2015 MONITORING REPORT

of

CITY OF GULF BREEZE DEADMAN'S ISLAND RESTORATION PROJECT

For the

US Army Corps of Engineers

ESTUARY HABITAT RESTORATION PROGRAM

GULF BREEZE, SANTA ROSA COUNTY, FLORIDA

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Contents

1.0 Executive Summary

In the summer of 2015, one hundred fifty six rebar structures were removed from the waters of Deadman's Island and two hundred and thirty-eight Ecosystems reefs units, with pilings, were placed within the permitted footprint of the existing state land lease. This project was possible due to the second round of funding provided by the U.S. Army Corps of Engineers for the project titled Deadman's Island Part II.

The former pre-oil spill breakwater, the (Reefblks) rebar structures, along the north end decreased in functionality by 95% due to an oyster die-off and increase in the loss of shell being worn down by ongoing wave action. The damage from the non-functional reefs was a domino effect of slow devastation for Deadman's Island and the hard work of the community.

Consequently, once the oysters died off the reef, the shells fell from the bags, and the shells in the bags were exposed and were tumbled to a smaller size. Since 2011, each year the wave attenuation height of the rebar reefs was reduced, causing erosion of 16,000 cubic yards of sand and thousands of plants in the restoration area. This lack of recovery continued until 2014. The alternative solution was to replace the original live oyster dependent Reefblk reefs with Reefmaker's Ecosystems. The 2015 project replaced the offshore rebar reefs, which now protect the peninsula from a 4-12 mile fetch. The new breakwater project immediately showed success in attenuating wave action and enhancing fish habitat.

The purpose of the new Ecosystems reefs from past studies show if the reef has no oyster settlement or has a die- off from an environmental stressor, the reefs are still structurally sound and will continue to recruit oysters once the oyster population is established in the bay.

Interestingly, 2015 was the first year the entire ecosystem has shown excellent growth and ecological balance. In 2015, there has been 80% more settlement in oyster spat in all reefs than any previous year. The new Ecosystems reefs obtained 90% settlement within the first three months of placement. The majority of monitoring data from this report does not reflect the new breakwaters placed in August 2015. The 2015 summer monitoring reflects the Ecosystems placed in 2011.

The dune project is continually being monitored to determine the feasibility of rebuilding the dunes, which the past hurricanes washed out. The absence of the dunes leaves the rest of Deadman's Island and it cultural and natural resources vulnerable to other impacts. The breakwater is expected to reduce the storm surges and additional erosion.

1.1 Background Description of Project

Deadman's Island is unique and remarkable coastal place. It is one of the few areas that have a variety of ecological habitats in one, including historic cultural resources. It is a unique coastal ecosystem within a bay that is in danger of being washed away. Due to the bridge construction, dredgings, a 12-mile fetch impact, and seawalls causing scouring to adjacent property, Deadman' s Island have experienced accelerated erosion documented since the 1940's. This erosion has unearthed and exposed many historic structures including an unmarked cemetery, shipwrecks dating back to the 1500's. This erosion has threatened historic *Juncus sp*. saltmarsh and killed one-hundred-year-old marine oak trees. In 2005, Hurricane Dennis exposed several coffins and human remains. In an effort, to stop the erosion and prevent further exposure of human remains, eight hundred and fifty feet of the oyster breakwater (Reefblks) were placed in the within the 1,450 linear feet, permitted footprint. The oysters flourished on the Reefblk and created an effective breakwater. By comparing 2009, pre-oil spill monitoring data and 2011 monitoring data, the oyster coverage went from 95% to 1% coverage. The 2010 oil spill caused delays in construction, due to the project being blocked and surrounded by the oil boom, and additional breakwater was not placed as planned. The delays resulted in additional erosion to the area. In 2011 and 2012, four hundred feet of new breakwater called Ecosystems was deployed in the south west and north east location of the footprint, only 200-250 feet were left to complete the entire breakwater. In 2013, fifty feet more of a square shape prototype was placed. Not anticipating a complete die off, in 2012, the Reefblk began to lose the shells in the bags, making the eight hundred fifty feet of reefblk breakwater non- functional. This non-functional reef has caused 16,000 yds^3 of newly placed sand from summer of 2012 to shift and slowly erode. As the barriers containing the sand wear and breakdown; the sand is washed from inside the project area. The new Deadman's Island Part II project in 2015 removed, disposed and replaced eight hundred fifty feet nonfunctional breakwater. Also, two hundred feet of the breakwater, located in the barren area, was deployed to finish the permitted 1450' footprint of the State land lease. In 2016, sixteen thousand cubic yards of sand will be moved from the existing dredged spoil area located on Deadman's Island, to be placed in the areas where the sand has shifted and eroded, caused by the non-functional breakwater and the lack of breakwater.

1.2 Project Purpose

The purpose of the project is to protect the peninsula and an existing salt marsh habitat while increasing the biological productivity of the Gulf Breeze aquatic area. An incidental benefit of this project is to provide protection to numerous cultural resources artifacts identified at the site. The loss of the salt marsh in this area is the result of increased erosion due to wave energy. The project would create approximately 1.04 acres of emergent salt marsh for shoreline protection and an additional 0.046 acres of coastal dune. The structures protect the area by reducing the amount of wave energy that reaches the shoreline. Approximately 16,000 cubic yards of sandy material and vegetation is proposed to be placed to protect and cover historic resources and create a small peninsula that adjoins the land. The restoration area is separated by a dune fence, to reduce anthropogenic stressors on the project. In summary, the project would increase productivity and diversity of flora and fauna indigenous to the Florida areas, as well as protect and stabilize the existing shoreline.

1.3 Project Goals.

1. Complete the remaining breakwater (completed 2015)
2. Protect exposed cultural resource site by covering them with sand (proposed 2016)
3. Create a nearshore island wetland using a local sand source (proposed 2016)
4. Protect, conserve and restore seagrass beds (proposal in review)
5. Create sand dunes by constructing them on the nearshore island (completed 2014)
6. Install Gulf sturgeon monitoring equipment (proposal in review)
7. Increase the overall biological productivity of the Gulf Breeze aquatic and shoreline area (ongoing since 2011)

1.4 Status of erosion control structures, breakwater conditions, and vegetation

According to GPS surveys, the 2015 structures has appeared to have stabilized the shoreline. There has been higher than normal wave action due to higher tides above the mean high water level. These higher tides has caused some remaining vegetation to be buried. From previous events, sand covered vegetation should recover and begin growing in the spring.

1.5 2015 Project- preparation, removal and replacement of the first breakwaters

The Ecosystems placed on the west and east side have sustained themselves through many strong winds and storms, have provided critical fish habitat and have allowed oyster spat to settle. In 2015, the nonfunctional breakwater was removed and replaced by Ecosystems that stacked according to depth and promoted oyster settlement and increased fish habitat. The non- functional breakwater later became a hazard to the marine environment, once the byssal threads of the oysters deteriorated, the oysters fell off of the bags, and the mesh bags were exposed. This collection of shell on the bottom substrate provided additional habitat, egg laying substrate and even shelter for smaller organisms such as stone crabs and blennies.


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Figure 1: Removal of non-functional breakwater

1.5.1 Separating bags from rebar units and seeding the new reef

Some spat were noticeable on the existing bags (5%) and rebar. This spat was from 2014 winter spawn and 2015 spring spawning. With this concern, the bags were cut open and shaken over the new Ecosystems reef to remove trapped organism and any remaining oyster shell. These methods were used to seed and repopulate the new reef. Many stone crabs became trapped in the mesh and grew to a large size and could only be removed by cutting through the mesh. This task was partially accomplished underwater, but the stone crabs were removed more efficiently when the structures were out of the water. All known attempts, either by hand or mechanically, to save any marine life on the old reefs were used. The purpose was to save as many species as possible and seed the new reef efficiently. Once the units were on the barge, a majority of the bags were hand separated from the rebar for easier disposal.

Figure 2- 2013: Phase 1 of the first breakwater placed on Deadman's Island in 2008-2009. The breakwater has lost 67% of it seed shell within the bags. There is no live shell found on the bags. The live shell was found randomly on the inside anchoring system.

1.5.2 Historical Artifacts and Protection and on site design modification

The area has five shipwrecks dated back to the late 1500’s through 1800’s and an unmarked cemetery from Yellow Fever Quarantine victims. During the 1600's Deadman's, Island was used as ships’ careenage area by the Spanish and the British, where large schooners were pulled on marine railways for cleaning and repair. Remnants of this railway, ships and ballast rock, are present today. In 1816, the US bought the area for many purposes, including a Yellow Fever Quarantine station. Hurricane Dennis impacted the area in 2005 and exposed several peat-covered coffins. The State Historic Preservation Office requested erosion to be stopped and the unmarked cemetery and other historic cultural resources be protected and covered. In 2011, a human femur bone was found in a nearby area. A side scan sonar and ground penetrating radar study was performed and compared to other studies of Deadman’s Island’s history and findings. Once these structures were surveyed and mapped, the footprint of the breakwater was designed. The purpose of the design of the breakwater was to protect all historic cultural resources including the unique natural habitat such as the marine oak hammock, dune habitat, and Juncus saltmarsh.

During the removal, some shipwreck remnants were once again exposed and the new breakwater design and placement needed to be modified not to impact the wreck remnants. Any part of the exposed wreck were flagged underwater and avoided. These modifications remained still in the plan and boundaries of the original design and state land lease.

Figure 3: One of the documented exposed historic artifact of shipwrecks (left) The general area (circled in red) of design modification for breakwater placement around exposed historical structures.

1.5.3 Breakwater Completion

The entire breakwater project was finished in twenty days (August 26 to September 14). The project was planned around the tide phases to be able to access the shallow area and wait for low tide to install the breakwaters. To increase productivity the breakwaters were removed in sections and the pilings were set place. Quality assurance of the previous survey markers and set up lines were always monitored to make sure the project stayed within the boundaries of the state land lease. Water quality, primarily turbidity, was measured throughout the project.

Figure 4: Construction of the breakwaters. The remaining protruding remnants of the pilings were cut flush with the top tier of the breakwater.

2 2015 Summary of monitoring results

2.1 Description of Field Sampling Work Summary and results

Underwater monitoring of the existing breakwaters occurred from July 1 to August 22. It was important to complete the monitoring before the breakwater project. The noise from the large equipment would have possibly skewed the results of the monitoring data by startling the fish which were normally found on and around the reefs.   Other monitoring such as benthic sampling, oyster collecting for tissue tests, land surveys were performed until October.

2.1.1 Water Quality

Success criteria: No significant change The success criteria was met. Water quality was measured through YSI meter and kits.

2.1.2 Benthic monitoring

Success criteria: No significant change The success criteria was met. Benthic monitoring was performed by using sediment tubes and a sediment station left on the bottom near the reefs for over a year. Samples were preserved and specimens were counted under a microscope. Present/absent Benthic- 10% of Polychaeta’s were found within the substrate.

2.1.3 Oyster Spat Settlement, recruitment, growth rates, predation, and health inspection-

Success criteria: There was a significance in change (increasing) with the 2015 results The success criteria was met. There was 50% oyster coverage of live and dead oysters, on average, for the entire East breakwater system. The west side showed 58% coverage of combined live and dead oysters. The main predator of the reef, the oyster drills decreased by 63% from 2013.

2.1.4 Shoreline vegetation monitoring- success criteria:

There was a significance in change (decrease) with the 2015 results. The success criteria was not met. Due to storm surges and the lack of breakwater the shoreline erosion was accelerated and 80% vegetation was lost in 2015

2.1.5 Fin fish surveys

Divers count and record all species seen on each numbered unit, each tier and each section within the tier. The individual tiers on the tabletops Ecosystem have three sections . The sections are documented by which direction they are facing, landside (LS), north direction (ND), east direction (ED), west direction (WD).

Success criteria: There was a significance in change (increasing) with the 2015 results The success criteria was met

2.1.6 Wetland creation

Success Criteria was not met- Due to the failure of the breakwater, progressing from 2010, shifting there is an 80% loss of sand and vegetation. A new project is proposed in 2016 to create additional wetlands.

3 Monitoring Results and Description

3.1.1 Underwater Qualitative measuring techniques

It is difficult to quantify the oysters on a vertical reef by quadrat. Since the surface was completely covered, the results would naturally show 100% coverage. However, on top of the 100% coverage oysters were additional organisms competing for space, such as, spat, adult oysters, barnacles, egg casings, sponge, and coral. The live and dead oysters/spat were measured as percent coverage on the existing surface of oysters. A quadrat was easier to use on the Reefblk vertical reefs, mainly because the first set of quadrats were affixed to the reef to provide a reference point. During monitoring events a steel wire quadrat would be placed over the affixed quadrats. This made three dimensional monitoring much easier. The width of the reef growing outward could be measured more easily. The Ecosystems provided more of a challenge.

Figure 5: Biological Technician monitoring the Ecosystems reefs.

Some the Ecosystems have very little space in between tiers. Each space between tiers of each unit was measured. One phase of Ecosystems called Ecodiscs or Lillypads (named after students from Little Flower School who helped create the this prototype), the space in between tiers were relatively small (4 inches) the space grew together quickly for oyster growth. These units were very difficult to monitor and flashlights and underwater UV lights were needed for monitoring. The second and third phase Ecosystems were designed to have a larger spacing of ~ 8” in between tiers. Oysters are also growing together on these reefs and in some cases closing the gaps, by growing together, and forming a dome shape unit. This dome shape unit has oyster growth on the outside but because the growth has some of the sections, the section are hollow on the inside, providing additional shelter for reef organisms. The monitoring plan was modified to include this change and each spacing between tiers is measured to determine how much growth is occurring between tiers. These measurements will show how much flow of water comes though these units.

Statistical analysis for the new breakwater the first year, will only address basic statistics and basic biodiversity. As more years of monitoring data is gathered, the analysis of biometry with correlation of previous and past year’s data, ANOVA and regressions will be added.

3.2 East Breakwater vs West Breakwater

Monitoring occurred on the Ecosystems breakwater located on the east and west side. Each breakwater unit is monitored in sections, the landside (LS), the northern direction (ND), the eastern direction (ED) and the western direction (WD). The east and west direction have different orientation but the sections remain the same on the field sheets. The reason for the sectioning is because the landside exposure on each breakwater is protected. The opposite side is exposed to the open water and fetch wave impact.

The other two sections have little exposure to land or direct wave action and may provide a more protected habitat by being adjacent to the next unit. The east side breakwater is closer to residential property, is exposed to the twelve mile fetch and is in the path of littoral transport of sand from the north east. The east breakwater has more exposure to morning sunlight and afternoon sunlight and is subjected to fierce northern winds. The west breakwater is exposed to a 3-6 mile fetch and is protected from the strong current from the north east. The west end is the closest to the shoreline of Deadman’s Island.

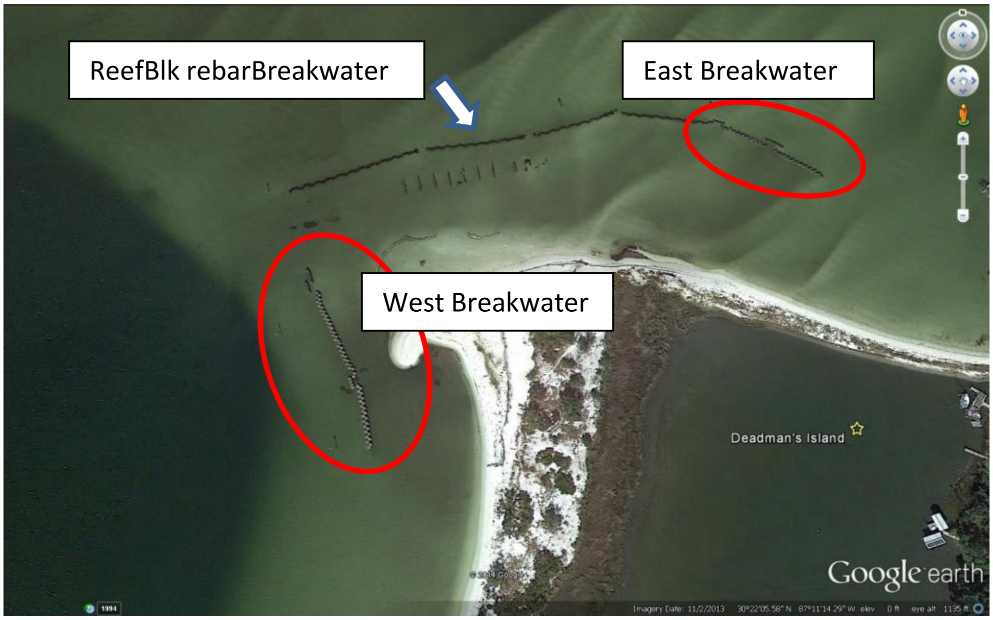


Figure 6: The location of reef monitoring sites at Deadman's Island

3.3 Oyster growth rate, spat settlement, recruitment, predation and health

3.3.1 Oyster Growth

Success Criteria: The success criteria was met.

There was more oyster growth on the Ecosystems breakwater placed in 2011 than pre-oil spill Reefblk reef. The Reefblk reef was intended to be the control to compare information with the two new reefs. At the time of placement of the new reefs, the Reefblk reefs was expected to recover within six months of the die-off. The main reason a recovery was expected to occur on the reefs, is because the oyster spat traveling from East Bay, Pensacola Bay,Santa rosa County, through the water current to Deadman's Island usually settle on the reefs within a one week after spawning. The East bay oyster beds also suffered a loss during the same time frame. In addition, as mentioned in the 2013 report, the Reefblk units in other areas, outside of Florida, were also reported in literature to suffer the same type of loss during the same timeframe as the Deadman's Island decline (Melancon et al, 2013). Deadman's Island is the only restoration project with thorough active monitoring before, during and after the 2010 Deep

Figure 7: A section of reef showing three dimensional oyster growth and monitoring challenges on one of the Ecosystems units of Deadman's Island.

Water Horizon Oil Spill. It would be helpful to compare other data sets with other restoration agencies and project. Unfortunately, after much inquiry, there are no other data sets from any agency or university in Florida to compare these results. The 2015 year is the first opportunity, since the time of the complete oyster die off, to repeat the same tests piloted with federal agencies and be used as a “post-baseline” study. The results of the post baseline study will be used to compare the tests results of the oysters tested during the oil spill to determine the fish die off and in turn, the oyster die off.

It is important to note, the development cycle of a reef depends on the short lifespan of the oyster. It is important to have small mortalities in oyster reefs but not a complete die-off. This life cycle and increasing growth of oysters’ shell is how oyster reefs build and become structurally sound. A complete die-off, loss of fish and in turn, an increase of predation was not expected on the first breakwater reefs. The Reefblks are effective reefs in particular areas but because it is 90% live oyster dependent, the functionality ceased once the die off of the oysters occurred. Because of this die-off, there is a new direction of how an offshore reef, subjected to heavy wave action, should be designed and built in order to maintain structural integrity, attenuate heavy wave action and provide additional habitat and settlement for oysters and other marine organisms.

Oyster spat living over one month and growing was first observed in spring 2014. Late 2014 and early 2015, the spat settlement and oyster growth increased exponentially. The year 2014 was difficult to monitor due to low visibility mainly from the run off from the April flood event (See aerial Fig. 28). The runoff from the flood event caused the water to become tannic for months. So it is difficult to say if more spawning occurred in the summer. Judging the salinity and temperatures of the water in 2014, the temperature fluctuated numerously and the salinity remained ideal, it is possible, although speculation, more spawning did occur.

After the placement of the new 2015 breakwaters, the spat had settled within two weeks. This spawning was more than likely due to the change in water temperature. It has been observed, if there is a 10^0 change in the water temperature, the oysters begin to spawn. Spawning has been observed throughout the spring, summer and fall seasons. The breakwaters were placed beginning August 25th 2015 and the project ended the first part of September. Surprisingly, the oyster settlement on the new reefs were was almost immediate. December 29, 2015 monitoring showed all the new reefs with 1-2 inch oysters. The temperature of the water when beginning the project was 83^0, the water temperature drop to 78^0 briefly, in mid September and then raised to 80’s again (Fig 7). The temperature dropped in late October briefly but dropped to 57^0 late November and maintained these lows. Another thing to consider when oyster are stressed by collecting and movement, they also are observed to spawn immediately. It wouldn’t be surprising if the seeding activities cause the oysters to spawn, this would have been an ideal temperature around September and additional stress. This is speculation, but what is known, is the tiers on the new reefs, placed in late August, have one to two inch oysters Fig 5).

Figure 8: Oysters ranging from 1 to 2 inches have covered each tier on the newly placed reefs. Photo: Heather Reed

December 29, 2015.

3.3.2 Oyster Spat Settlement Monitoring :

Method: Absence/ presence-percent cover- size-species-disease (Functional) two weeks after placement, each oyster spawning, then quarterly, (every three months) for the first year. After the first year, sample twice a year every year for the next five years.

Pre-monitoring occurs around February to determine the number of biological technicians needed to complete the monitoring in two or three months (weather permitting). The pre-monitoring in 2014 and 2015 spring, summer and fall showed 80% more spat settlement than any previous year. Oysters were observed spawning in July 2015. It is observed, if there is a 10 degrees temperature change (increase or decrease in temp) then the oysters will spawn. Originally it thought that oysters spawn only in the spring and fall.

3.3.3 Oyster Recruitment Measurement Method:

Method: Percent coverage at random stations, evaluation of spat settlement measured at the time of placement and two-weeks after placement, then quarterly (every three months) for the first year. After the first year, sample twice a year every year for the next five years.

This measurement was taken by observing percent coverage. The entire reef was snorkeled for an overall percent estimate. Random unit numbers were chosen to observe and count any spat which may have settled. Any purple colored shell would be considered new settlement and counted as new spat.

3.3.4 Oyster Growth Rates:

The growth rate in oysters met the criteria for 2015. This was the first year of minimum market sized oysters, 3-5 inches, which show healthy full shell growth instead of unhealthy signs of thin shells, indentations and mortalities. Although there were dead oysters, the appearance of the shells indicated these were once healthy oysters and most likely suffered mortality due to predation.

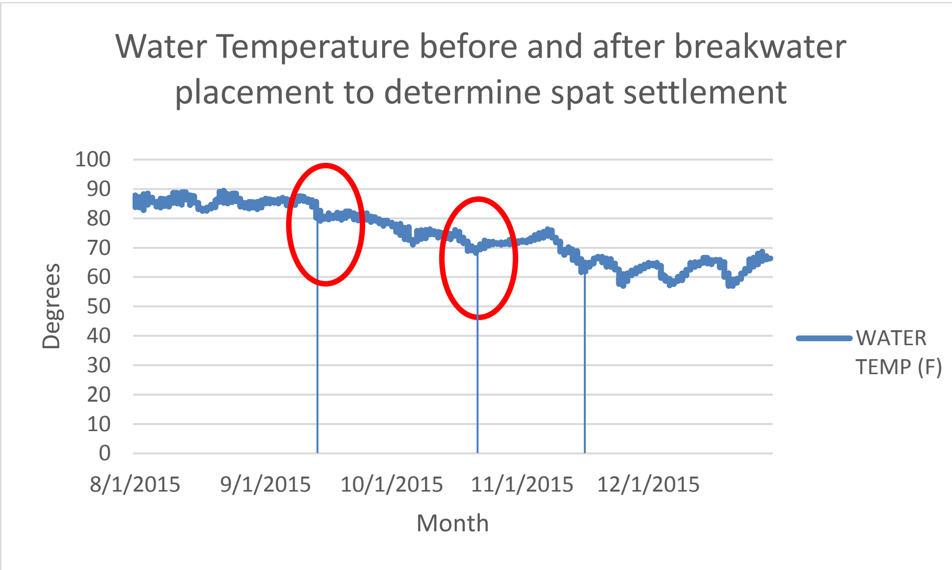


Figure 9: Water temperature before and after placement of the reefs. This chart was used to determine the settlement and age of the new oyster growth on the new breakwaters. The red circle estimates the times of spawning and settlement.

3.3.5 Oyster Predation:

Evaluation will be done throughout random stations- using the point count method of the quantitative underwater ecological surveying techniques. Drills are also counted individually. Sampling will occur twice a year for a period of five years.

Predators –There are many predators of oysters on the reefs but the most abundant threat to the oysters, are oyster drills, *Stramonita haemastoma*. Oyster drills prefer salinity above 15 parts per thousand (ppt), but can survive in 8 ppt.There was a presence of oysters drills on both reefs but the population of oyster drills count were not as large as 2013. This could also be due to an increase in species which prey on oyster drills. The stone crab population increased exponentially on both reefs. It was interesting to observe, another predator of the oyster drill, Sheepshead, were not present on the east reef but were present on the west reef. The west reef showed only eight, 12- 14" (large) sheepshead.

There was a large presence of oyster drill and whelk egg casings. The presence of crushed drill shells and feeding observations, showed the oyster drill population may be starting to be controlled by Sheepshead, stone crabs and other fish. It will be interesting to see in a few years if the oyster drill larvae survive with the large presence of stone crabs, which were absent during the drill boom in 2011. During this boom, the fish and crab population had not recovered from such a rapid mortality in 2010.

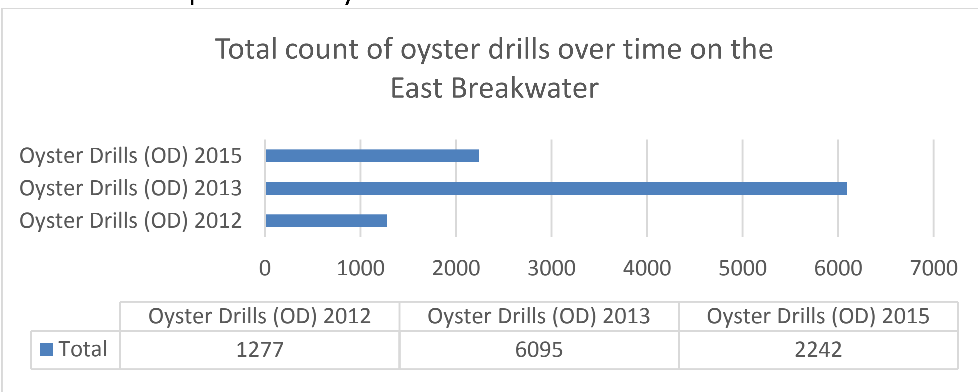


Figure 10: Total count of oyster drills over time.

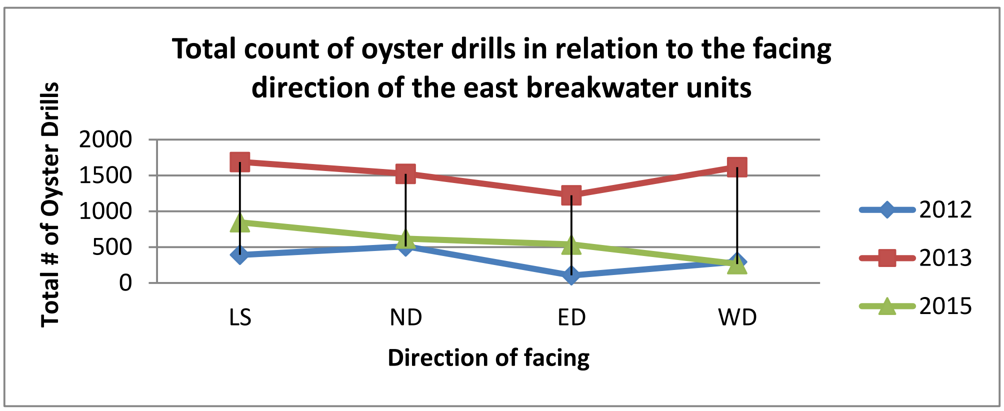


Figure 11: The number of oyster drills in relations to the direction the units are facing. Landside(LS), North direction (ND), East direction (ED), West direction (WD),

There wasn't a statistical difference in the direction the reef was facing, whether landside, north direction, east direction or west direction (Fig 11). Therefore, there was no preference for oyster drills to be seen in sides with more or less wave action, more or less sunlight, more open space vs less open space.

3.4 Oyster Health

Evaluation will be done throughout random stations- using the point set method of the quantitative underwater ecological surveying techniques and samples collected. Sampling will occur twice a year for five years.

3.4.1 Analytical Testing Results

During the oil spill of 2010 the oysters were tested to NOAA standard testing instead of the State of Florida criteria. The State criteria was extremely low, all analytical tests showed no detection of any oil contamination, yet oysters (and fish) were still dying off. Samples of pure crude oil was found on Deadman's Island, reported and sent to lab for testing. FDEP collected the organic matter around the crude oil sample. The NOAA test results were the only testing methods showing there was above the max range of chemical compounds in the diesel range. This means chemical compounds of crude oil compounds were found in the tissue of the fish and oysters instead of the basic PAH from boat pollution.

Figure 12: A picture of oil, from the 2010 Deep Water Horizon oil spill event, found at Deadman's Island.

2015 was the first year since early 2010, the reefs had a majority of minimum market size oyster (3-5 inches). In 2010, oysters were tested for basic PAH and no results were found. A sample of submerged oil found was halved with the FDEP laboratories and scat team. This sample was a pure sample of crude oil. The FDEP results came back as no detection. The certified petroleum laboratories results were 100% crude with a profile of MC252. This was the first realization the State criteria of normal PAH was too low in the detection of crude oil in organisms. NOAA Laboratories were contacted along with BP certified labs to discuss these tests. These particular tests were able to show why fish and oysters were dying off. The fish and crabs died off much quicker than the oysters in 2010. Oysters cannot process PAH so these were considered as "windows to the health of bay". Naturally, we can't say the oil spill killed off the fish and oysters, but there was much oil in the bay, the city of Gulf Breeze and Coastwatchers were constantly locating and reporting oil washed up on Deadman's Island. At the time, these new tests showed petroleum hydrocarbons in the diesel range in the tissue of oysters and fish. The fish died off in 2010 and the oysters completely died off in 2011. These tests are now used as "post baseline" test and should be used as a primary monitoring tissue test. Not only does this test show the lighter compounds which are volatile, and in some cases, less significant, but the tests show heavier compounds which can penetrate the lipid fat layer and show an effect on human health. The same collection method was performed for the 2015 tests. These tests show small levels of primary PAH, which indicates pollution from anthropogenic stressors and the levels were relatively small. There was no detection of the carcinogen compounds in the 2015 samples as were detected in 2010 during the oil spill. What this shows is the recovery from the oil spill has finally occurred, and the oyster male to female ratio has come back into balance with more growth and less observed die-offs.

The carcinogen compounds found within the tissues of oysters during 2010, were fluoranthene, which is a Group 3 carcinogen, napthalene which is a Group 2B carcinogen and known to damage or destroy red blood cells and phenathrene, a Group 1 carcinogen (Fig. 13). Phenathrene is not listed as hazardous to humans under Clean Water Act, but the rate of exposure is unknown. Pyrene, which is toxic to liver, blood, and kidneys was also found. The exposure rates to toxins were estimated from May 2010 to the sample date of the oysters.   In the earlier stages of the oil spill (August 2010) when the die off and sick fish were first seen, the same chemicals were found but also chrysene. Some of these chemicals occur naturally in the environment, and can be detected in lab controls but there is a certain detection limit which is acceptable. These levels were above the detection limit and some of these numbers increased with time. The 2015 oyster tissue analysis showed no detection of any of these levels.

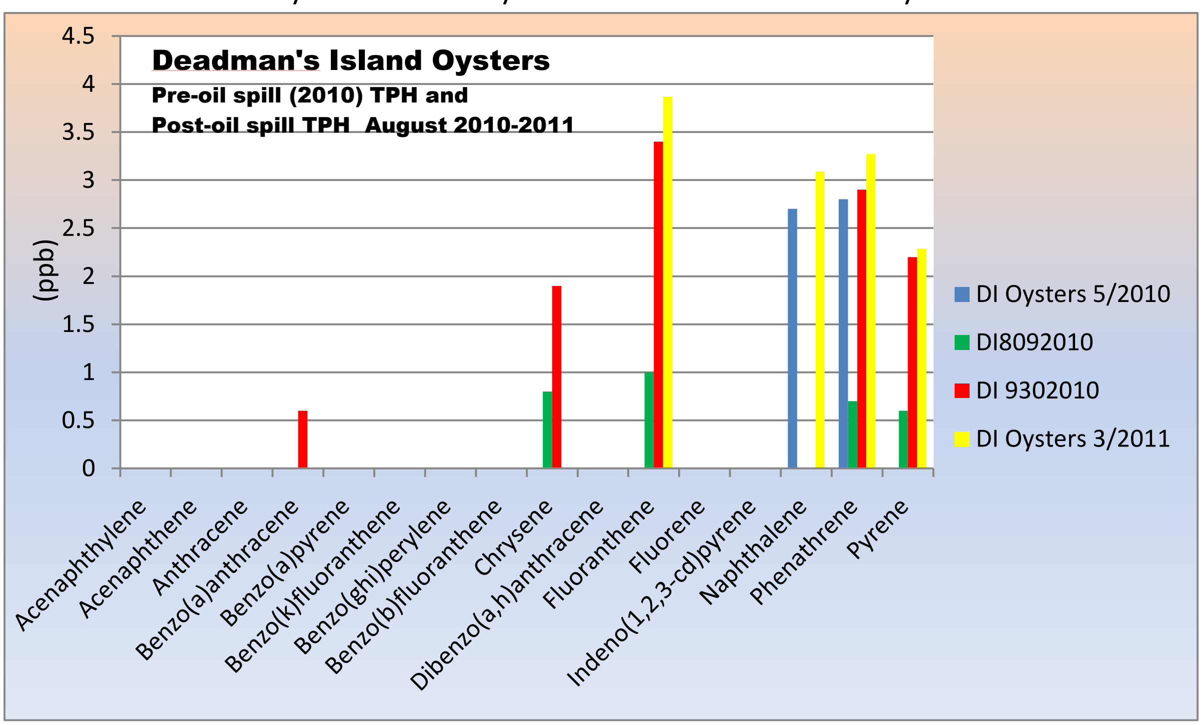


Figure 13: Carcinogenic compounds seen in the oysters of Deadman's Island during the DWH oil spill event. Recent 2015 Total Petroleum Hydrocarbons (TPH) tests show no sign detection of the harmful compounds in the new oysters.

3.4.2 Diseases -DERMO

Another test to determine stress or a dieoff in oysters is Dermo. Dermo is caused by a single-celled Protozoan parasite, known as, *Perkinsus marinus.* Dermo is an intracellular parasite (2-4 µm) infecting the hemocytes (blood cells) of the eastern oyster, known as, Crassostrea Virginia. DERMO is not known to be harmful to humans but can be spread to other oysters and cause a massive dieoff. Dermo is usually controlled in salinities less than 9 ppt. A salinity of 15 ppt is required for infection, 20 ppt is required for rapid and high mortality. The salinity of Deadman's Island in 2015 ranged from 11-30 ppt. Dermo testing was performed in partnership with Auburn University Shellfish Laboratory at Dauphin Island Sealab.

Several samples of juveniles and minimum sized adult oysters were collected and measured from Deadman's Island and tested for DERMO. A comparison was made of a dermo infected oyster tissue and the tissue from Deadman's oysters showed there was no infection in the Deadman's oysters in 2015 (Fig. 14). The DERMO tests showed negative for Deadman's oysters. The Deadman's oysters were randomly selected from various areas and inspected for worms, fungus, indentations, spots, and discolorations. Out of the 75 oysters selected there were no signs of diseases or fungus.

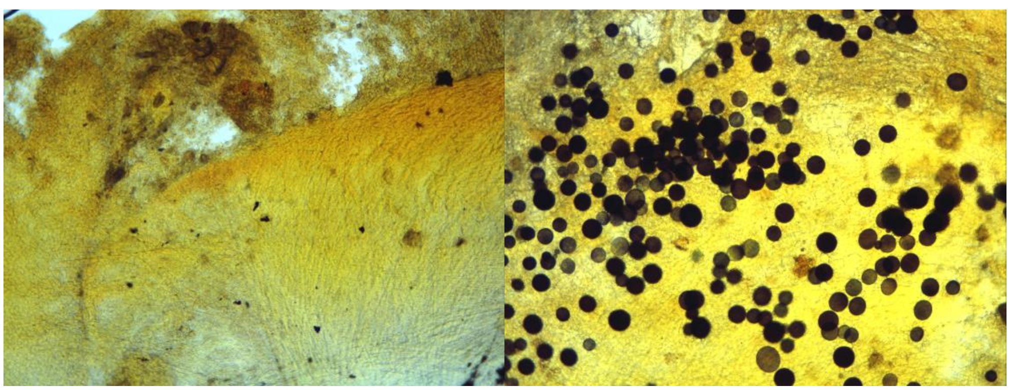


Figure 14: Oyster tissue DERMO results. (Left) Clean tissue from Deadman's Island adult oysters (right) an example of a dermo infected tissue in another bay (Photo credit Heather Reed, DERMO sample credit by Dr. Bill Walton, Auburn University)

4 Abiotic Factors affecting the reef

4.1 Salinity

Salinity is the most important physical factor to trend in order to understand whether the oysters will have a healthy year or predict a possible change in growth. Salinity influences the health of the oyster and also its predators. Higher salinity accommodates a majority of the predators of the oysters. Oysters can grow and spawn in intermediate salinity such as 5-25 ppt (Bartol et al., 1999). At times, the maximum level of salinity would reach 32 ppt yet the year's average is still in the range of healthy oyster growth (Fig. 15). In 2013, the salinity reached it's highest in the bay at 32 ppt and every year went above the maximum limit, only briefly, the lowest in 2015 at 4.57 ppt. Although these limits were reached outside the limits, on average the salinity was at optimal levels (Table 1).

4.2 Temperature

Salinity can be affected by water temperature. As the temperature rises the salinity increases in the bay (Fig. 16). The exception would be fresh water influx as observed with the floods of 2014 (Fig 15). The salinity was much lower in the bay despite the temperature. Observations of nearshore shallow water oysters are more susceptible to disease from stress and literally baking in the sun from hotter temperatures when exposed. The offshore distance of the breakwater keeps the temperature and dissolved oxygen ideal for the oysters because of continual underwater exposure. Monitoring shows some oyster growth out of water but this exposure is normally tidal influenced.

4.3 Dissolved Oxygen

In shallow water reefs, dissolved oxygen can be depleted at higher temperatures. The oysters can withstand lower dissolved oxygen but over time, the fish health and ecosystem food supply can be affected. The dissolved oxygen fluctuates from 20.49 mg/L to 0.16 mg/L in Pensacola Bay. The average of the three years is 7.1 mg/L. (FDEP Storet 2013-2015) There is much flushing coming into Deadman's Island from current and wave action, the reefs are flow through reefs which always provide circulation. Dissolved oxygen is of little concern for these reefs but should be monitored in case of long term low dissolved oxygen events which may affect the reef ecosystem.

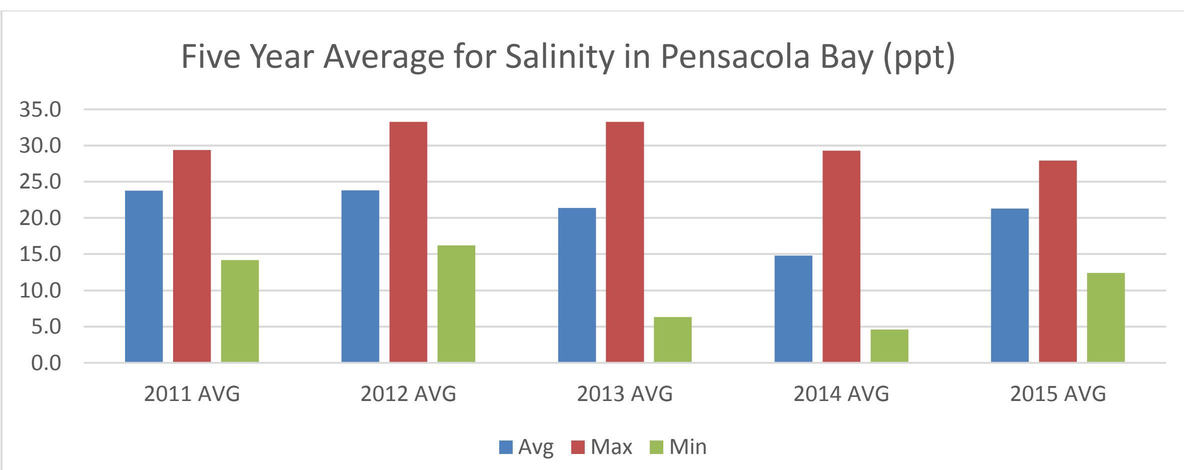


Figure 15: Salinity chart for 2011-2015. Note: Salinity data was limited to the month of October for 2014 and 2015 (FDEP STORET). 2015 shows an average range between 21.3 (ppt) and min and max range 12.4-28.9 (ppt).

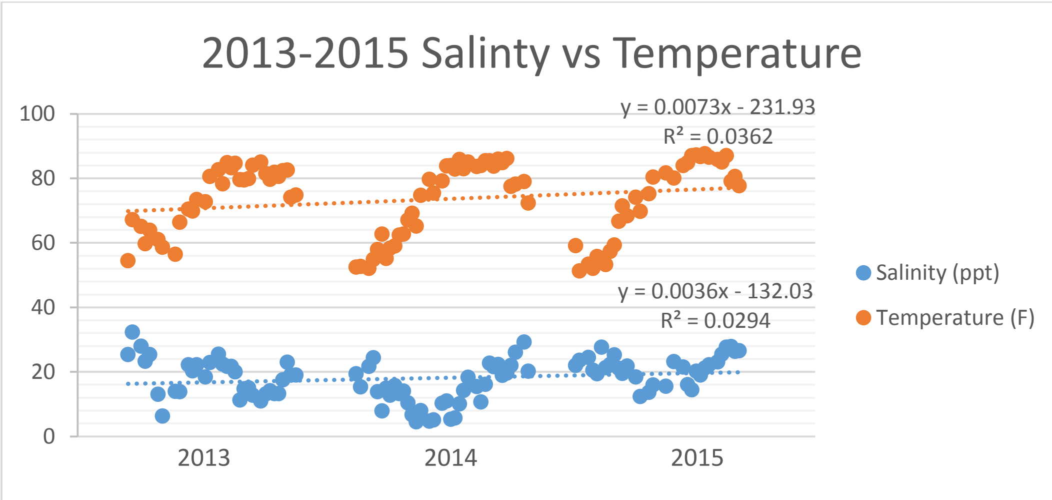


Figure 16: Water Temperature/Salinity trends from Jan 2013 thru Oct 2015 showing a steady trend temperature and salinity correlations.

Table 1: Salinity versus water temperature from 2013-2015 in Pensacola Bay

Salinity (ppt)			
Year	AVG	MAX	MIN
2013	18.63	32.35	6.32
2014	14.88	29.30	12.40
2015	21.29	27.90	4.57
Water Temperature (F)			
Year	AVG	MAX	MIN
2013	74.37	85.12	52.45
2014	81.10	86.18	65.23
2015	73.04	87.62	51.26

5 Community Structure

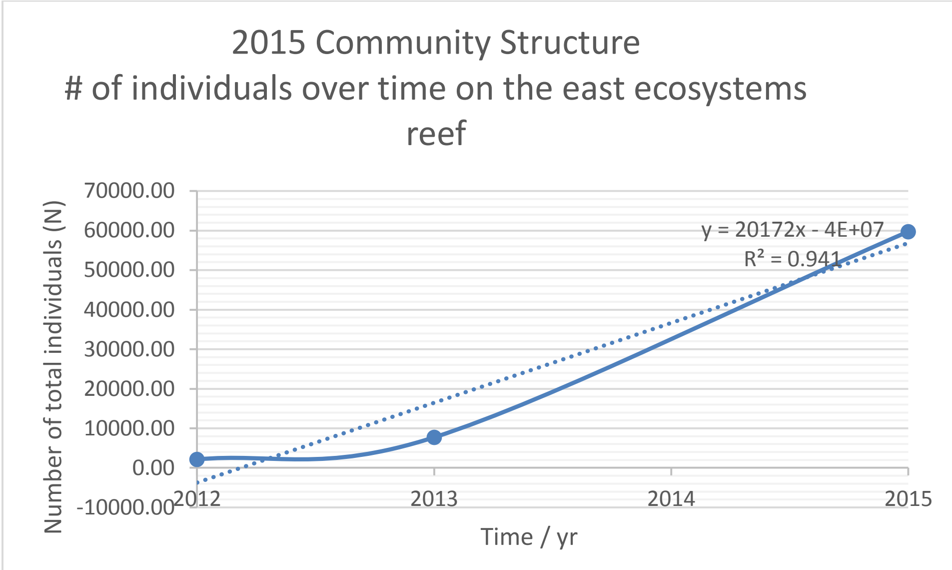


Figure 17: The number of species located on the East breakwater units throughout the years of 2012-2015

Since the placement of the East 2012 reefs, monitoring data showed, in the first year, growth was slow, then exponentially increased over time in the following years. (Fig. 17). Normally, oyster growth can be seen within a few months, if not immediate if deployment is planned correctly. This was the slowest growth ever observed in five years. The 2013 results showed an increase in fish population but oyster growth is still slow. There are certain methods to plan the placement of a reef to get fast growth numbers. The 2015 reef showed oyster spat almost immediate.

As these increases occur, oyster growth, species competition, species diversity, predatory species, and water quality are observed to predict any trends or population events, and whether populations are declining or increasing. In most species, an increase has been observed in 2015 . This increase could be certain species controlling the most destructive species, such as stone crabs reducing the drill larvae. Also, an increase in species unaffected by certain species is also occurring, such as hooked mussels. It will be interesting to see how these populations fluctuate over time and to see if the curve levels and the carry capacity of reef with be achieved or if the carrying capacity is not achieved possibly due to certain species or events. It is too early to tell which direction the curve will go. The data should also show whether the oyster reef is once again in danger of another complete or partial die- off or it at a sustainable level with growth and mortality. The important point to observe with the Reefblk reef which had the 2010-2011 oyster die-off, is the Ecosystems are not oyster dependent on maintaining structural integrity and wave break functionality. If there were an oyster die off on the

Ecosystems, the Ecosystems would continue to attenuate waves and provide a substrate for new growth and populations.

Table 2: Species found on both reefs from 2012-2015 East breakwater reef and 2015 West breakwater reef

Species name	Common name	2012	2013	2015 East Side	2015 West side
Urosalpinx cinerea	Oyster Drills (OD)	1277	6095	2242	3138
Urosalpinx cinerea	Egg Casing (EC)	38	28	56540	17840
Crassostrea virginica	Live Oyster (LO) %	43	85	32	31
Crassostrea virginica	Dead Oyster (DO) %	368	0	18	29
Barnacles sp.	Barnacles sp %			17	31
Archosargus probatocephalus	Sheepshead	55	10	0	8
Lutjanus campechanus	Red Snapper	10	0	0	1
Lutjanus griseus	Mangrove Snapper	60	96	58	65
Zooanthis sp.	Zooanthids	13	0	0	23
Hypsoblennius hentzi	Blenny (Feather)	9	204.3	1716	2859
Cerianthus spp.	Tunicates	18	185.7 3	0	0
Menippe mercenaria	Stone crab	4	0	6325	5965
Pagurus longicarpus	Hermit Crab	49	161	840	547
Lagodon rhomboides	Pinfish	79	140	877	459
Chaetodipterus faber	Atlantic Spadefish	23	59	0	2
Astrangia danae	Coral	1	101	0	3
Opsanus beta	Toadfish	0	359	19	29
Brevoortia patronus	Menhaden juv*	0	100	0	2
Sabellidae spp	Feather duster worm	0	21	0	3
Cerianthus spp	Anemone	3	0	276	1479
Micropogonias undulatus	Atlantic croaker			81	18
Ischadium recurvum	Hooked mussels			12489	8490
Callinectes sapidus	Blue crab			136	52
Gobiosoma bosc	Naked Goby			1361	594
Littorina littorea	Periwinkles			3703	1479
Total fish		236	868.3	4112	4035
Total oysters %		43	85	32	31
Total crabs		4	0	6461	6017
Land Side		695.0 2	2000	30615	11857
Bay Side (North Side)		747	1844	27384	41834
East Side		196	2034	22607	37143
West Side		505	1852	6067	10420

5.1 Species abundance and Individuals present:

In 2012 and 2013, the species abundance coincided with the community structure graph showing there was a steady increase in 2012 and 2013 in 2015 (Fig 17). Normally, a stable ecosystem will have a constant change in species abundance numbers. Certain species numbers increased significantly on various sides facing the reef and remained the same on one particular side. The units that face landside, towards Deadman's Island, have an exponential growth in species as opposed the opposite the north side which shows little change and even a decrease in the presence of some species (Table 1, Fig. 17). The east side shows the most steady rise in species numbers.

Again, the differences to note in each direction, the landside is more protected from wave action from the open bay. The east and west side of the breakwater would appear to have similar exposure to the wave action, except, The East side of the breakwater is more exposed to the morning sun than the west side.

On the entire reef, which includes the Reefblk and the Ecosystems, the oyster drill population seems to fluctuate. There was an increase in the drill population by a factor of 4.7 from 2012-2013, however, there was a 65% decrease in the oyster drill population in 2015 while their egg casings increased by over 2000 when compared to the 2012 to 2013 data. With the 2014 floods, the salinity was the lowest of all the years so that would have most likely contributed to the drop in numbers. It would be good to see a rise in the number of sheepshead which can also help control the population of drills. Unfortunately, these reefs are a good spot for fishers so anthropogenic stresses may have an impact on the fish population and in turn, the drill population.

Other species still found on the reef was coral (*Astrangia danae*) (Fig. 18), sand perch, wrasses, whelks, mudskippers and skilletfish. The smaller fish were found in the upper two tiers, and the larger fish were found on the bottom section of the breakwaters. In 2015, there were other species added to the spreadsheet this year, hooked mussel, *Ischadium recurvum*. Hooked mussels prefer the low salinity ranges. The literature says they are symbionts. However, there is still a competition for space with the oysters. The main predator of hooked mussels is blue crabs. There is a presence of blue crabs on the reef, but not in abundance (0.15%, Table 2) . Species found swimming around the reefs were butterfly fish, sergeant majors, sea robin, black rum, red drum, mullet, menhaden, pompano, white trout.

Figure 18: Solitary coral of *Astrangia danae* found on the reefs of Deadman's Island

6 Biodiversity

6.1 Competition and Species present:

Coverage of 100% on most the entire units is not expected because the top units are exposed to the air from various tides. Completion of surface area is primarily oysters, barnacles, algae, hooked mussels and sponges.

Percent coverage: The East side breakwaters had 54 structures. On average, out of those 54 structures there was 50% oyster coverage on the entire reef, 32% coverage of live oysters and 18% of dead oysters. Barnacles comprised of 17% coverage. Other coverage included coralline algae and hooked mussels.

The west side breakwater had 78 structures (statistically 76). On average, out of the 76 structures there was 58% coverage on the entire reef, 31% coverage of live oysters and 18% coverage of dead oysters. Barnacles comprised of 20% coverage. The majority of the remaining coverage is an orange sponge, coral, hooked mussels and coralline algae.

The Shannon Weiner Diversity index showed the mobile species on East breakwater 1.25 and 1.75 for the mobile species on the West breakwater. The Simpson Diversity index to measure species richness for mobile organisms on the East breakwater side was .45 and .21 for the West breakwater. The species evenness (Evar), for the East breakwater of species is 34% and the West breakwater is 73%. The relative abundance of the West breakwater shows the species are more distributed in the community than the east breakwater. Oysters and barnacles were not included in these indexes due to higher numbers skewing the results.

The diversity index was based on what was found on each tier of each unit of the reef only. The calculation for this index did not account for the schools of fish swimming among the reef. There were more numbers of different species of fish in schools on the West breakwater than the East breakwater. It was obvious the West breakwater side had more coverage of the total area of the units and a larger number of species. Besides having 40% more breakwater on the west side, what is unique about the west side is the ballast rock, left by historic ships are still present, and undisturbed by the project. In addition to the species on the Ecosystems reefs, the visual fish surveys show there are more free swimming fish species such as sheepshead, croaker, sergeant majors, wrasses ,pompano, black drum that frequent the rocky bottom on the West side than the all sandy bottom on East side.

Table three shows the proportion number of species within the overall community of each breakwater. What is interesting and is a concern that 65% of oyster drill egg casings comprise the smaller East reef as oppose to only 16% on the west side. The oyster drill population would appear to be the same for both sides except once again the West reef has 40% more structures so technically there are more drills on the East side also. If we examine the fish that help control the drills, such as sheepshead, it is found there are no sheepshead on the East side. There is a larger number of crabs but may not be enough to control the juvenile population of drills.

Table 3: The proportion of species in relation to the entire population of each breakwater section 2015

Species name	Common name	Proportion East %	Proportion West %
Urosalpinx cinerea	Oyster Drills (OD)	2.58673	2.92530
Urosalpinx cinerea	Egg Casing (EC)	65.23369	16.63078
Crassostrea virginica	Live Oyster (LO) %	0.03692	0.02890
Crassostrea virginica	Dead Oyster (DO) %	0.02077	0.02703
	Barnacles sp %	0.01961	0.02890
Archosargus probatocephalus	Sheepshead	0.00000	0.00746
Lutjanus campechanus	Red Snapper	0.00000	0.00093
Lutjanus griseus	Mangrove Snapper	0.06692	0.06059
Zooanthis sp.	Zooanthids	0.00000	0.02144
Hypsoblennius hentzi	Blenny (Feather)	1.97986	2.66521
Cerianthus spp.	Tunicates	0.00000	0.00000
Menippe mercenaria	Stone crab	7.29754	5.56068
Pagurus longicarpus	Hermit Crab	0.96916	0.50992
Lagodon rhomboides	Pinfish	1.01185	0.42789
Chaetodipterus faber	Atlantic Spadefish	0.00000	0.00186
Astrangia danae	Coral	0.00000	0.00280
Opsanus beta	Toadfish	0.02192	0.02703
Brevoortia patronus	Menhaden juv*	0.00000	0.00186
Sabellidae spp	Feather duster worm	0.00000	0.00280
Cerianthus spp	Anemone	0.31844	1.37875
Micropogonias undulatus	Atlantic croaker	0.09345	0.01678
Ischadium recurvum	Hooked mussels	14.40933	7.91453
Callinectes sapidus	Blue crab	0.15691	0.04848
Gobiosoma bosc	Naked Goby	1.57027	0.55374
Littorina littorea	Periwinkles	4.27238	1.37875
	Total fish	4.74427	3.76150
	Total oysters %	0.03692	0.02890
	Total crabs	7.45446	5.60916

6.2 Direction of face

During the monitoring events, each direction the unit section is facing is documented. For example, land side (LS) is the outward side of the unit facing in the direction of the land or shoreline. Depending on which reef is being monitored, the orientation direction might be different. The rebar and the Eastern section of the breakwater footprint which show LS, facing south. The Western reefs that show the landward side to face east. It is important to address landward side to understand any signs of accretion, and whether there are particular species that prefer the protection and shallow depth that is represented on the landward side. For simplicity, LS remains as facing landward, and the other faces are according to their direction. The increase may show species preference concerning facing direction. The graph shows there is 4.2 times more individuals on the north side than on the west side of the reefs (Fig. 19). Also, the landside shows 5 times more growth than the east on the Eastern reefs. This could possibly be due to more protection from the heavy wave impact of the 12 mile fetch these reefs are subjected too.

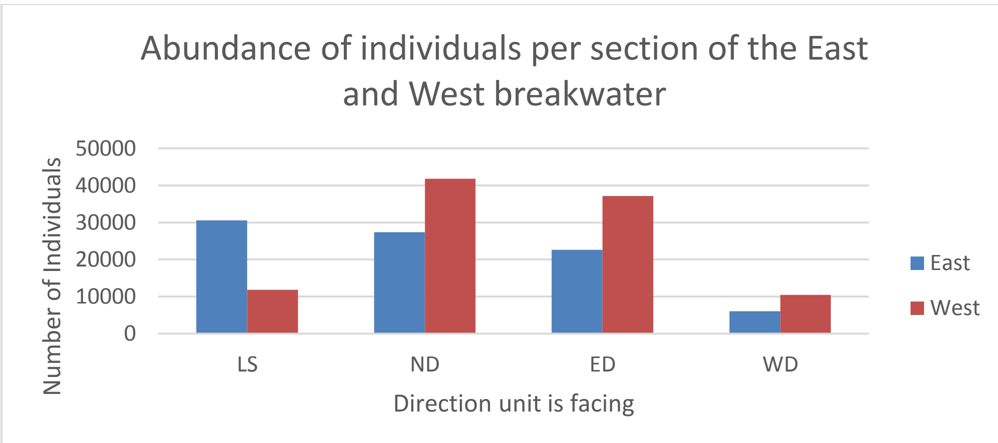


Figure 19: The chart shows the number of individuals found on the various directions the unit is facing on East breakwater and the West breakwater.

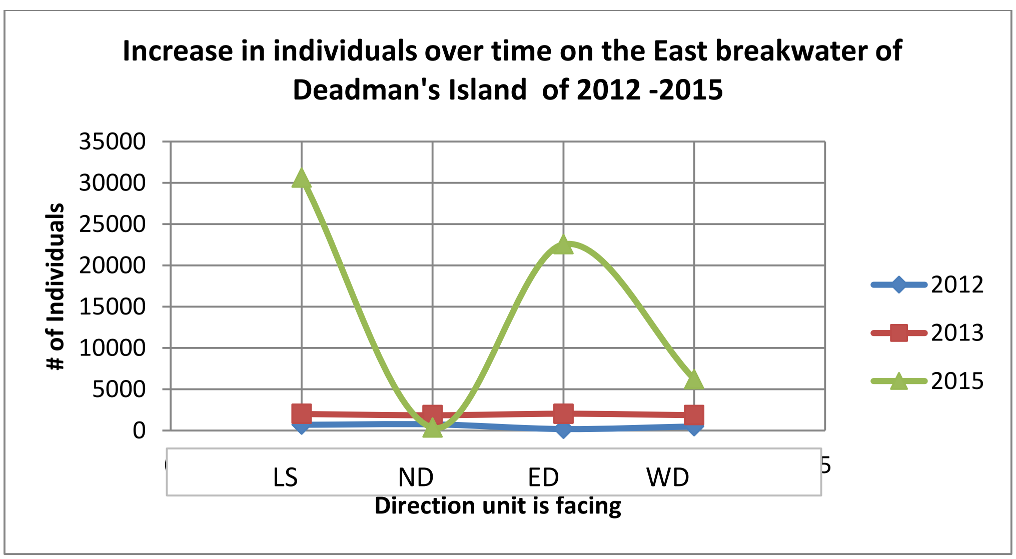


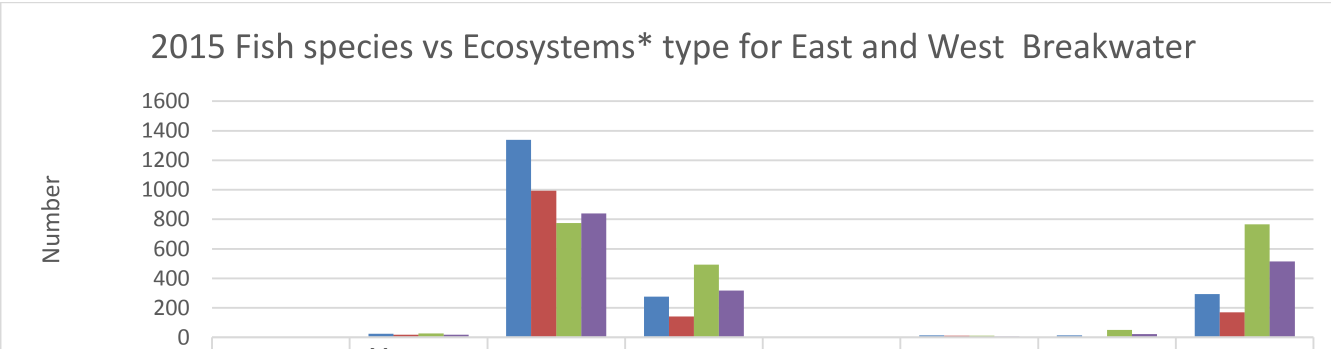
Figure 20: Historic trend of species abundance for 2012-2015 for the East breakwater

7 Fish Surveys

Fish surveys are conducted throughout the monitoring event as fish are seen on each unit- using the visual census method of the quantitative underwater ecological surveying techniques. Fish swimming in the vicinity of the reef are counted and fish inside the reef are counted. After a few transects, the fish are more relaxed with the presence of divers and easier to quantify.

After placement of the 2015 wave attenuators, the fish and crabs showed on the new reefs within 24 hours. Blennies and pinfish were the first species to appear on the new reef, along with grey snapper. Within a week, the new reef was teaming with a variety of fish.

Blennies and Gobies are the dominating species on the reef. The blennies show a higher number on the western tabletops but since there is over twice as many table tops (41) as Lillypads (24), there was no significant difference in the preference of ecosystems type between tiers. The snapper do not seem to have preference for either tabletop or lillypads Ecosystems reefs (Fig. 21)



	Sheepshead	Mangrove Snapper (Grey)	Blenny	Pinfish	Spadefish	Oyster Toadfish	Grunt	Goby
W Table Tops	4	25	1339	277	2	14	13	293
W Lilly Pads	2	18	993	142	0	11	4	171
E Table Tops	0	28	775	493	0	12	50	766
E Lilly Pads	0	18	841	317	0	7	22	514

Figure 21: The fish population vs the various sections and units of the East and West breakwater reefs.

8 Seasonal Monitoring and Ecosystem designs

Monitoring is difficult with the Lillypads because of the four inch gap. It is more difficult to count the marine organisms without the assistance of flashlights. The Ecodisc Table Tops are also circular; however, they have three partitions on each disc, about 9 inches high. These partitions deflect the wave action more, and the spacing provides easier viewing and counting. However, field observations data shows smaller juveniles preferred the smaller gap of the Lillypads for habitat over the larger spaced Table Tops breakwater. Both designs showed functional wave attenuation. However, the table tops showed better wave attenuation than the Lillypads. In addition to the top design, various breakwaters have two types of footing. One footing model has a pad that deploys over the Pearson piling which rests on the sub tidal floor. The other footing is without the pad, and only the piling is exposed. All units are secured by separate collars underneath the tiers to prevent sinking.

8.1 Tabletop unit vs Lillypad unit Ecosystems

The "Table Top" Ecosystems show an increase in species abundance of the East breakwater (Fig. 22), however; the 8" spacing between the table tops units are larger than 4" spacing of the "Lillypads". This spacing difference makes counting easier because more species can be seen due to more surface area for habitat than with the smaller spaced units. There may be more species within the unit but it is difficult to tell even with flashlights.

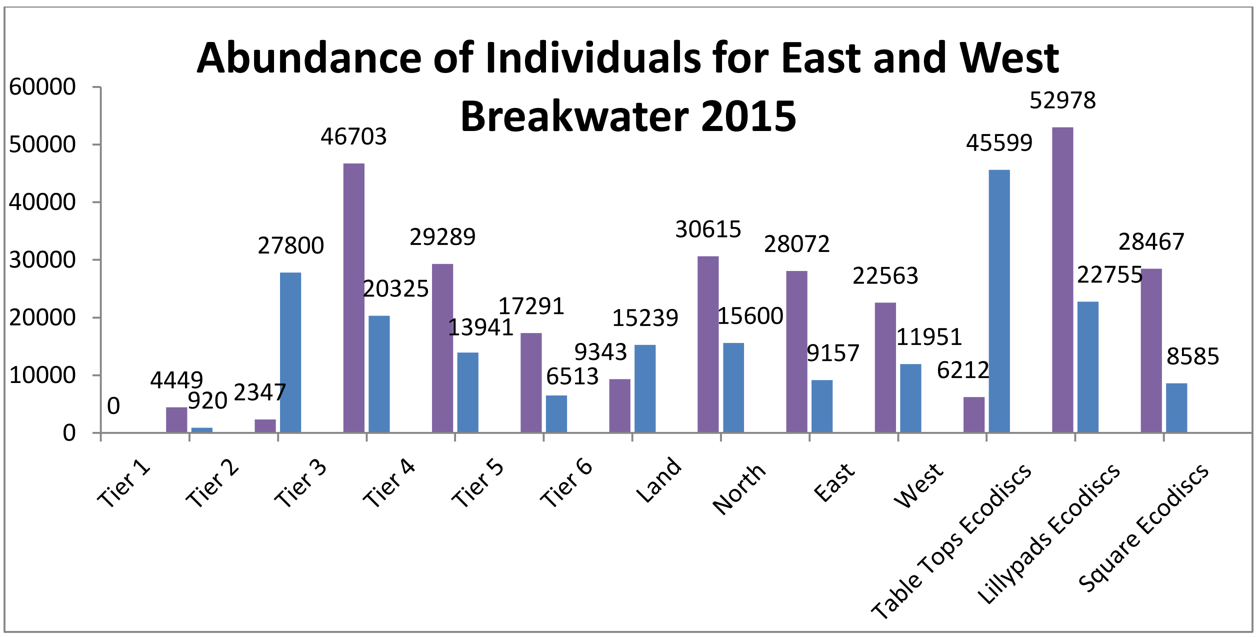


Figure 22: Total abundance of individuals on the East and West breakwater reef in relation to all tiers of each unit, all directions of Land side, north direction, south direction, east direction, west direction and the two different structure designs.

8.2 Tiers vs species abundance

The tiers of the Ecosystems support an interesting ecosystem hierarchy among fish. The stacked units stand in a shallow 4-5 feet depth, with tier 1 being the top unit. Tier 1,2,3 of figure 22, show juvenile fish and the lower tiers show the larger fish. The deeper in the water column the tiers have the larger fish. What is consistent in all years, the third tier seems to show more species (including fish) abundance. The reason could be is this area keeps juveniles safe from predators, or it could be due to tier three and four is a few are 90% submerged underwater all year, providing protection from surface wave impact and providing a more sustainable habitat.

Tier 6 is usually where the larger fish are found. There is little growth on the last tier. This lack of growth could be because the larger fish control the species population on the sixth tier or since the sand builds near these reefs the wave action cause the sand to irritate some of the species, reducing the ideal habitat for most species.

8.3 Flow through studies of the Ecosystems

As mentioned previously, the oyster growth is causing the spacing in between the tiers to become smaller. These spaces were measured and recorded. There is not enough confidence in the data or method to determine flow or lack of flow.

There are few concerns with the validity of this method. Various habits of marine life breaking the oyster clusters and creating gaps. It was observed that stone crabs continually create openings, by pushing through the oyster shells with their claws, to enter and exit the tiers. Using flashlights, the divers were able to see inside some sections of the Ecosystems which were closed from oyster growth. The inside of the tiers remain open and could still provide flow through the tier sections. There is oyster growth on the inside of the tabletop tiers but since the oysters are on the embedded recycled and fossilized shell, the oysters cannot easily grow together as they could on the outside. This inability is due to the height of the section and the limited vertical growth capability. The area inside the tier presumably provides more protection and space for the reef's marine organisms. With the population increasing exponentially, it is unknown what the carrying capacity will be or if it will be reached with an evolving reef which is being continually changed by the habits of various marine species.

Figure 23: The existing oyster reefs on the north east section of Deadman's Island. The picture shows the entire oyster reef is growing into a dome from the oyster growth on the outside of the reef. The inside of the reef is still open and provides safe habitat for reef species.

9 Substrate monitoring

9.1 Benthic

Benthos Monitoring: The sandy substrate harbors fewer polychaetes and other benthic organisms. According to the tracking receivers, Gulf Sturgeon *Acipenser oxyrinchus desotoi*, frequent the area around the breakwater. It is hypothesized as the sediment accretes and builds the sediment will become finer. This fine sediment is the ideal foraging habitat. The method to determine the amount of foraging food present for the sturgeon is still being pioneered.

Thirty-five sediment samples were taken directly, by core tube, under and beside the breakwater units and preserved and dyed with Rose Bengal. The dyed samples set overnight and were sifted, viewed through a microscope and the individual organisms were counted. There wasn't much diversity in the benthic organisms. Most were easy to discern under a microscope. Interestingly, when the breakwater were removed, the sand underneath the breakwater appeared to be hydric and less species. The sand two feet from the breakwater, showed mostly Ghost shrimp, *Callichirus majorwas,* polychaete worms, *eten heterpoda, Mediomastus ambiseta, and Leitoscoloplos fragilis,* lancelets, *Branchiostoma carabaum* and mysid shrimp, Mysideacea. These species are good foraging species for the Gulf Sturgeon.

10 Bathymetric Survey

To monitor the sediment movement, erosion, and accretion, a bathymetric survey was taken by a professional surveyor in the month of October. The survey elevation points were then compared to the 2007 bathymetric baseline survey, 2007 funded by US Fish and Wildlife(Fig. 25). The baseline of 2007 was before any breakwater was placed offshore of Deadman's Island (Fig. 26).

Points from 2007, 2011 and 2012, 2013, 2014 and 2015 were mapped to determine how the sand shifted. The results from 2007-2013 were discussed in the previous year's report and won't be addressed in this report. Although most points in the surveys are not exact each year, the survey uses fixed reference points that stay the same each year. By converting the elevation points in contours, it is easy to see the changes and movement of sediment visibly.

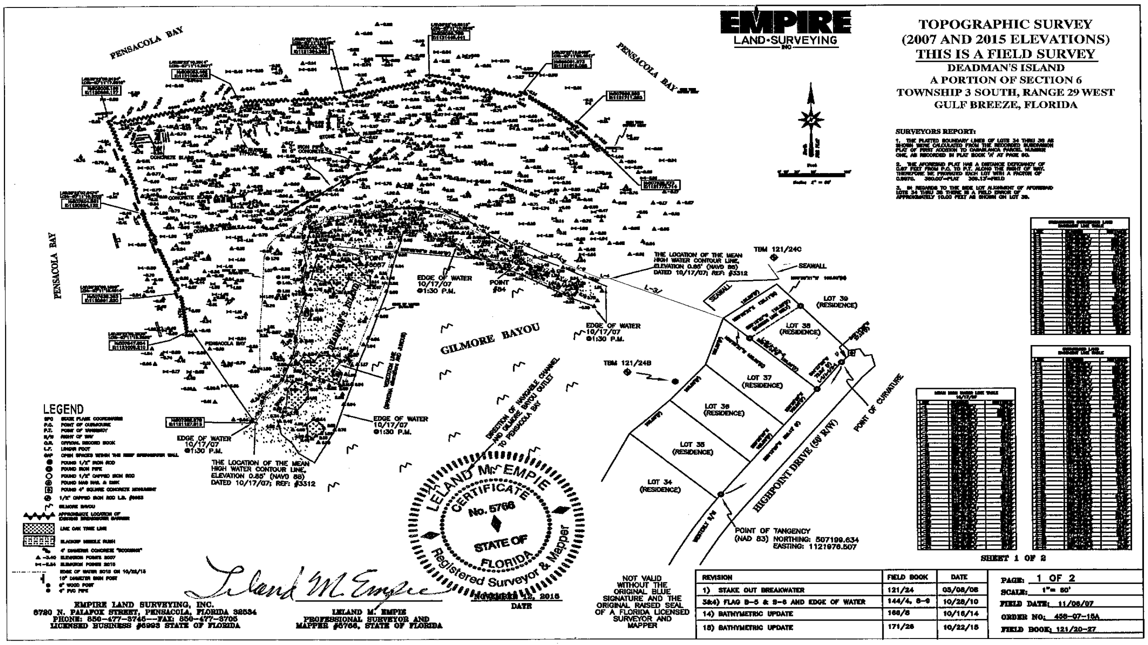


Figure 24: 2015 bathymetric survey and as-built breakwater survey

Since there is a new type of breakwater, and the breakwater footprint is complete, the behavior of the previous year’s sand transport and shifting is expected to be irrelevant when compared to the new bathymetric. For monitoring purposes, the baseline of 2007 and the prior years’ of 2014, will be compared to the 2015 survey. It is not expected to show an immediate result from the breakwater placement show in the 2015 survey due to the timeframe of the project being completed one month before the survey.

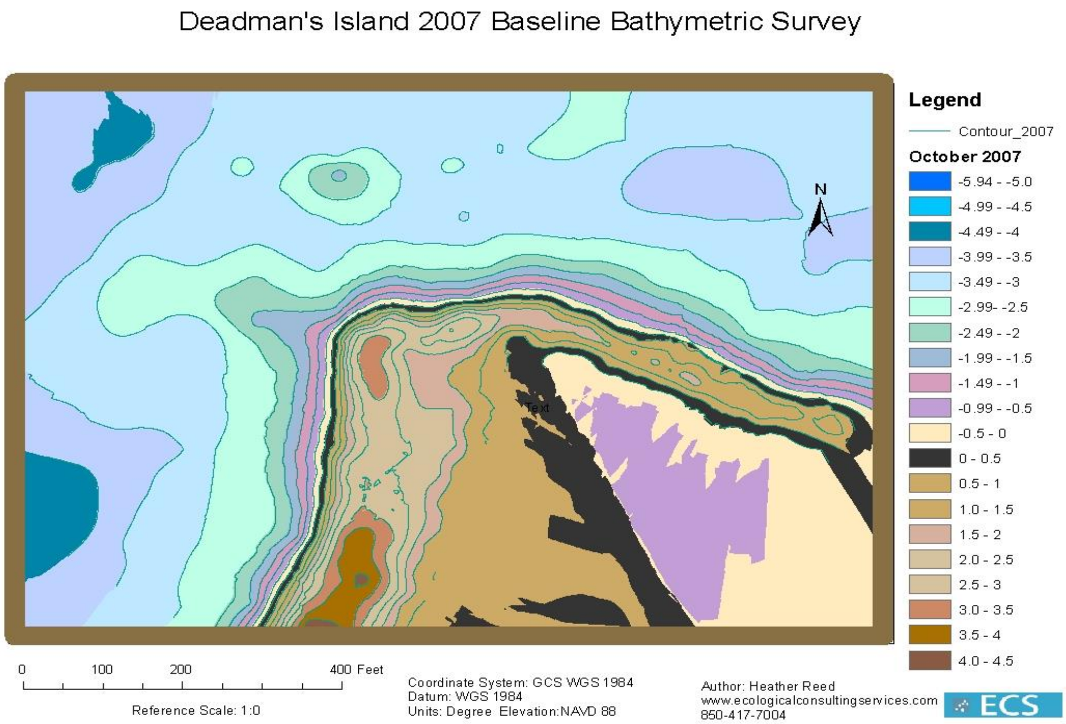


Figure 25: The 2007 Baseline survey of the bathymetry of Deadman's Island prior to breakwater placement.

Figure 26: Deadman's Island aerial taken in November 2007

10.1 Sand movement

The 2007 baseline shows a deeper depth throughout the project and in some areas (Fig. 25) , there was no gradual profile. This steep profile is what was causing trees and vegetation to uproot and fall into the water. The roots systems were undermined and destroyed. This depth along with the harsh current from the 12 mile fetch was the main factor the historic resources were being unearth and the saltmarsh was in danger of being smothered and impacted by high salinity or saltwater intrusion.

The 2014 bathymetric shows the sandmovement since the breakwaters and sand was placed (Fig. 27, 28) Naturally, the elevation changed, but what important to note, a gradual beach profile was created by a barrier system, to allow the sand to settle in a slope causing the water to roll onto shore rather than scour and undermine the shoreline. The failing breakwater and north east open section with no breakwater, caused the wave action to push the sand to the east and south east to spread around the project and accrete behind the existing breakwaters.

Sand continued to shift prior to the year, 2015. There appears to be no loss of sand in the area. Yearly bathymetric showed the lack of breakwater on the northwest corner (Fig. 28) was causing sand to shift around the original location of placement (Fig. 29). Once the sand moved behind the western breakwater, less shifting occurred. The Northwestern section of Deadman's island was constantly eroding due to the failed rebar breakwater. Since there were no shells in the bags of the rebar reefs, wave attenuation decreased 95%. Deadman's Island is most impacted by this lack of wave attenuation and protection from the 12-mile fetch. This problem has caused a continual erosion of the vegetation planted for stabilization.

Since the breakwater has been placed, a monthly GIS reading is taken to observe any change in the shoreline (Fig. 32). Although this bathymetric is a baseline for 2015 since the breakwater as been replaced, the depth of the sediment has changed around the breakwaters due to the removal of the old reef and replacement of the new reef. This was due to constrcution activities around around the breakwater and the sediment being disturbed by the equipment.   This disturbance does not represent a typical stable condition. The sandy bottom needs to reach equilibrium to determine whether the movement of the sediment is permanent.

10.2 Sand Accretion and Erosion

Monitor the decrease or increase in sand accumulation. Monitoring will occur after every hurricane or large storm. Erosion device measured quarterly for the first year and after storms. After the first year, monitor twice yearly every year for the next five years.

When comparing the 2007, 2014, 2015 bathymetric surveys, the most noticable change in depth on all the surveys is the darker green area. This depth, located on the legend is -2.49 ft to -2 ft (Fig. 27-29). The depth of the water is decreasing and sand accumulation is spreading. The section on the north western side remains deep due to the lack of breakwater. The sand has not moved from the site but is shifting due to this scouring from lack of breakwater in one area and accretion from the protection of the breakwaters. Since the breakwater footprint is complete, it is expected to see less shifting and more stability.

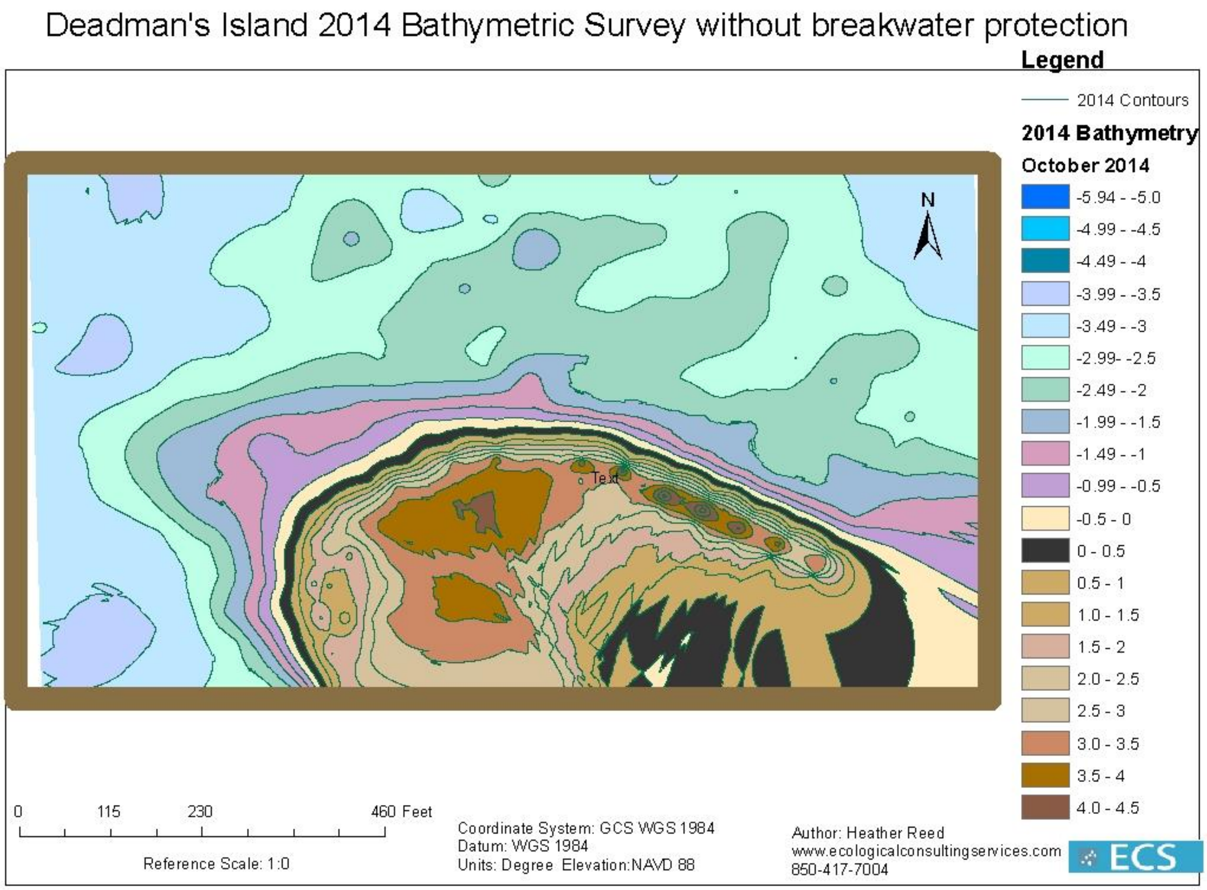


Figure 27:The 2014 bathymetric survey a year after placement of sand

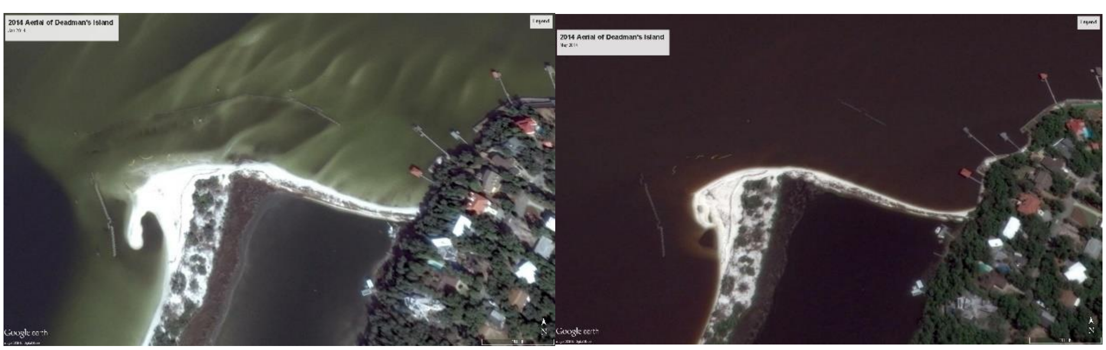


Figure 28: The aerial showing the breakwaters and shifting of sand due to an absence of the breakwater was taken January 2014. The aerial to the right is dated May 2014. Note: This May aerial was taken following the April 2014 flood events.

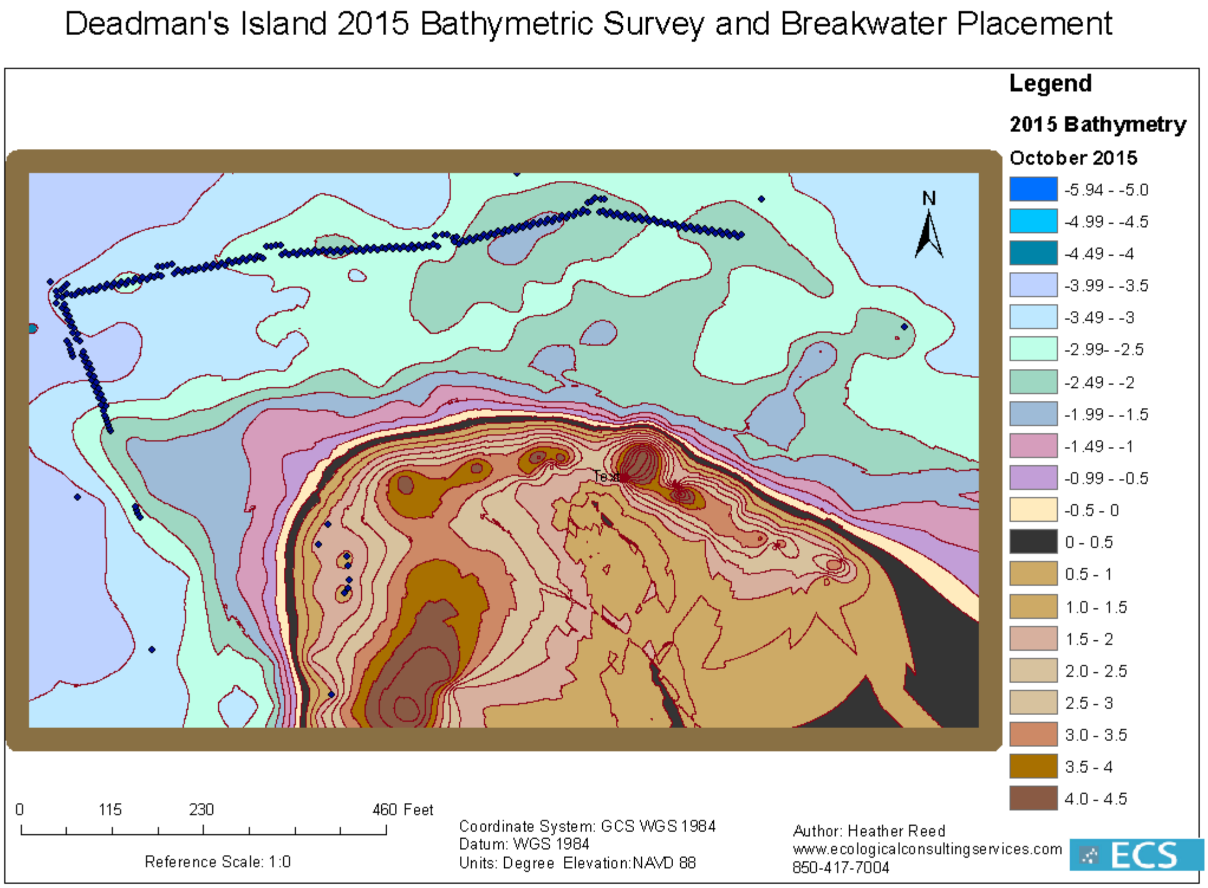


Figure 29:The 2015 bathymetric survey shows the location of the recently placed 2015 breakwaters for reference.

Figure 30:. The aerial was a drone photo taken during a community planting event.

Drone services: Wes Morgan, Morgan Creative October 17, 2015.

11 Storms

The year of 2015 did not endure as many storms, in relation to hurricanes. The past year did have many tropical storms and tidal surges throughout the year. The breakwaters were placed August 25-September 14th. After this placement, the water levels rose above normal MWH due to storms and surges.

In late June, Tropical Storm Ana hit the panhandle of northwest Florida. TS Ida arrived in September through October, along with TS Fred, TS Grace and TS Henry. In October, TS Joaquin became a category two storm in the Gulf of Mexico, this storm raised the winds and water. Hurricane Patricia came from the Pacific and across Mexico and into the Gulf. Although Patricia did not impact the Gulf directly, it did impact the project indirectly with heavy rain and winds. Patricia raised the water levels and increased the storm surges. There was a planting event October 17, 2015. The planting event was two days before the remnants of TS Patricia impacted Deadman's island with over 2.5 feet above normal tidal surge (Fig.31) . The high water washed over the breakwater and washed the newly planted vegetation. We lost 90% of our plants the next day. The new vegetation did not have time to take root.

These storms tested the stability of the *Ecosystems* oyster breakwater. The oyster breakwater showed stability through storms and tides and ecological growth. There is nothing that can be done about higher than normal water level. The breakwater has been able to stop the fast underwater current from the 12-mile fetch. This fetch has caused much destruction to the shoreline in the absence of the breakwater.

11.1 Number of high water events/ significant storms and duration of each

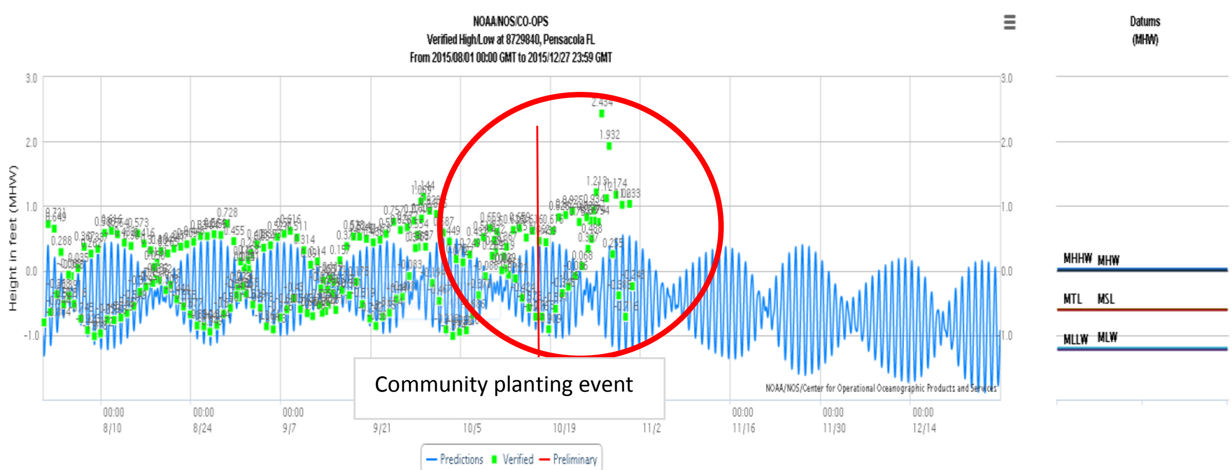


Figure 31: The high water events in 2015, due to storm the water levels were raised above mean high water (MHW) consistently. October 26, 2015, showed the highest water level of 2.14 above MHW level.

12 Measurements: Shoreline Vegetation Survival, Mortality and

Shoreline Vegetation Monitoring: Monitoring two weeks after placement, quarterly for the first year and after every major storm.

12.1 Shoreline Vegetation Measurements:

1. Survival/mortality percent coverage increase/decrease (Functional)
2. Measurement method- percent coverage (Functional) quadrat, transect from fixed reference points

Timeline: First two weeks after planting, monthly for three months and twice a year thereafter for the next five years.

Species composition: From the loss of functional breakwater, the vegetation on the north end of the project site, that was located directly behind the project site, an 80% loss due to excessive wave and erosional impacts.

12.1.1 Test planting results

Community volunteer test planting occurred along the shoreline throughout the summer after the breakwater was placed. The shoreline vegetation behind the west end breakwaters seems to have stabilized. The new vegetation located on the west has stabilized and has shown l. Moreover, the north end has not shown stabilization due to heavy wave action and lack of protection. It is anticipated upon complete funding with the placement of the breakwater; the shoreline vegetation will have less wave action to for the roots to tolerate and the plant can use it is energy for growth instead of trying to take root in ongoing wave action.

12.1.2 Shoreline Erosion Conclusion

In 2012, the plants were buried under the sand due to storms. In 2013, the plants had recovered 100% and were becoming dense clumps. Even though the storms completely covered the plants in the previous year, exposing only small sprigs of green leaves, it seems as long as there is a little exposure to sunlight for photosynthesis, the vegetation can recover or grow when buried underneath the sand. These same results occurred in 2014 and 2015 on the upland areas. Most of the sand shifted and washed from the shoreline. It is expected to stability now that the new reefs have been placed and the breakwater footprint has been completed (Fig. 32).

Overall, the information from the monitoring data from the vertical reefs show these reefs were the best alternative to high wave impact as opposed to bagged shell. Bagged shell can promote much growth but environmental stressors can cause the reef to die off and break up in the heavy wave action. No matter what stress, whether salinity, high temperatures, heavy wave action or even environmental disasters, these reefs will maintain it's structural integrity as a wave attenuator. In addition, the data shows there is exponential growth on the reefs of the marine ecosystems.

Figure 32: A shoreline survey showing GPS point from September and December 2015 along the shoreline of Deadman's Island. There is currently no change in the shoreline and appears to have become stable. Drone overlay supplied by Wes Morgan of Morgan Creative.

13 Project Future needs

The breakwater footprint has been completed and the Ecosystems are now in place, the 16,000 cubic yards of sand and vegetation lost over the years can now be replaced. The dune pilot project shows additonal dunes can be built and the seagrass bed located south of the project can also be expanded. This project is anticipated to occur in the summer of 2016 and 2017.

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