta caerulea</i>	23	32
Mottled duck, <i>Anas fulvigula</i>	5	39
Osprey, <i>Pandion haliaetus</i>	2	2
Red-breasted merganser, <i>Merqus serrator</i>		2
Ring-billed gull, <i>Larus delawarensis</i>	14	32
Snowy egret, <i>Egretta thula</i>	2	13
Spotted sandpiper, <i>Actitis macularius</i>	1	18
Tree swallow, <i>Tachycineta bicolor</i>	10	200
White ibis, <i>Eudocimus albus</i>	4	55
Yellow-crowned night heron, <i>Nyctanassa violacea</i>	1	10
TOTAL Individuals:	245	465
TOTAL Species:	17	16

- Smalltooth sawfish, *Pristis pectinate*, utilization of the reefs - The Florida Fish and Wildlife Conservation Commission (FWC) has been monitoring sawfish in the Lower Peace River as part of their grant with the National Marine Fisheries Service (NMFS) over the last several years. TNC provided some additional funding to FWC so that these grant funded studies could be extended to the portion of the Lower Peace River near the reef restoration area. In first year of our commissioned work (2014) and prior to reef installation, 24 juvenile sawfish were tagged in the Lower Peace River mostly near their known “hotspot” on the north side of the Peace River near where it intersects I-75.



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FWC found that during the day, the juvenile sawfish remained along the north shore of the Lower Peace River tending to be close (< 25 m) to mangrove stands (predominantly red mangroves). At night, sawfish left the north shore and headed toward the south shore of the Lower Peace River. Of the 24 juveniles tagged in the Peace River during 2014, 17 were detected on the acoustic receivers moored near the Trabue project area, nearly always at night (96%). Because of the information collected during TNC funded work, the sawfish hotspot in the Lower Peace River was extended to the entire area between the I-75 and US 41 bridges.

During a second year of monitoring and post reef installation (fall 2016 through spring 2017), a more intensive array of listening stations (which include receivers) was installed near the reef sites (Sites B, C and D; Figure 15). Nineteen juvenile fish were tagged and 11 were picked up by the receivers. The more intensive array of listening stations enabled triangulation of the results and a much more detailed assessment of where juvenile sawfish are traveling in relation to the reefs. Six of the fish picked up by the receivers were reliably detected by the listening stations. Overall, these fish did not exhibit a statistically significant preference for the restored reefs as compared to the surrounding sandy-mud flats with sparse seagrass (Poulakis et al. 2017). However, two of the juveniles observed were one-year-olds and demonstrated activity around and on top of the reefs (Figure 15). Additional years of research and more observations will be required to definitively determine the extent to which sawfish utilize the restored reefs as compared to other available ecosystems.

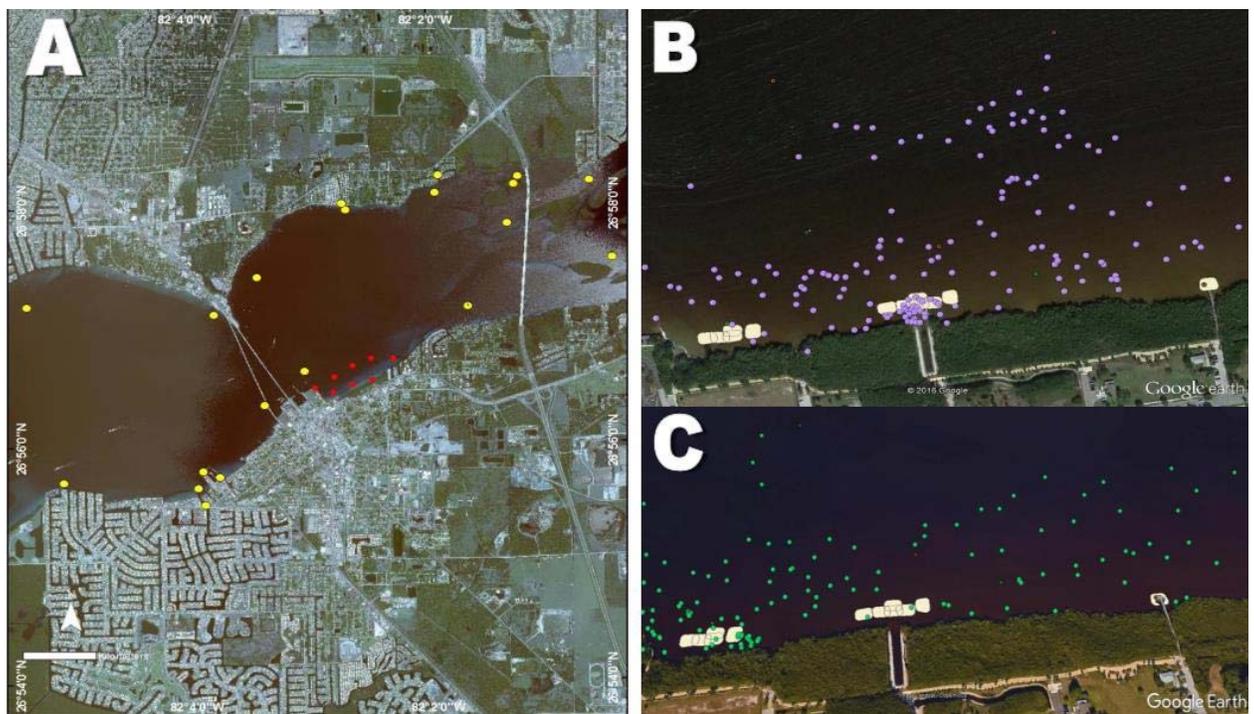


Figure 15. Acoustic receiver array (red and yellow dots) in the Lower (Tidal) Peace River between the US 41 and I-75 bridges (panel A). Red dots represent the TNC funded array. The yellow dot with the red circle is a receiver purchased with NMFS funds, but included in the receiver array around the restored reefs due to its proximity. Panels B and C illustrate the location of the two 1-year old juveniles in relationship to the reefs (yellow rectangles) over a 12 to 24-hour period.

Habitat stability - Accretion/erosion between reef and mangrove shoreline and change in distance between the reefs and the shoreline was surveyed on November 27, 2015 to collect baseline information. This date was selected because there was a negative tide during daylight hours (-0.13 m at 10:34 am). A negative tide was required for the intertidal area between the reefs and the shore to be exposed. Figure 16 below shows the transect lines (in black) used to conduct the two surveys. Existing markers such as the PVC reef corner markers and seagrass survey markers were used rather than adding additional markers to the intertidal zone or mangrove area. Photos were taken from the shoreline out to the reef along each survey line. An example of these photos

is provided below as Figure 17. The full set of transect photos is provided in Appendix D. The 1-year post-installation habitat stability surveys were conducted on November 29, 2016 to again take advantage of the negative tide during daylight hours. In addition to photo documentation, the distance between reef and shoreline at the point that emergent vegetation begins was measured along each transect. These distances are provided in Table 10 below. The methodology to collect shoreline position measurements changed over the course of the study to enhance accuracy. Tape measures were used for the initial measurements and an ultrasound measuring device was used during the 1 year monitoring. In addition, semi-permanent markers have been placed at the shortest distance where emergent vegetation is attached to the substrate (i.e., attached mangrove prop roots). to reduce future sampling error. Semi-permanent marker position will be adjusted as necessary where attached emergent position changes location prior to measuring shoreline position in the future. Use of the ultrasound device enhances accuracy somewhat by eliminating sag over a long distance. More importantly, the ultrasound device is much quicker and easier to use than a standard tape measure. Change, if it does occur, will likely not be discernable for at least a few years.

Shoreline Transects at Trabue Harborwalk Oyster Reefs

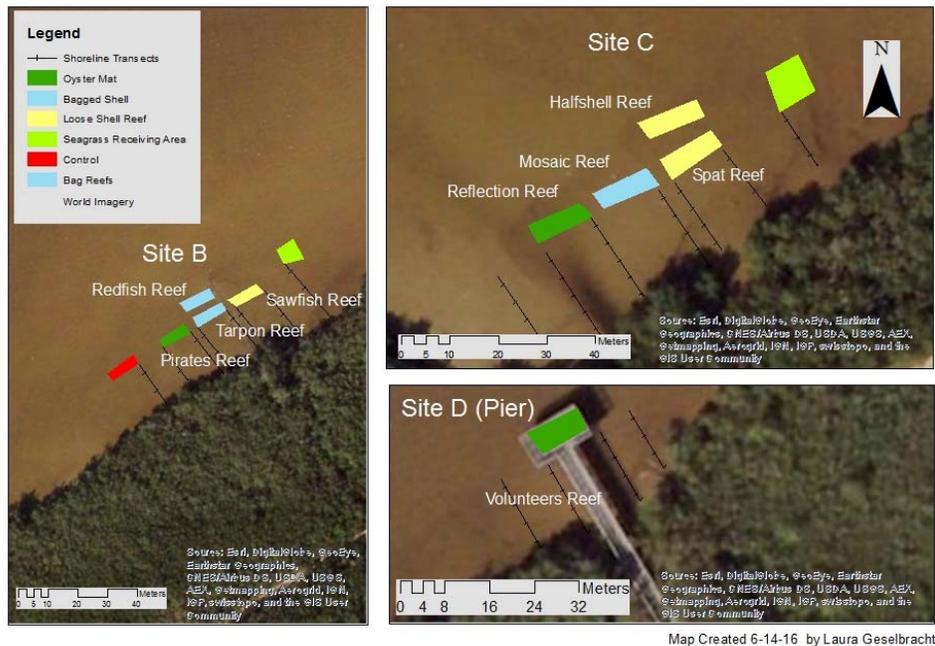


Figure 16. Reef sites showing habitat stability transects used to measure the distance between the reefs and the shoreline over time.

Table 10. Distance between reefs and shoreline (shortest distance to emergent vegetation attached to the substrate)

<u>Site</u>	<u>Reef No.</u>	<u>Transect Number</u>	<u>Photo Numbers</u>	<u>Ultrasound Length (m), 11-29-16</u>
D	9	1	115858, 115904	15.52
D	9	6	120355, 120356	20.64
D	9	8	120520, 120529	17.83
D	9	9	120725, 120732	16.6
B	B-SAV	1	104320, 104657	26.53
B	8	2	104324, 104905	18.89
B	8	4	104905, 104706	19.09
B	6	5		18.46
B	6	7	105207, 105401	19.66
B	5	8	105605, 105609	19.81
B	5	10	105818, 105840	19.09
B	Ctrl	12	105840, 110219	21.23
B	Ctrl	14	110346, 110404	20.7
C	C-SAV	1		18.7
C	C-SAV	1		24.09
C	3	3	113252, 113407	29.28
C	3	5	113116, 113143	17.77
C	2	6		18.87
C	2	8	112839, 112532	19.82
C	1	9	112512, 112519	27.82
C	1	11		20.08



Figure 17. Sample photo of shoreline survey. Photos are taken from shore out to the reef area along a transect line. Photos will be repeated every year or so to determine if the oyster reefs are affecting sedimentation or change in shoreline position relative to the reefs over time. Length measurements are also taken.

- Submerged aquatic vegetation (SAV) - FDEP-CHAP staff established transect lines (Figure 18) and conducted a SAV survey in August 2015 prior to reef installation to collect baseline information and again in June 2016 and October 2016 using the same techniques. Transects were established at each reef area (B, C and D) and the control area. Fifty-foot long transects were established in each cardinal direction (N, S, E and W) with sampling stations at 0, 10, 25 and 50 feet. After 1 year, the change in shoot count at the reef sites and at the control site were not significantly different (P-value = 0.33 and 0.92, respectively; see Figures 19 and 20). Appendix B, Table B-14 provides detailed information on total shoot counts. There was also no significant change found in SAV abundance at the 1 year post-installation timeframe at either the reef sites or control (P-values = 0.83 and 0.12, respectively; Table 11). Blade lengths decreased at both the reef and control sites, however, these changes were not significant either (P-Values 0.06 and 0.98, respectively; Table 12). SAV abundance varies seasonally and spatially. Additional years of monitoring may help to determine if SAV at the reef sites is changing in density, abundance and blade lengths as compared to the control site.

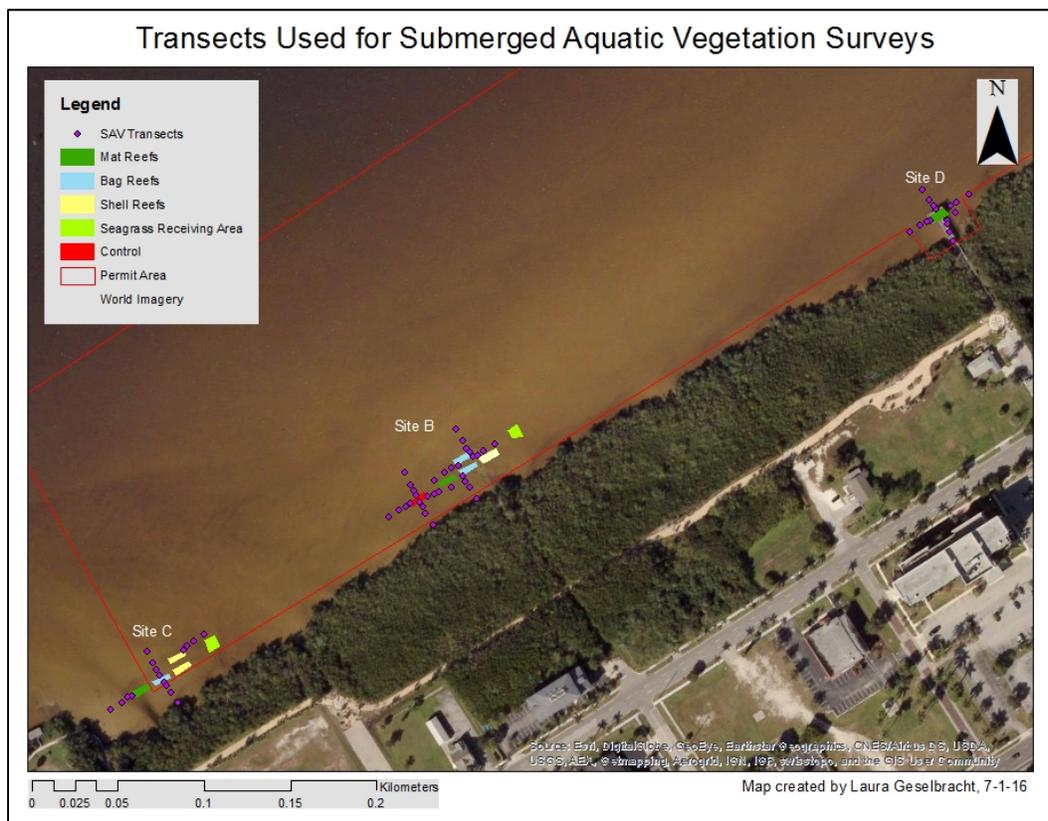


Figure 18. Location of transects for surveying the effect of oyster reef installation on surrounding SAV.

Figure 19. Oyster Reef Sites, SAV Total Shoot Counts

1 = Pre-restoration, 2 = 6-months post-restoration,
3 = 1-year post-restoration

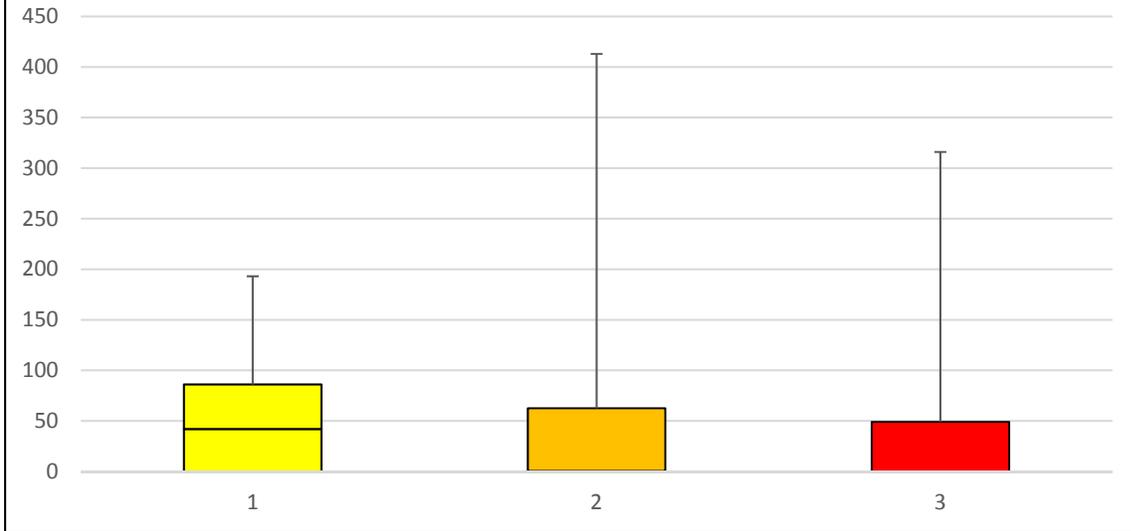


Figure 20. Control Plot, SAV Total Shoot Counts

1 = Pre-restoration, 2 = 6-months post-restoration,
3 = 1-year post-restoration

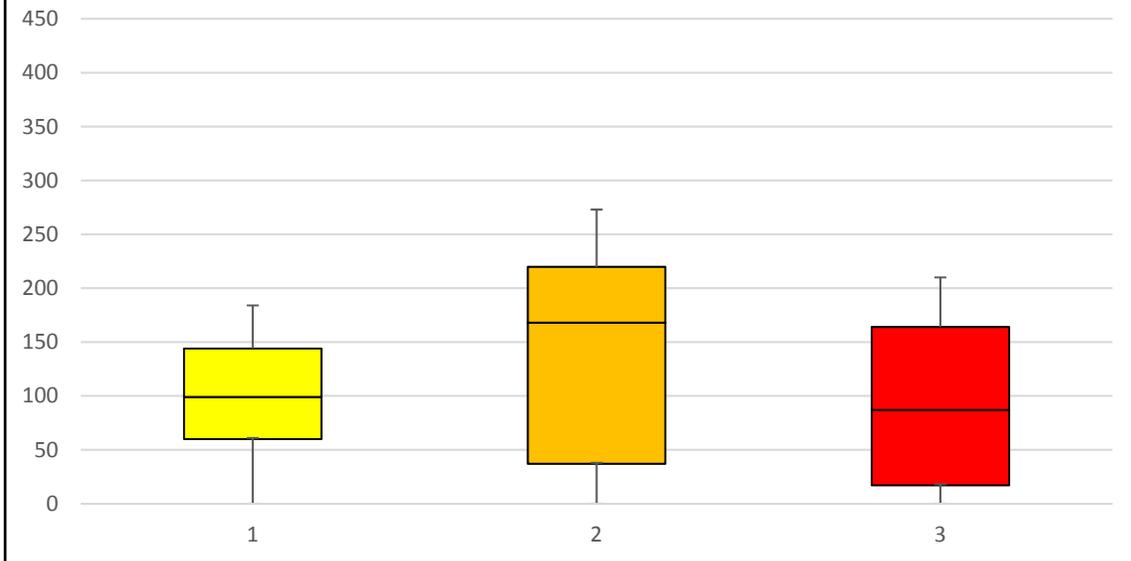


Table 11. Change in SAV abundance after 1 year near reef and control sites

Site	Average Total abundance, August 2015	Average Total, April - June 2016	Average Total abundance, October 2016	P Value
Reef Sites	0.01	0.02	0.01	0.83
Control	0.03	0.08	0.05	0.12

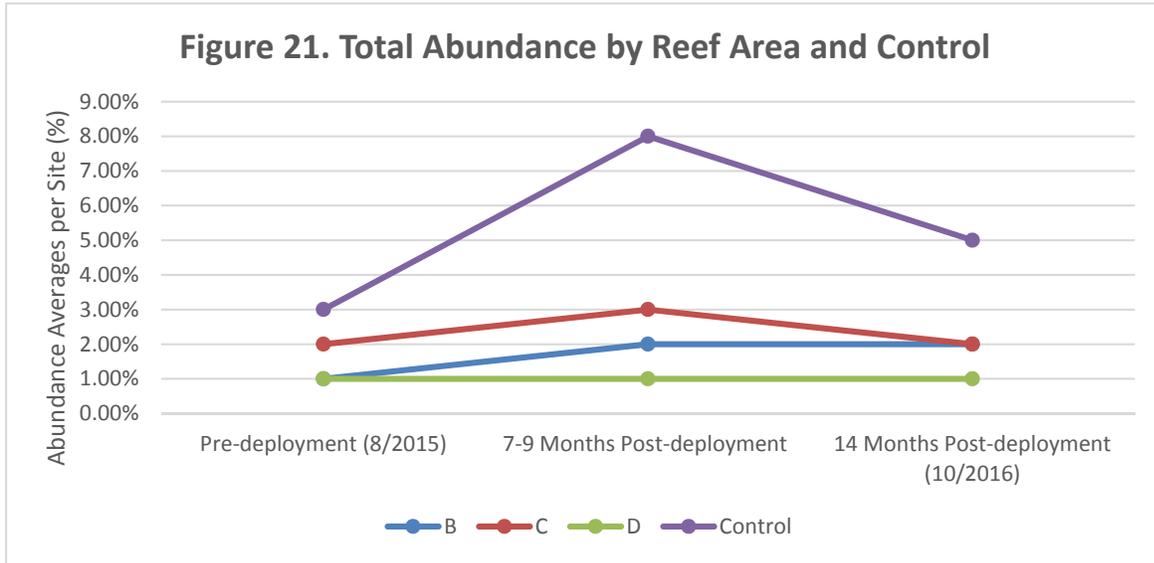


Figure 21. SAV abundance at reef and control sites at each sampling event.

Table 12. Change in SAV Blade Lengths after 1 Year

	Average Blade Length (cm), August 2015	Average Blade Length (cm), April - June 2016	Average Blade Length (cm), October 2016	P Value
Reef Sites	8.3	6.5	7.5	0.06
Control Site	8.4	6.8	8.3	0.92

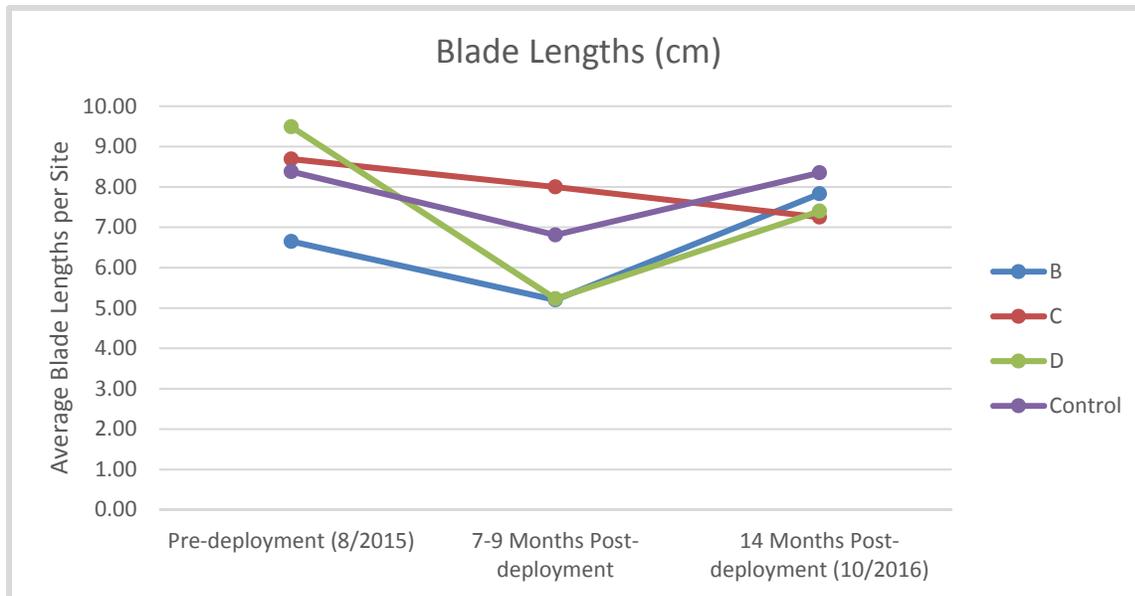


Figure 22. Blade lengths of SAV at control and reef sites during the project period.

- Entanglement monitoring - All reefs were examined weekly for the first month after reef materials installation to determine if they were a hazard to the smalltooth sawfish in terms of entanglement. No entanglements were observed and so these surveys were scaled back to once a month. Subsequently, no entanglements of any species on the reefs have been observed since reef installation.

Community Involvement and Outreach

The community outreach activities associated with this project began on 01/24/14 when TNC contracted with FDEP-CHAP to hire a part-time volunteer coordinator. Kate Aug was hired and recruited volunteers of all ages from the local community to take part in the project.

Initially Kate created a display and PowerPoint presentation that she brought to group meetings and events to share information about the pilot project and the importance of oyster reef habitat. Most of these educational presentations were conducted in March and April of 2014 and were given to following groups:

- Peace River Audubon Society
- Edison State College (STEM event)
- Punta Gorda Isles Civic Association
- Team Punta Gorda
- S. Charlotte County Coalition
- CHNEP Watershed Summit (display)

Kate was based at the FDEP-CHAP lab on Burnt Store Road where stations were set-up for preparing materials needed to build the oyster mats, including drilling shells, bundling zip ties and cutting the mesh mats to size. Individual volunteers came to the lab on scheduled workdays to complete this part of the project. Once the materials were ready, Kate organized events with a variety of groups to construct the mats. These workdays were mainly scheduled at local schools, the Laishley Park marina community room and pavilion, and the FDEP-CHAP facilities. All volunteers were required to sign a liability release form prior to participating, which included an optional photo/video release.

The workdays began with an educational presentation introducing the project, its partners, the importance of oysters, and what each of the participants can do to help. The presentation was followed by detailed instructions on how to properly construct an oyster restoration mat. Participants typically made at least one mat, sometimes more depending on the group and timeframe. A total of 18 mat-making events were held.



After all the mats needed for the project were completed, the focus shifted to creating oyster bags. These workdays were held in June and July of 2014 at the Burnt Store Road facilities. A total of 11 workdays were scheduled to bag the oyster shell needed for the reefs.

The community groups listed below participated in organized mat-making and bagging events:

- Big Brothers and Big Sisters
- Coastal Conservation Alliance
- CrossFit Punta Gorda
- Crossroads AMI
- Edison High School
- FDEP –Fort Myers office, state park and aquatic preserve staff
- Friends of the Charlotte Harbor Aquatic Preserves
- Girl Scouts of Gulf Coast Florida
- Keller Williams Realty
- Parrotheads of Charlotte Harbor
- Port Charlotte High School
- Punta Gorda Isles Boat Club
- Punta Gorda Isles Civic Association
- Punta Gorda Middle School

In August 2014, at the completion of this phase of the project, 900 mats and more than 1,600 bags were created and stored at the off-site lot in Punta Gorda.



The deployment was successful due to the help of volunteers. Many of the same individuals who had constructed the reef materials came back to help put them in the water. In addition, the following groups organized their members or staff to help:

- The Mosaic Company
- CrossFit Punta Gorda
- Punta Gorda Isles Fishing Club

Volunteer Totals as of April 2017

Total # of volunteers = 1,300

Total # of hours = 2,950

These numbers include materials assembly, deployment and monitoring.

Photos of the Community and Volunteer Involvement can be found in Appendix E.

Project Presentations

PowerPoint presentations were made by the TNC project team to the following groups:

- TNC staff: Anne Birch, Laura Geselbracht and Andrea Graves, along with project consultant Jaime Boswell gave 4 contiguous presentations describing coastal habitat restoration at the CHNEP 2014 Water Summit held March 25-27 at the Charlotte Harbor Event & Conference Center in Punta Gorda.

The presentation titles are provided below:

Session 6: Restoring Shellfish - John Ryan, Sarasota County, Chair

-A Consensus Based Regional Approach to Oyster Habitat Restoration in Southwest Florida - Jaime Boswell, Jaime Boswell LLC, et al.

-Facilitating Oyster Habitat Restoration by Developing a Florida General Permit - Anne Birch, TNC, et al.

-Pilot Project to Create Oyster Reef Habitat in the Peace River Estuary - Andrea Graves, TNC, et al.

-Building Coastal Resilience in the Charlotte Harbor Region and Beyond - Laura Geselbracht, TNC, et al.

- Laura Geselbracht presented project updates to the Punta Gorda City Council as listed below:
 - The Nature Conservancy's Oyster Reef Restoration Pilot Project, May 1, 2013

- Update on Trabue Harborwalk Oyster Reef Restoration Project and Coastal Resilience Activities, February 2014
 - Update on Trabue Harborwalk Oyster Habitat Restoration Project, July 2014
 - Preliminary 6-Months Post-Installation Monitoring Results for the Trabue Harborwalk Oyster Restoration Project, July 13, 2016
- As part of The Nature Conservancy’s Blowing Rocks Preserve Annual Winter Program Series, Andrea Graves presented “Putting Boots in the Water in Charlotte Harbor” on February 12, 2014 to approximately 50 people.
- Laura Geselbracht presented an update on the project on April 17, 2015 at the Friends of the CH Aquatic Preserves Annual Meeting held at the Punta Gorda City Council Chambers.
- Following deployment of the reef materials, Laura also presented to the following two groups: The Punta Gorda Isles Boating Club on November 5, 2015 to approximately 50 people and As part of the CH Environmental Center’s sunset program series in Port Charlotte on January 7, 2016 to more than 30 people.
- Laura Geselbracht presented the 1-year post-installation results at the CHNEP Watershed Summit on March 30, 2017.

Community Events

Coastal Awareness Day

On April 26, 2014, The Nature Conservancy in Florida hosted Charlotte Harbor Coastal Awareness Day at Laishley Park Municipal Marina. This special event was an opportunity for the public to learn about the multi-partner project underway in Punta Gorda to restore oyster reefs, volunteer to make oyster mats, and meet leaders in the city who are advancing natural solutions to help protect shorelines from the future impacts of storms and sea level rise. Exhibitors also participated with displays and information on local environmental activities. More than 230 people attended the event and volunteers of all ages made oyster mats for the Trabue Harborwalk Oyster Habitat Restoration Project. (See Appendix F for event invitation, newspaper wrap and rack card.)



Ribbon Cutting Ceremony

To celebrate the reef installation, The Nature Conservancy and City of Punta Gorda organized a ribbon cutting ceremony on September 28, 2015 at the Trabue Harborwalk, inviting the Mayor and City Council and project partners, volunteers, and media. This event kicked-off with remarks about the importance of restoration of the estuary from the City of Punta Gorda’s Mayor Freeland, followed by Anne Birch who described the significance of the pilot oyster reef restoration project and recognized the project partners and volunteers. After the ceremonial cutting of the ribbon, volunteers went into the water and completed construction of the oyster mat reef located under the Adrienne Street pier.



Pictured from left to right: Anne Birch (TNC), Judy Ott (CHNEP), Keith Laakkonen (FDEP), Mayor Strickland (City of Punta Gorda), Liz Donley (Friends of the CHAP), Gregg Poulakis (FWC), Kaley Miller (Mosaic), Heather Stafford (FDEP-CHAP), Laura Geselbracht (TNC), Andrea Graves (TNC)

Volunteer Appreciation Event

Following the 6-month monitoring of the reefs, TNC held a volunteer appreciation party on May 17, 2016 at the Laishley Park Marina Community room for the project volunteers and partners. The agenda included an update of the 6-month project monitoring results presented by Laura Geselbracht followed by Q & A. The finale was the showing of a special video created by volunteer videographer Ernesto Lasso de la Vega who has filmed the project since its inception. More than 50 volunteers, partners and staff attended.

Education/Outreach Materials and Press Coverage

During the first year of the project implementation a series of print materials were created to help spread awareness in the local community and recruit volunteers. These included fact sheets, fliers, rack cards, and promotional materials surrounding Coastal Awareness Day. Additionally, several magazine articles were published highlighting the project and the importance of oyster reef habitat. Once the project was underway, TNC's Florida Marketing Department coordinated opportunities for local media, television and newspaper reporters, to learn more about the project. Media were invited to the following events: deployment of the first loose shell reef, the ribbon-cutting ceremony and a presentation of the 6-month monitoring results made during the City of Punta Gorda Council Meeting. See Appendix F for more information on the press events and coverage, and samples of the print materials and articles.

Project Funding and Partners

TNC's project team (Anne Birch, Laura Geselbracht and Andrea Graves) coordinated all aspects of the project described in this report: site selection, reef design, community outreach, materials assembly, deployment and monitoring. However, this project would not have been possible without the enthusiastic dedication and support from our partners, many of which were also funders of the project.

Significant financial support for the project was provided by a grant to TNC from The Mosaic Company Foundation, without which this project would not be a reality. Additional multi-year grant support was received from the Sally Mead Hands Foundation. Private donors also provided financial and volunteer support. We are grateful for the donations we received from local businesses including: Home Depot-Punta Gorda, the Laishley Park Marina, Clamtastic Seafood Inc., Tara Landscaping, and Keesling Construction, which donated large equipment and operators to move the loose shell material as well as load the pallets of constructed mats and bags onto the barge for deployment.

City of Punta Gorda. The City was involved in helping us select the project site and has been supportive of the project since its inception. The staff in the urban development department worked closely with us through each stage of the project, including facilitating our presentations to the City Council. The Council was excited about the project since it was first brought before them and continued to be supportive as we kept them informed of progress and challenges. The City generously donated use of one of their properties for storing the materials. They also regularly kept the residents of Punta Gorda updated on the project.

FDEP-CHAP. TNC contracted with the FDEP-CHAP to implement the initial community outreach portion of the project to recruit volunteers and assemble the reef materials. This was an enormous undertaking and thanks to their many connections to the local community the project involved volunteers ranging from schools, community groups, businesses, and individuals. We are also grateful for the help from the FDEP-CHAP staff with permitting, multiple field visits, monitoring and technical advice and support.

CHNEP. Staff from the CHNEP have been very supportive of and involved in helping make this project successful through every stage from site selection, to permitting, community involvement and monitoring. Staff were especially helpful in the field assisting with seagrass transplanting, deployment, pre- and post-monitoring and providing scientific expertise. The CHNEP leads the SWFOWG and we also received input, advice and assistance from many partners in this group.

Jaime Boswell, LLC. Jaime was contracted by TNC to develop and submit the project permit applications. Jaime also worked for the CHNEP to lead the new citizen scientist program that will continue monitoring the project site post-one-year construction. Jaime collaborated with TNC in the 6-month and 1-year monitoring, helping to recruit and oversee the participating volunteers.

Carlton Ward, Jr. and Ernesto Lasso de la Vega. Thank you to both Carlton and Ernesto for helping to document this project. Carlton, a renowned photographer, captured stunning images of the project site pre-installation for use by TNC. Ernesto Lasso de la Vega donated hours of his

time and videography skills to document all phases of the project including materials assembly, reef construction and the ribbon-cutting ceremony.

Additional partners included: Florida Fish and Wildlife Conservation Commission, FDEP-Charlotte Harbor State Parks, Friends of the Charlotte Harbor Aquatic Preserves, and the Peace River Audubon Society.

Project Challenges and Solutions /Lessons Learned

Permitting was the greatest challenge we faced in implementing this pilot project. This was largely due to the presence of critical habitat for the federally endangered smalltooth sawfish in the intertidal waters of most of the Charlotte Harbor estuary and the presence of seagrass. The presence of sawfish critical habitat triggered an additional step in the Army Corps permit requiring development of a biological opinion from the National Marine Fisheries Service, which created a longer permit approval process. We contracted with an experienced consultant, Jaime Boswell, to coordinate and prepare the project permits, which was extremely helpful.

At the deployment stage of the project, the presence of a transient species of seagrass was discovered throughout the project site. When the seagrass persisted through the colder winter months, we developed a mitigation plan to minimize impacts to seagrass, which was permitted by FDEP. Critical to making this work was the large permit footprint we had originally included that gave us the flexibility to shift our reef layout design with the permitted area, as opposed to starting from scratch in a new unpermitted location.

Oysters mats were originally used as the restoration methodology in the Mosquito Lagoon. In that area, the mats are placed on top of a layer of disarticulated oyster shells. The shells are from ‘dead margins’ – oysters displaced from nearby reefs due to repetitive boat wakes - that are leveled prior to the mats being placed on top of the shell material. This method proved very successful for restoring intertidal oyster restoration in the Mosquito Lagoon. At the Trabue project site there are no dead margins or other sources of in-water shell material. We opted to place the mats directly on the sediment without placing a layer of recycled or fossilized shell underneath the mats. If successful, this would have prevented the need to use extra material for this method. The results, however, showed that a layer of shell is needed and, if we use mats as a restoration method in the future, we will consider this option.

Another challenge was working through the project logistics for a community-based project. This was more involved than we originally anticipated. The size of our design, although small, was complex and required many hours of volunteer time and coordination. Since we were building a volunteer base in a new area, we now recognize the importance of building in more start-up time on the front-end of the project. The oyster mats, in particular, are time consuming to create, but offered the best opportunity for educating citizens of all ages about the benefits of oyster reefs and involving them in a hands-on activity where they can help improve their local environment.

It was helpful that all three restoration materials we tested had been used previously in Florida. This enabled us to receive recommendations and input from our partners on vendors for the

supplies needed and best practices for assembly and deployment. Finding an appropriate storage site was more difficult than we originally anticipated, but the partnership with the City of Punta Gorda was once again critical to the project success as they worked with us to locate a site. When this area did not prove suitable for materials assembly, our partner FDEP-CHAP stepped forward and offered space at their local facility.

Future Work in Charlotte Harbor

Charlotte Harbor Large-scale Oyster Reef Restoration

A subcommittee of the SWFOWG, which includes TNC, is currently working on submitting a permit application to restore up to 20 acres of oyster reef habitat in the Charlotte Harbor Estuary. TNC submitted this large-scale project for funding through the state's online Gulf of Mexico Deepwater Horizon RESTORE proposal portal. The working group subcommittee met from May 2014 to February 2015 to identify potential sites for future oyster habitat restoration projects. All oyster habitat restoration activities will be located within areas of the CHNEP identified as 80-100% suitable for successful restoration of intertidal and/or subtidal reefs, as defined by the CHNEP Oyster Habitat Restoration Suitability Model and included in the Plan. Following field visits, the sites were prioritized using several considerations, including: a) space availability, b) seagrass presence, c) likelihood to succeed based on environmental characteristics, d) sediment type and depth, e) presence of live oysters near the site, and f) potential benefits of the project to local resources. The subcommittee identified a total of 53 sites totaling 28 acres within 11 estuary segments. These sites were presented to and approved by the full SWFOWG in April 2015 and the CHNEP Technical Advisory Committee in July 2015. TNC is now leading the SWFOWG in working through the permitting requirements and challenges associated with future projects.

Volunteer Monitoring Initiative

CHNEP received a grant from FDEP through the Coastal Partnership Initiative in 2015 to form a Volunteer Oyster Habitat Monitoring (VOHM) program. The purpose of the program is to engage volunteers with restoration efforts and to educate them about the value of restoring oyster reef habitat. The program developed a Volunteer Coordinator Manual, Volunteer Manual, and Standard Operating Procedures (SOP) for monitoring oyster reefs. The manuals and SOP will be used to train citizen scientists to help monitor the Trabue project reefs, future oyster habitat restoration projects in Charlotte Harbor, and could serve as a model for programs in other bays and estuaries. The materials developed for the VOHM program are kept on the Charlotte Harbor Water Atlas and can be accessed at the web link below:

http://www.chnep.wateratlas.usf.edu/upload/documents/Final_Volunteer-Coordinator-Manual-1517-with-Appendices.pdf.

References

- Baggett, L.P., S.P. Powers, R. Brumbaugh, L.D. Coen, B. DeAngelis, J. Greene, B. Hancock, and S. Morlock, 2014. Oyster habitat restoration monitoring and assessment handbook. The Nature Conservancy, Arlington, VA, USA., 96pp.
- Baker, S.M. and R. Mann. 1992. Effects of hypoxia and anoxia on larval settlement, juvenile growth, and juvenile survival of the oyster *Crassostrea virginica*. *Biological Bulletin* 182:265-269.
- Beck, M.W., R.D. Brumbaugh, L. Airoidi, A. Carranza, L.D. Coen, C. Crawford, O. Defeo, G.J. Edgar, B. Hancock, M. Kay, H. Lenihan, M.W. Luckenbach, C.L. Toropova, G. Zhang. 2009. Shellfish Reefs at Risk: A Global Analysis of Problems and Solutions. The Nature Conservancy, Arlington VA. 52 pp.
- Bobo, M.Y., D.L. Richardson, L.D. Coen, and V.G. Burrell. 1997. A Report on the Protozoan Pathogens *Perkinsus marinus* (Dermo) and *Haplosporidium nelsoni* (MSX) in South Carolina Shellfish Populations. SCDNR-MRD-MRRI Technical Report #86, 50 pp.
- Boswell J, J Ott, A Birch, D Cobb. 2012. Charlotte Harbor National Estuary Program Oyster Habitat Restoration Plan. Charlotte Harbor National Estuary Program Technical Report. 170 pp.
- Boudreax ML, Stiner JL, and LJ Walters. 2006. Biodiversity of sessile and motile macrofauna on intertidal oyster reefs in Mosquito Lagoon, Florida. *Journal of Shellfish Research* 25:1079-1089.
- Ewart, J.W. and S.E. Ford. 1993. History and impact of MSX and dermo diseases on oyster stocks in the Northeast region. Northeastern Regional Aquaculture Center Fact Sheet No. 200, www.nrac.umd.edu/files/Factsheets/fact200.pdf.
- Fernandez, C. 2012. Fly fishing for Redfish. Stackpole Books, Mechanicsburg, PA.
- Geselbracht, L., R. Torres, G. Cumming, D. Dorfman, M. Beck. 2005. Marine/Estuarine Site Assessment for Florida: A Framework for Site Prioritization. Final Report for Florida's Wildlife Legacy Initiative, a program of the Florida Fish and Wildlife Conservation Commission. The Nature Conservancy, Gainesville, Florida.
- Geselbracht, L., K. Freeman, E. Kelly, D.R. Gordon and A. Birch. 2013. Retrospective analysis and sea level rise modeling of coastal habitat change in Charlotte Harbor to identify restoration and adaptation priorities. *Florida Scientist*. 76(2): 328–355.
- Grant J and J McDonald. 1979. Dessication tolerance of *Eurypanopeus depressus* (Smith) (Decapoda: Xanthidae) and the exploitation of microhabitat. *Estuaries* 2:172-177
- Johnson, M.W., S.P. Powers, J. Senne, and K. Park K. 2009. Assessing in situ tolerances of Eastern oysters (*Crassostrea virginica*) under moderate hypoxic regimes: implications for restoration. *Journal of Shellfish Research* 28:185-192.

Kulp, R.E. and B.J. Peterson. 2013. Who controls whom? Linking the predator-prey dynamics between mud crabs and juvenile Eastern oysters to restoration efforts in the New York Metropolitan Region. Section IV: 1-32 pp. In S.H. Fernald, D.J. Yozzo and H. Andreyko (eds.), Final Reports of the Tibor T. Polgar Fellowship Program, 2012. Hudson River Foundation.

Meyer, D.L. & E.C. Townshend. 2000. Faunal utilization of created intertidal eastern oyster (*Crassostrea virginica*) reefs in the southeastern United States. *Estuaries* 23: 34-45.

Poulakis, G.R., R.K. May, P.W. Stevens, S.G. Tolley, R.M. Scharer. 2017. Vemco Positioning System monitoring of juvenile Smalltooth Sawfish (*Pristis pectinata*) to characterize use of created oyster reef at Trabue Harborwalk, Punta Gorda, Florida. Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, Charlotte Harbor Field Laboratory. FWC-FWRI File-code: F4265-16-17-F, 36 pp.

Shumway, S.E. 1996. Natural environmental factors. In: Kennedy V.S., R.I.E. Newell, and A.F. Eble (eds). *The Eastern Oyster Crassostrea virginica*. Maryland Sea Grant College, College Park, MD. pp. 467-513.

Volety, A.K., S.G. Tolley, A.N. Loh and H. Abeels. 2010. Oyster monitoring network for the Caloosahatchee estuary 2007-2010. Final Report submitted to the South Florida Water Management District. 145 pp.