Restoring and Monitoring Brevard County Oyster Reefs Utilizing Citizen Science and Community Outreach

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Brevard Oyster Restoration
Brevard Zoo
Executive Summary

The Indian River Lagoon is a prominent characteristic of Florida’s East Coast, providing a home to over 4,000 species of diverse flora and fauna. For the five counties that encompass the Indian River Lagoon, the biologically unique estuary provides approximately $7.6 billion in recreational, residential, and commercial economic benefits. Brevard County comprises 71% of these vital waterways, and the county’s residents are directly impacted by the environmental conditions of the estuary and its wildlife. One of the organisms that plays a key role in the Indian River Lagoon’s ecological stability is the Eastern Oyster (*Crassostrea virginica*). A single adult oyster can filter algae and particulates out of the water at a rate of 50 gallons per day, providing a powerful natural filtration system as the “liver of the river”. However, the Indian River Lagoon and its oysters are severely threatened by rapid human development, habitat destruction, overharvesting, and pollution. Decades of excess nutrients from pesticides, fertilizers, and insecticides have seeped into the waterways and settled onto the bottom of the estuary floor as dense layers of noxious sludge. Oysters can no longer maintain their water filtration capabilities and can in time be smothered by the built-up pollution. Fortunately, significant efforts have been enacted by private, county, and state organizations for oyster restoration and water quality improvement within the Indian River Lagoon. In 2014, the Brevard Zoo Oyster Restoration team received a grant from Brevard County Commissioners to create the Oyster Gardening Program, a community-based restoration project focused solely in Brevard County. By recruiting and training over 1,000 community members to raise juvenile oysters or spat, the Oyster Gardening Program has been able to gather weekly data collections on recruitment and survivability from its citizen scientists. The first oyster gardening season showcased summer’s oyster spawning season, as well as the increased competition from fouling organisms like barnacles and sea squirts. The second oyster gardening season showcased winter’s much reduced competition from fouling species and more favorable growing conditions for the developing spat. As a result of the valuable information gathered from the first two sessions, the Oyster Restoration team strategically constructed its first pilot oyster reefs within Brevard County. Through quarterly monitoring, the team evaluated the best strategies for reef building methodology and nutrient removal from the Indian River Lagoon in association with the restored reefs. As the Oyster Gardening Program expands, the Brevard Zoo Oyster Restoration team plans to construct reefs throughout Brevard County, in addition to implementing a “living shoreline” program to coincide with the oyster reef restoration. It is through the efforts of private citizens, government organizations, and groups like the Brevard Zoo Oyster Restoration team and Brevard County Natural Resources Management Department that the Indian River Lagoon and its oysters have a chance at rejuvenation. Restoration requires time, resources, and revenue; the long-term benefits of success include bringing back the bountiful Indian River Lagoon that the people and wildlife of Brevard County rely upon.
The Indian River Lagoon

Covering almost one-third of the entire Florida East Coast, lies the Indian River Lagoon. The Indian River Lagoon (IRL) spans 156 miles long and is the culmination of three prominent water systems: Mosquito Lagoon, Banana River, and Indian River (Smithsonian 2014) along with several associated tributaries. A unique and highly diverse shallow-water estuary, the IRL and its different habitats “provide a home for more than 4,000 species of plants and animals”, making it an estuary of national significance and a rarity throughout the world. Swain (1995) stated that the Indian River Lagoon contains “more listed species than any other estuary in the United States”, ranging from the charismatic West Indian Manatee and the dignified Wood Stork to the often overlooked Mangrove Tree Crab. In 2016, economists estimated that the five Indian River Lagoon counties (Volusia, Brevard, Indian River, St. Lucie, Martin) received approximately $7.6 billion in economic benefits as a result of recreational, residential, and commercial enterprises within the estuarine region. 71 percent of the Indian River Lagoon’s total area, and nearly half of its length, lies within Brevard County; due to its vital waterways, Brevard County residents benefit from waterfront real estate, charter fishing companies, and the rapidly expanding ecotourism industry. Locals, domestic tourists, and international visitors are drawn to all sections of the Indian River Lagoon and its myriad of fascinating flora and fauna.

Why Oysters?

One of the estuary’s most vital organisms is the Eastern Oyster (Crassostrea virginica, see Figure 2). The oyster serves as an ecosystem engineer and keystone species within the Indian River Lagoon. The oyster is an intertidal species, meaning that as the tides flow the thousands of individual oysters massed together will periodically be above and below the water line. Due to their strong need to live among other oysters in large aggregations, oysters are known as a gregarious species as well. Oyster reefs trap sediment underneath and around them when water levels change, and through this sediment accumulation, the oyster reefs will stabilize the lagoon substrate and surrounding shorelines, enough so for aquatic vegetation like seagrasses to take root. Oysters provide a foundation for the growth of shoalgrass (Halodule wrightii, see Figure 1: Map of Florida with magnified Indian River Lagoon region.
3), a favorite source of food and habitat for numerous species, including highly prized sportfish. In addition, oysters prevent soil erosion into the waterway, serve as an important food source for a variety of organisms, and provide habitat. Studies have shown that up to 149 different species rely upon restored oyster reefs as a means of food, habitat, and nursery space for juvenile marine organisms and many other functions (Barber et al. 2010).

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However, arguably the most crucial ability of the oyster is its water filtration capabilities. Oysters are filter feeding bivalves, which means that they use their gills to absorb dissolved oxygen, and they use their digestive organs within the mantle to strain particles out of the water. Some of the legacy load particulates inhabiting the Indian River Lagoon, in the form of dense muck, that otherwise contribute to further pollution accumulation are actually processed by the oysters to help build their shells. A single adult can filter plankton and organic matter out of the water at a rate of 50 gallons per day, or more than 1500 times its body volume, finally expelling clean, clear water. With these gregarious invertebrates dwelling together on a reef in different life stages, the effect on water quality and clarity can be astounding. In a study published by Grabowski et al. (2012), researchers were able to estimate “an average annual value of services provided by restored and protected oyster reefs that ranges from $10,325 to $99,421 per hectare”.

**FUN FACT:** Did you know that Eastern Oysters have been reported to live up to 20 years?

Unfortunately, shellfish reefs throughout the world are in peril. Oysters form one of the most degraded estuarine habitats in the world; roughly 85% of oyster reef habitat has been lost globally over the last 130 years (Beck et al. 2011). The Eastern Oyster has been in decline throughout the American Atlantic seaboard for generations, due to historic overharvesting, boat and wind wakes, disease, ocean acidification, and poor water quality. Waycott et al. (2009) spoke of declining water quality due to nutrient runoff and development. Rapid human development has overexploited the Indian River Lagoon to the point where habitat transformation and pollution have undermined the natural resilience of the estuary (Grabowski et al 2012). In 2014, the Smithsonian Marine Station at Fort Pierce reported that 58 special status species currently reside within the Indian River Lagoon, according to the state’s criteria for a
species’ “significant vulnerability to habitat modification, environmental alteration, human disturbance, or human exploitation.” Previous research has displayed anthropogenic effects from increasing urbanization along the Indian River Lagoon include coastal hypoxia (Vaquer-Sunyer & Duarte 2008) and permanent seagrass bed loss through eutrophication (Waycott et al 2009).

Nutrient pollution is one of the challenges facing Brevard County oyster reefs. Excess fertilizers, pesticides, and insecticides seep into the groundwater or flow into the storm drains after a Florida rainstorm, eventually reaching the Indian River Lagoon. Once there, the excess nutrients remain within the water system and its substrate and continue to build up over time. The once clear water column becomes a murky soup from the pollution particles and overfed algae, and even though oysters can seal their shells against pollution for extended periods of time, the oysters cannot remove themselves from the turbid mess and eventually lose to the nutrient overload. Without the oysters industriously straining the water of algae, the water turbidity can become so dense that sunlight cannot penetrate to the estuary floor and reach the seagrass beds. The seagrasses will not be able to photosynthesize and therefore not produce dissolved oxygen for other organisms to utilize, which can then lead to oxygen starvation and mass mortality of countless aquatic species. In addition, the algae can become so engorged on nutrients that an overgrowth of algae occurs (known as an “algal bloom”). In time, the bloom will die out and decompose, further robbing the estuary of dissolved oxygen, and can trigger a considerable mortality event among the fish populations (known as a “fish kill”).

Figure 4: Prized sportfish like red drum were among the casualties from the March 2016 fish kill
Figure 5: Numerous fish and marine invertebrate species could not survive the depleted dissolved oxygen levels during the March 2016 fish kill

Brevard County experienced a massive fish kill in March 2016 when, over the course of a few days, the dissolved oxygen levels plummeted to below 2 milligrams per liter (mg/L) within Brevard’s section of the Indian River Lagoon; warm water fish generally require dissolved oxygen levels of at least 5 mg/L in order to successfully function (Abeels 2016). Rapidly after water quality meters detected the dissolved oxygen drop, and over the course of the following weeks, over 125,000 total recorded deceased animal specimens (FWRI 2016) were collected from the estuary by concerned community members (see Figures 4 & 5). Unfortunately, state officials were only able to calculate the loss of marine wildlife based upon the amounts citizens reported clearing from the waterways. On March 24th, a total of 16 Brevard Zoo staff and volunteers collected approximately 6,750 pound of dead fish from the IRL, with close to an additional 1,000 pounds of decomposing fish removed from the estuary over the next following
days. The actual total loss of marine wildlife, as well as the fiscal losses suffered by Brevard County businesses, tourism, and real estate, may never be fully quantified.

The Restoration Projects

With only 15% of the world’s oyster reef habitat left, substantial efforts are now under way to protect remaining reef habitat, as well as to restore oyster reefs (Lotze et al 2006). Started by Dr. Linda Walters of UCF in 2005, the Oyster Mat Program has achieved substantial success in terms of community-based oyster reef restoration and public outreach in Volusia County within Mosquito Lagoon. Mosquito Lagoon is the northernmost extension of the Indian River Lagoon and is part of the Canaveral National Seashore. Mosquito Lagoon is predominantly a very shallow water body and its oyster reefs experience a high amount of boat wakes from the frequent boating traffic. The wave energy from the boat wakes disrupts the oyster reefs, piling the clusters of oysters on top of each other, and eventually the animals are no longer underwater, even at high tide, and die. The leftover mounds of empty oyster shells, called dead margins, continue to build in size and can restrict water flow to surrounding aquatic plants and still-living oyster reefs.

To combat this dilemma, Dr. Walters created the oyster mat design (see Figure 6), which utilizes 36 recycled oyster shells attached to an aquaculture-grade marine mesh square. Once a degraded oyster reef has been scientifically selected as a restoration site, the dead margin is leveled to the water line using rakes, shovels, and pickaxes wielded by many hardworking staff, students, and volunteers. Afterwards, the oyster mats are laid on top of the newly flattened surface in a quilt-like design and attached to concrete sprinkler donuts for weight and protection against future boat wakes. Over time, the blank oyster shells recruit wild baby oysters (spat), forming a new oyster reef around the mat materials, and further aid in improving the Indian River Lagoon’s water quality. Since the Oyster Mat Program began restoring Mosquito Lagoon oyster reefs in 2007, the project has created over 45,063 oyster mats through various community events, over 47,820 volunteers have participated in some fashion, 77 oyster reefs have been restored, and over 2.20 acres of essential estuarine habitat have been restored to Mosquito Lagoon. Furthermore, Dr. Walters and her team continue to monitor the restored reefs post-deployment to assess wild oyster recruitment, species abundance within and among the restored reefs, and any damages to the reefs from human interference (see Figure 7).

![Figure 6: Completed oyster mat](image1)

![Figure 7: Oyster mat field monitoring](image2)
To restore the once plentiful oyster reefs within Brevard County and combat the failing water quality in the Indian River Lagoon, Brevard County Natural Resources Management Department (BCNRMD) wanted to have a project expanding the efforts of the Oyster Mat Program, but focused solely on Brevard County and its community. The Brevard Zoo Oyster Restoration team had been involved with Dr. Walters’ research since 2009, and in January 2014, Brevard County Commissioners granted $150,000 to the team to create the Oyster Gardening Program. The team encompasses a small staff of Brevard Zoo employees and partners with BCNRMD, but the vast majority of its members are community volunteers. Utilizing social media, public advertisements and word-of-mouth, the Oyster Gardening team enlisted over 1,036 citizens to become oyster gardeners and “oyster buddies”. Oyster gardeners are Brevard County residents who live along some extension of the Indian River Lagoon (canal, Banana River, Indian River, etc.) and possess a suitable environment on their properties for juvenile oysters to mature and thrive. Oyster buddies, Brevard County residents who do not live along the waterfront, assist the gardeners and can step forward in case the gardeners have a vacation, illness, or some other situation where they cannot care for the oysters at that time. Both groups of volunteers participate in a two-hour training workshop, where they learn about the basic biology of oysters, their role in the Indian River Lagoon ecosystem, the goals for the Oyster Gardening Program, and the proper maintenance and data collection of their personal oyster collections. The final step of the workshop is to construct the PVC-coated metal cages (called “habitats”) which will shelter the gardener’s developing oysters and then await the arrival of their infant bivalves.

**Project Objectives**

The objectives of this program are to implement:

(i) a community-based restoration project based in Brevard County, Florida;
(ii) weekly data collections on recruitment and survivability utilizing citizen scientists;
(iii) large-scale reef restoration; and
(iv) scientific monitoring to analyze reef building methodology and denitrification in the Indian River Lagoon associated with the restored reefs.

**Project Methods**

Before each oyster gardening cycle can commence, the Oyster Gardening team works with its partners at Florida Oceanographic Society in Stuart to collect and spawn the gardeners’ oyster spat. The Oyster Gardening team is responsible for collecting wild oysters to serve as broodstock or the parent generation for the gardened spat. Typically, the team has collected wild oysters from around the Sebastian River in Brevard County, where natural populations are visible and accessible. Then, the wild oysters are set up in an aquaculture hatchery at Florida Oceanographic Society and provided with the ideal conditions for spawning. After spawning has concluded, the male and female gametes are carefully mixed to promote genetic diversity. Once the larvae begin to develop sensory organs and a foot, they are transferred to settlement tanks filled with bags of blank shell. The spat settle onto the blank shell and are then distributed to the oyster gardeners about one week post-settlement.

After successfully completing the training workshops, the oyster gardeners receive approximately 100 oyster shells, harboring anywhere from 100-1,000 spat on average, and raise them over a six to nine-month period. The oyster habitats are suspended at least one foot above
the estuary substrate to avoid predation and at least one foot below the high water line to avoid long periods of exposure during periods of low water levels. Once a week, the gardeners hoist the oysters in their habitats from the water, onto their docks, and conduct some basic cleaning and observations.

The gardeners record the weight of the habitats, both before cleaning and after cleaning, and removing any possible fouling, then record any organisms found with the oysters and if any wild oysters have been recruited to the habitats. Examples of oyster “friends” found within the habitats include seahorses, fish eggs, hermit crabs, gobies, blennies, and different species of shrimp. Organisms classified as “friends” rely upon the oyster reefs for habitat and other essential habitat requirements that are not harmful to the oysters. On the other hand, examples of oyster “foes” found within the habitats include tulip snails, different species of crabs, juvenile sheepshead and mangrove snapper, boring sponges, crown conch, and oyster toadfish. Organisms classified as “foes” predate upon oysters at some point in their life cycle and can inflict serious damage to the reefs over time. In addition, fouling organisms such as barnacles, mussels, and tube worms are observed living on the oyster shells and habitat structure. These weekly data collections go into an online database and allow the Oyster Gardening team to study the survivability and recruitment of oysters within the Brevard County portion of the Indian River Lagoon. The gardeners also record the time spent during their weekly observations; these time submissions represent the dedication of the citizen scientists and are utilized to provide matching funds during grant proposal applications.
Since the formation of the Oyster Gardening Program in 2014, the defining characteristics of the project’s layout have evolved to incorporate newly accumulated information. For the inaugural Phase One, each oyster gardener was supplied with four habitats identified by either a red, blue, green or yellow zip tie attached to a sample oyster shell on the exterior of the habitat (see Table 1). The gardeners were tasked with tending to their infant bivalves from early spring and throughout the Florida summer months before concluding in November after approximately nine months. Before Phase Two began later in November 2014, the Oyster Gardening team decided to reduce the number of habitats per gardener from four to two, and the habitats would be identified by either a red or blue zip tie on the exterior of the habitat. The team also decided that the Phase Two gardening season would span over the Florida winter months and conclude during April 2015 after approximately six months. There were a few reasons as to the shift in habitat quantity and gardening season, which will be further discussed in a later section, but one of the primary causes was to avoid the heavy fouling loads that occur during the summer months. After much success through Phase Two, the Oyster Gardening team decided that Phase Three would follow a similar structure in that the oyster gardeners received only two habitats and tended to the developing oysters during the winter months. However, Phase Three transformed into the longest oyster gardening season so far with gardeners rearing their oysters for approximately ten months.

<table>
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<tr>
<th>Phase</th>
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| One   | February-November 7, 2014 | • First round of spat  
|       |                        | • Gardeners received 4 color-coded habitats  
|       |                        | • Gardening period: summer months                   |
| Two   | November 14, 2014-April 2015 | • Number of habitats reduced from 4 to 2  
|       |                        | • Habitats designated red or blue color code  
|       |                        | • Gardening period: winter months                   |
| Three | September 2015-July 2016 | • Gardeners received 2 habitats as in Phase Two  
|       |                        | • Gardening period: winter months  
|       |                        | • Longest gardening season                          |

Table 1: Oyster Gardening Program Timeline

Once the gardeners have raised the oysters from highly vulnerable baby spat to thick shelled young adults, the Oyster Gardening team prepares for oyster deployment and pilot reef construction. Through the data and observations electronically submitted by the gardeners, the
team, in collaboration with BCNRMD, choose three pilot reef locations in different sections of Brevard County. Collection days were set up near the pilot reef sites where gardeners dropped off their oysters and a multitude of staff and volunteers packed the oyster clusters mixed with blank shell into mesh bags (see Figure 13). These bags are then transported to the pilot reef site and laid above a base layer of blank shell bags (see Figure 14). A certain percentage of the oyster bags are then given a three-digit identification number to assist with future monitoring. The primary goal of the pilot reefs is to determine the most effective strategy for future large scale oyster restoration in Brevard County. The pilot reefs evaluate five different methodologies for oyster reef construction including:

1. Phase One summer gardened oysters inside mesh bags
2. Phase Two winter gardened oysters inside mesh bags
3. Blank shell inside mesh bags
4. Oyster mats
5. Control (base sediment without any restoration material)

Quarterly monitoring efforts post-deployment assess survivability of the gardened oysters and natural recruitment among the pilot reefs, as well as construction methodologies and materials. With each restored and monitored oyster reef, the Oyster Gardening team is able to evaluate the best strategies for upcoming large scale oyster restoration and the locations within the county where the oysters can thrive, survive, and improve the lagoon’s water quality. From the very beginning to the final oyster bag laid onto a restored reef, community engagement is paramount for the Oyster Gardening Program to prosper and develop into a larger project throughout Brevard County.

Data Analysis

Through the weekly electronic data submissions by the oyster gardeners, the Oyster Restoration team was able to assess where the oyster habitats were attracting natural recruitment of native oysters. During their weekly observations, the oyster gardeners inspected a sample blank shell attached to the exterior of the habitat. Due to that exterior shell being the only blank shell associated with the habitat, it serves as the natural recruitment indicator; if there is a spat on the exterior shell, then natural recruitment has occurred and native oysters are within the area of that particular habitat. Whenever gardeners observed spat on the recruitment shell, they simply
acknowledged “yes” or “no” on their data report to the Oyster Restoration database. During Phase One, a cluster of gardeners within the Cocoa Beach/Merritt Island area identified natural recruitment, as well as small gatherings of gardeners near Palm Shores and Melbourne Beach/Malabar (see Figure 15). However, there were also gardeners within those same areas who did not report the same findings. During Phase Two, a more concentrated group of gardeners, within the Satellite Beach/Indian Harbour Beach area, identified natural recruitment, as well as locations south of Rockledge and Cocoa Beach, but north of Viera (see Figure 16). Unlike Phase One, where the southern part of the county displayed concentrated areas of natural recruitment, the vast majority of Phase Two oyster gardeners, south of the Melbourne Causeway, did not report natural recruitment. The primary explanation for the variation in natural recruitment is that oysters reproduce far less in the wintertime, which means far less natural recruitment for the Phase Two gardeners during their winter gardening season.

In addition to the oyster gardeners’ regular data input, the Oyster Restoration team conducted planned site visits to the gardening locations throughout each phase. Each oyster gardener was notified which day of the week and an approximate time block for when members of the team would be visiting. During each site visit, the team would count the number of live oysters within each habitat, assess for natural recruitment, and observe any additional organisms living along with the oysters. During Phase One, the team documented natural recruitment within the Merritt Island canal system, followed by predominantly natural recruitment south of the Melbourne Causeway (see Figure 17). The area between Sykes Creek and Cocoa Beach, as well as the region between the Pineda and Eau Gallie Causeways, showed little natural recruitment. During Phase Two, the Oyster Restoration team encountered a very different scenario. With the exception of a few site visits, the team observed no natural recruitment within Brevard County (see Figure 18). The few sites that did have natural recruitment were concentrated around Indian Harbour Beach, Cocoa Beach, and Grant. However, site visits represent a single “snapshot” of the oyster gardener’s habitats and the surrounding area. The oyster spawning season typically
peaks during summertime and decreases as the cooler winter months arrive. By the time the Phase Two gardeners received their habitats and infant oysters in November, the spawning season may have already concluded for the year; likewise, once the Oyster Restoration team conducted site visits, those particular regions may have finished their minor winter spawning season and be awaiting their much more productive summer spawning season. Another explanation for the variation in natural recruitment lies in the location of natural oyster reefs. Information compiled from historical accounts and field monitoring shows that natural oyster reefs are heavily present south of the Pineda Causeway, which would result in higher levels of natural recruitment for oyster gardeners within that region. Some fragments of natural oyster reefs have been located scattered farther north, but the overall location of natural oyster reefs within the northern half of Brevard County remains unknown.

As part of their weekly data reports, the oyster gardeners were also required to account for additional organisms found living within and on the habitats. Fouling organisms, such as barnacles and sea squirts, are important to note because they compete with oysters for substrate, nutrients and dissolved oxygen. During Phase One, the majority of oyster gardeners located between the 528 Causeway and the Pineda Causeway experienced high levels of barnacle abundance, while the majority of gardeners south of the Pineda Causeway only experienced low to medium levels of barnacle abundance (see Figure 19). During Phase Two, the oyster gardeners who documented high levels of barnacle abundance extended from the 528 Causeway to the Gallie Causeway (see Figure 20). In addition, there were more oyster gardeners located south of the Melbourne Causeway who tallied high levels of barnacle abundance compared to Phase One. One possible explanation for the deviation in barnacle abundance might relate to the salinity levels and circulation of the estuarine water throughout Brevard County. The county’s southern section of the Indian River Lagoon possesses a higher salinity level, due to its proximity to Sebastian Inlet, than the northern section of the estuary. Likewise, the southern section experiences greater circulation from the tides moving through Sebastian Inlet, which improves
water quality for the southern oyster gardeners and prevents fouling organisms from overwhelming the habitats. On the other hand, the northern oyster gardeners experience a greater amount of fouling and can be more affected by algae blooms due to the longer residence time and less flushing of the surrounding water. Furthermore, fouling levels skyrocket throughout the Indian River Lagoon during the warmer months with increased water temperatures, which can explain why Phase One gardeners experienced high levels of barnacle abundance as well.

Moreover, the oyster gardeners’ sea squirt observations were more geographically sporadic than the barnacles. During Phase One, gardeners reported high levels of sea squirt abundance from North Melbourne to Sharps, as well as from the Pineda Causeway to north of Grant, but there was no apparent dominant region where the sea squirts were most abundant (see Figure 21). An oyster gardener who submitted an observation of high sea squirt abundance could be situated directly next to another oyster gardener who submitted a low sea squirt abundance report, perhaps indicating the variation in micro-locations or frequency of data collections. During Phase Two, high levels of sea squirt abundance were most commonly cited between the 520 Causeway and the Eau Gallie Causeway (see Figure 22). Low and medium levels of sea squirt abundance were almost exclusively documented between the 528 and 520 Causeways as well as south of the Melbourne Causeway. During Phase One and Phase Two site visits, the Oyster Restoration team documented higher levels of sea squirt abundance in canal systems. Typically, canals can possess low flow-stagnant water with lower salinity levels than the main body of the estuary, and the water can contain a greater concentration of nutrients due to the storm water runoff from residential and commercial developments. The combination of very slow-moving water and excess nutrients could provide the perfect habitat for fouling organisms like barnacles and sea squirts, especially during the warmer summer months of Phase One.
Although the barnacles and sea squirts were observed to be the principal fouling organisms, when assessing the overall fouling load of the oyster habitats, the Oyster Restoration team needed to take into account all possible fouling debris. At each weekly monitoring session, the oyster gardeners were required to weigh the habitats before and after removing fouling, which could also include mussels, algae and muck from the estuary substrate. Those weight measurements were submitted as part of their electronic data submissions and charted through the Oyster Restoration database throughout the course of the Oyster Gardening Program. Every gardener’s total fouling amounts were combined to showcase a cumulative pattern for Phases One and Two. During Phase One, the highest amount of fouling occurred during June, with habitats accumulating over 220 pounds of fouling throughout Brevard County. June coincided with the peak of Phase One and of the summer months. May and September followed with high fouling levels, with habitats accumulating over 190 pounds of fouling throughout Brevard County (see Figure 23). The excessive amounts of fouling experienced during Phase One was proving to be too time-consuming and physically draining for the oyster gardeners, especially during the grueling Florida summer heat. As a result, the fouling level was a primary cause for Phase Two spanning the winter months instead of the summer season. The Oyster Restoration team hypothesized that as the water temperatures increased within the IRL during summertime, the growth rate for all of the species interacting with the oyster habitats would increase as well, including the fouling organisms. Conversely, the Oyster Restoration team hypothesized that as the IRL water temperatures cooled during wintertime, the growth rate of the fouling organisms would decrease and not overwhelm the habitats.
During Phase Two, the highest amount of fouling occurred during March, with habitats cumulatively gaining over 77 pounds of fouling (see Figure 24). Besides the weight gains contributed by the fouling, the team utilized the gardeners’ weekly reports to assess the amount of average fouling removed from the habitats. During July of Phase One, nearly 23 pounds of cumulative removed fouling was reported, whereas in November of that same session the report displayed a loss in weight from habitats (see Figure 25).
Phase Two showed its highest average amount of fouling removed during March with a cumulative value over 39 pounds (see Figure 26). Phase Two also displayed a loss in habitat weight during the month of November. However, the negative values showcased in Phases One and Two are considered outliers and do not follow the pattern documented throughout the rest of the seasons. The discrepancy in the data could be attributed to equipment/human error during the monitoring sessions and data submissions. Furthermore, both sessions exhibited minor levels of fouling load within the first two months and then began to log sporadic reports of larger fouling loads until the conclusion of each phase.

Lessons Learned

Throughout the first two segments of oyster gardening, the Oyster Restoration team discovered vital information about the relationships between the Indian River Lagoon and its wildlife. For example, Phase One stretched across the entire 2014 oyster spawning season; oysters can spawn starting as the water temperature increases, but the actual time frame can vary every year. However, during the summertime, barnacles within the estuary reach their highest concentrations.
and blanket any possible substrate. For the free-swimming oyster larvae searching for oyster reefs for settlement, their chances of being outcompeted by the barnacles for space is very likely. As a result, Phase Two began during the winter months to allow the gardened oysters time to develop with far less competition. In addition, after Phase One, the team realized that maintaining four habitats with hefty summer fouling loads was proving to be extremely time-consuming for the oyster gardeners. The Phase One sea squirt abundance was especially high for gardeners situated on canals, which made their weekly monitoring sessions particularly strenuous. Therefore, before Phase Two initiated, the number of habitats was reduced from four to only two, which vastly reduced the physical demands and time commitment needed for several habitats. The sea squirt and barnacle abundances within the canals were much more manageable during the winter months, which encouraged more canal residents to participate in the Oyster Gardening Program. Having the oyster reef sites constructed by the summer spawning season proved to be beneficial as well because the free-swimming oyster larvae were able to settle upon fresh quality habitat without battling for space on an older, more established area. Furthermore, the difference in survivability between the two sessions could have been affected by the summer rainy season. Oysters can tolerate temporary drops in salinity, but after weeks of heavy rainfall the mortality rate for the oysters will begin to increase. It was imperative then to understand each gardener’s location in relation to storm water drains and other freshwater inputs. For those Phase One oyster gardeners within poorly circulating canal systems, if there had been several strong summer rainstorms and their habitats were near large storm drains, then the spat likely could have perished from the onslaught of fresh water. On the other hand, some Phase One oyster gardeners with canal sites near stormwater outfalls showcased encouraging growth. Many canals are short enough that, even with strong summer rainstorms, the salinity level is not suppressed for long.

Further Investigation

As the Oyster Gardening Program develops and expands, the Oyster Restoration team plans to construct reefs throughout Brevard County. Monitoring the pilot reefs for one year post-deployment has enabled the team to select the most strategic methodology as well as the most effective materials to utilize for future reef development. In addition, the team is actively working to implementing a “living shoreline” program to coincide with the oyster reef restoration, now known as “Restore Our Shores”. A living shoreline consists of oyster reefs, marsh grasses, and mangroves; together the system provides ecosystem services such as substrate stabilization, erosion prevention, storm surge protection, and habitat for numerous flora and fauna. Traditional development companies construct artificial seawalls for storm surge protection or deposit offshore sand for beach renourishment and erosion prevention, but with little long-term benefits. In 2011, a study by Beck et al. stated “we must take care to ensure that ecosystems and services are restored, not just the latter”. Not only will the Oyster Restoration team be implementing living shoreline sites throughout Brevard County for their ecological and economic benefits, but the team plans on utilizing the sites to educate the public about climate change and its effects on our local environment.

Continued Restoration Efforts
As of Fall 2016, the Brevard Zoo Oyster Restoration team has trained over 1,036 Brevard County residents to become oyster gardeners/citizen scientists at 42 community workshops. In 2014-2015, volunteers and staff had deployed over 180,000 live oysters back into the Indian River Lagoon through the construction of three pilot reefs in Brevard County. Restoration plans for 2016-2017 involve building approximately 2,400 linear feet of oyster breakwater living shorelines, including four more oyster reefs built in Brevard County. Three of the oyster reefs have already been constructed by volunteers and staff within northern Brevard County, deploying over 16,250 live oysters back into the estuary. An additional 20,000+ live oysters will be incorporated into the fourth site of 2016 in Melbourne at Kiwanis Park at Geiger Point. This project will be completed pending permits. In 2017, an extended portion of the living shoreline will be constructed at the pilot reef locations in Port St. John and Melbourne Beach. After field monitoring displayed success of those restored oyster reefs, the Oyster Restoration team and BCNRMD decided to add native saltmarsh vegetation to further aid in shoreline stabilization and water filtration. The Oyster Gardening Program has secured funding from Brevard County, St. Johns River Water Management District, Wells Fargo, and the Indian River Lagoon National Estuary Program in order to continue its Indian River Lagoon restoration work and expand its impact throughout Brevard County into the coming years.

Beck et al. (2011) stated that “native oysters must be recognized for the reef habitat that they provide” and that it is imperative to devise “shellfish habitat conservation and restoration designed not just for fisheries production but specifically to recover these critical ecosystems and their services.” Considering that the Indian River Lagoon has the capability to provide over $7.6 billion in economic benefits to its surrounding counties, the oyster can substantially contribute to the economic potential of the estuary. Unfortunately, the diminished oyster reefs of Brevard County stand as “another example of the unsustainable use of a natural resource that resulted in its rapid depletion” (Kirby 2004). However, through the efforts of private citizens, commercial fisheries, and groups like the Brevard Zoo Oyster Restoration team, the Indian River Lagoon and its essential bivalves have a chance to rebound. The process will need time, resources and revenue, but the long-term benefits of success include restoring natural oyster populations and, an even greater reward, bringing back the bountiful, vibrant Indian River Lagoon. The wildlife and people of Brevard County are linked with what has happened to the Indian River Lagoon up to its present condition, and it is the community who will determine the future of the estuary for generations to come.
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Without a doubt, the Oyster Gardening Project would never have gotten this far in just a few short years without its army of tirelessly dedicated volunteers. Whether caring for the developing oysters as oyster gardeners or oyster buddies, to assisting with shell bagging and reef deployment events, our volunteers have shown the team that citizens all around Brevard County care tremendously about the Indian River Lagoon and its wildlife.

Thank you for helping us make a difference!
Works Cited


**Glossary**

1. **Anthropogenic**: “Of, relating to, or resulting from the influence of human beings on nature.” –Definition from Merriam-Webster Dictionary

2. **Coastal Hypoxia**: “Hypoxia, or oxygen depletion, is an environmental phenomenon where the concentration of dissolved oxygen in the water column decreases to a level that can no longer support living aquatic organisms. […] major events leading to coastal hypoxia include: freshwater discharge and nutrient loading, nutrient-enhanced primary production, or eutrophication, decomposition of biomass by bacteria, and depletion of oxygen due to stratification.” –Definition from NOAA Center for Sponsored Coastal Ocean Research Coastal Ocean Program

3. **Ecosystem Engineer**: “An organism that modifies, maintains and/or creates habitat.” –Definition from Oxford Bibliographies

4. **Estuary**: “Estuaries and their surrounding wetlands are bodies of water usually found where rivers meet the sea. Estuaries are home to unique plant and animal communities that have adapted to brackish water-a mixture of fresh water draining from the land and salty seawater.” –Definition from NOAA Ocean Facts

5. **Eutrophication**: “A process in which an aquatic environment accumulates high nutrient levels due to factors such as industrial or urban pollution or run-off of fertilizers from nearby agricultural lands. The nutrients lead to dense blooms of algae and aquatic plans that cloud lake water, deplete specific minerals and dissolved gases, and can cause natural plant and animal populations to decline.” –Definition from Pearson The Biology Place

6. **Gregarious**: “Tending to live in groups; tending to associate with others of one’s kind.” –Definition from Merriam-Webster Dictionary

7. **Keystone Species**: “A species that is of exceptional importance in maintaining the species diversity of a community; when a keystone species is lost, the diversity of the community decreases and its structure is significantly altered.” –Definition from Pearson-The Biology Place

8. **Muck**: “A layer of fine silt and sediment […] that has accumulated over years of excess sedimentation. Silt, sediment, and other fine particles carried in by tributaries, canals, and break down on the bottom, forming thick black ooze. This ooze or ‘muck’ builds up in channels and deep pockets where it has reached depths of up to 15 feet. The muck blocks light from benthic grasses and organisms and it serves as a legacy load that slowly releases nutrients into the water column.” –Description from Marine Resources Council

9. **Ocean Acidification** (“Osteoporosis of the sea”): “Ocean acidification refers to a reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of carbon dioxide (CO₂) from the atmosphere.” –Definition from NOAA National Ocean Service
10. Photosynthesize/Photosynthesis: “The conversion of light energy to chemical energy that is stored in glucose or other organic compounds; occurs in plants, algae, and certain prokaryotes.” –Definition taken from Pearson-The Biology Place

11. Substrate: “The foundation to which an organism is attached.” –Definition from Pearson-The Biology Place
Contact Information

Brevard Oyster Restoration website: http://Restoreourshores.org/

Facebook page: http://facebook.com/OysterRestoration

Brevard County Natural Resources Management Department website: http://www.brevardcounty.us/naturalresources

Brevard Zoo website: http://brevardzoo.org

Oyster Restoration Team Staff:

Sammy Anderson, Habitat Restoration Program Manager: SAnderson@brevardzoo.org

Karina Briceno, Restoration Project Coordinator: KVega@brevardzoo.org

Amanda Brinkman-Parker, Lagoon Restoration Specialist: AParker@brevardzoo.org

Kate Brown, Restoration Project Coordinator: KBrown@brevardzoo.org

Faith Higgins, Restoration Outreach Coordinator: FHiggins@brevardzoo.org

Katey Leban, Lagoon Restoration Specialist: KLeban@brevardzoo.org

Jake Zehnder, Restoration Project Coordinator: JZehnder@brevardzoo.org