2016 FINAL MONITORING REPORT

of

CITY OF GULF BREEZE DEADMAN'S ISLAND RESTORATION PROJECT PART 1

For the

US Army Corps of Engineers

ESTUARY HABITAT RESTORATION PROGRAM

GULF BREEZE, SANTA ROSA COUNTY, FLORIDA

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2017

Contents

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1 Executive Summary

In 2011, grant funding of $715,000 was awarded to the City of Gulf Breeze from the Estuary Habitat Restoration Program by the Department of Army, U.S. Army Corps of Engineers, Mobile District, Alabama, for the Part II of Deadman's Island Restoration. This is the fifth and final monitoring report for Part one of the original restoration activities.

This project protected approximately 13 acres of coastal habitat, including salt marsh, installed 500 additional feet of innovative oyster reef breakwater/habitat and restored over 1,200 feet of shoreline.

Monitoring results showed the innovative breakwater was successful in attenuating wave action, protecting the shoreline and creating oyster habitat. The innovative breakwaters, called Ecosystems, showed success through the years. The oyster breakwater showed stability through storms, low level rogue surges and high tides.

Included as part of the restoration project, In 2008 before the oil spill, a breakwater (Reefblks) made of rebar structures and oyster shell was placed along the north end of the restoration site. The Reefblks structural integrity was oyster-growth dependent. The growth of oysters on this recycled material determined the structural integrity, functionality and success of the reef. The Reefblks decreased in height due to the increase in the loss of shell that was worn by ongoing wave action. Due to the lack of wave protection and the failing breakwater, the sand shifted but remained behind the reefs. The shoreline continued to erode throughout the years from this lack of functionality from the deteriorating Reefblks breakwater. The Ecosystems placed on the west in 2011 and the east side in 2012, provided immediate fish habitat and allowed oyster spat to settle and grow into market sized oysters.

In the summer of 2012, 16,000 cubic yards (cys) of sand was placed in the permitted area of the North West end. This placement of sand restored the area of Deadman's Island to the location of the 1972 aerials.

In 2013, oyster coverage had increased 80%, and market size oysters occurred in the spring season of 2014. Heavy rains, flooding and low visibility made monitoring extremely difficult in 2013. The low visibility was due to the runoff from overflow of the rivers that filled the bay and turned the normally clear water to tannic brown.

During the year 2014, the project endured more erosion than the previous years. The pre-oil spill oyster reef breakwater showed an 80% loss of wave attenuation as compared to a 65% loss from 2013. This particular reef was placed to attenuate the strong impact of the 12-mile fetch and the strong underwater current coming from the northeast direction of Pensacola Bay and was slowly losing its wave attenuation. The oyster reef die-off is believed to have been caused by the BP oil spill. The erosion was caused by the compounded domino effect of actions from the die off, currents, runoff along with the BP oil spill. Fortunately, unlike the Reefblks, the Ecosystems were not oyster growth dependent and remained a structurally sound reef. This demise of the older reef caused a mass movement of sand from the end of the island. Many community planting efforts from the year of 2012 were also lost.

The monitoring results of 2015 and 2016 showed an ongoing increase in oyster growth and increased species composition for the entire reef ecosystem. A comparison of bathymetric surveys from 2007 to 2016 showed the interesting movement of the sand. Fortunately, the sand was shifted throughout the project and was not completely lost. The movement of sand showed the wave attenuation effectiveness of the various prototypes of the Ecosystems placed.

In 2015, grant funding of one million dollars was awarded to the City of Gulf Breeze from the Estuary Habitat Restoration Program by the Department of Army, US Army Corps of Engineers, Mobile District, Alabama, for the Part II of Deadman's Island Restoration. The Part II project was a large scale three task project which consisted of: 1) removal of the nonfunctional degraded reef and replacement of the breakwater with Ecosystems reef, 2) transporting and placement of 16,000 cys of sands to restore the eroded shoreline and 3) provide wetland creation/shoreline stabilization of this sand. Unfortunately the storms of the summer of 2016, caused delays in the transport and placement of 16,000 cys of sand, but the project was completed in early 2017.

The Part 2 project removed, disposed and replaced 850 feet of the non-functional, oyster growth dependent breakwater, Reefblk. The project also included completing the remaining 200 feet of breakwater by closing the open north west section which now protects the remainder of the northwestern point of Deadman's Island. Task two of the project includes transporting 16,000 cys of sand from the existing stockpile area. The sand was placed in the areas where the previous sand had shifted and eroded. Task three completed the project by planting of wetland and upland vegetation to stabilize the transported sand material. Monitoring is required for five years once the project is complete.

The same monitoring plan from Part 1 is being used and shows one of the most thorough monitoring plans for environmental restoration. Monitoring of the reef includes water quality monitoring, benthic monitoring, oyster ecology, finfish surveys, erosion control, shoreline vegetation monitoring and sand accretion/scouring from bathymetric surveys. This monitoring plan has been adopted and incorporated into the monitoring plans of The Nature Conservancy of the Florida region.

2 Background Description of Project

Deadman's Island is a remarkable coastal place. It is one of the few areas that have a variety of ecological habitats such as oyster reef, salt marsh, dune, pine, desert, wetlands, marine oaks in one, in addition includes cultural and historical resources. Deadman' s Island has experienced accelerated erosion documented since the 1940's. This was due to the construction of the Three-Mile Bridge , local dredging activities, a 12-mile fetch impact, and nearby seawalls causing scouring to adjacent property.

This erosion has unearthed and exposed many historic structures, including an unmarked cemetery and 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, 850 feet of the oyster breakwater (Reefblks) were placed within the 1,450 linear feet permitted footprint outline. The oysters flourished on the rebar oyster reef, Reefblk, and created an effective breakwater. The Reefblk is a rebar skeleton with bags recycled loose oyster shell within the frame. The bagged oyster shell allows oyster spat to settle and grow, on the bags of oyster shells, to create a reef . Not anticipating a complete die off in 2012, the Reefblk began to lose the shells in the bags resulting in the 850 feet of reefblk breakwater nonfunctional. 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. The project was 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, 400 feet of new breakwater called "Ecosystems" was deployed in the south west and north east location of the footprint, leaving only 200-250 feet to complete the entire breakwater. In 2013, an additional 50 feet of a square shape, as opposed to circular prototype was placed. Ecosystems are stackable limestone and oyster shell reef. The Ecosystems have several tiers and each prototype is shaped differently for research purposes. The Ecosystems are not oyster dependent for structural integrity.

This non-functional reef has caused 16,000 cys 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. In August 2015, the old Reefblk breakwater was removed, disposed and the Ecosystems replaced the eight hundred fifty feet non-functional breakwater. Also, 200 feet of the breakwater, located in the barren area, was deployed to finish the permitted 1,450 feet footprint of the State land lease.

2.1 Project Purpose

The project has several main goals: restore and conserve habitat, replenish and protect living coastal and marine resources, restore water quality, enhance community resilience and restore and revitalize the gulf economy through juvenile fisheries. The purpose of the project is to protect the peninsula called Deadman's Island 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 and artifacts identified at the site and enhance recreational enjoyment.

The loss of the salt marsh in this area is the result of increased erosion due to wave energy. The project created approximately 1.04 acres of emergent salt marsh for shoreline protection and an additional 0.046 acres of coastal dunes. The structures protect the area by reducing the amount of wave energy that reaches the shoreline. Approximately 16,000 cys of sandy material and vegetation protects and cover historical resources and creates 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 increases productivity and diversity of flora and fauna indigenous to the Florida areas, as well as protect and stabilize the existing shoreline.

2.2 Project Goals

1. Place 16,000 cys of sand and stabilize with vegetation (2016 and 2017)
2. Complete the remaining breakwater (completed 2015)
3. Protect exposed cultural resource site by covering them with sand (completed 2016)
4. Create a nearshore island wetland using a local sand source (completed 2016)
5. Protect, conserve and restore seagrass beds (2017)
6. Create sand dunes by constructing them on the nearshore island (completed 2014)
7. Install Gulf sturgeon monitoring equipment (proposal in review)
8. Increase the overall biological productivity of the Gulf Breeze aquatic and shoreline area (ongoing since 2011)
9. Protect the north east isthmus from breaching due to heavy wave action and impacting the wetlands and residential homes (proposal in review).

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

According to GPS and bathymetric surveys, the 2015 structures appears to have stabilized the shoreline. Shoreline sand movement has been significantly reduced. In comparison to the 2015 and 2016 tides and wave action, higher than normal wave action above the mean high water level are continuing. According to the National Oceanographic Atmospheric Administration (NOAA) tides charts, the actual tides were above the predicted tides. Sea level rise is speculated due to increasing high tides not matching the predicted levels over the past two years. Certain sites on Deadman's Island not protected by a breakwater continue to erode and lose more vegetation.

3 2016 Summary of monitoring results

3.1 Description of Field Sampling Work Summary and results

Underwater monitoring of the existing breakwaters occurred from July 1 to September 30. Other monitoring such as benthic sampling, oyster collection for tissue tests, bathymetric surveys were performed until October.

3.1.1 Water quality

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

3.1.2 Benthic monitoring

Success criteria: The success criteria was met. Benthic surveys were performed using a coring device. Samples were preserved, and specimens were counted under a microscope.

As compared to barren sand there were 15% more species found in the sandy substrate next to the Ecosystems reef. Species identified were Polychaeta, mollusks, and amphipods.

3.1.3 Oyster spat settlement, recruitment, growth rates, predation, and health inspection

On average, for the East breakwater system there was 30% live coverage of oysters. The west side showed 16% coverage of combined live and 17% dead oysters. The main predator of the reef which is the oyster drill, increased 8% on the East side and 43% on the West side. There were no signs of unhealthy oysters noted during the surveys.

3.1.4 Shoreline vegetation monitoring- success criteria

The success criteria were not met. Due to storm surges and the lack of breakwater, the shoreline erosion was accelerated and the vegetation lost in 2015 was not replanted. The new vegetation had not become established by completion of this report.

3.1.5 Finfish 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 the section of tiers are facing, (1) landside (LS), (2) north direction (ND), (3) east direction (ED), and (4) west direction (WD).

Success criteria: The success criteria was met. There was an increase of 69% in fish species as compared with the 2015 results.

3.1.6 Wetland creation

Success Criteria was not met at this time. The new vegetation had not become established by completion of this report.

4 Monitoring Results and Description

4.1.1 Underwater Qualitative measuring techniques

The 2015 monitoring reports discuss the difficulty and ineffectiveness of using a quadrat to quantify species and percent coverage on the Ecosystems. It is difficult to quantify the oysters on a vertical reef by using a quadrat. Since the surface was completely covered, the results would naturally show 100% coverage. However, on top of the 100% coverage oysters are 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. Unique species not normally found on oyster reefs, such as the octopus, was not included in the statistics (Figure 1).

Figure 1: A common octopus found while monitoring on Deadman's Island.

The completion of the 2015 breakwater has been beneficial for monitoring (Figure 2). It is easier to determine the benefit of the Ecosystems by counting the reef as a whole rather than separate sections.

The 2015 reports discuss the differences in spacing between each tier of the units and why each system is beneficial to the reef ecosystem in its own way.

Statistical analysis for the new breakwater will only address basic statistics and basic biodiversity. Longitudinal statistics may address the fifth year of the Part 2, which will give a growth comparison over five years.

4.2 East Breakwater vs. West Breakwater

Monitoring only occurred on the Ecosystems breakwater located on the east and west side to compare the effectiveness of the Ecosystems. In the previous years, a rebar recycled shell called Reefblk were used on the north end of the breakwater. This breakwater was funded by a different grant agency and was not part of the Estuary Restoration Act grant; the ERA grant focused on the Ecosystems reef.

Each breakwater unit is monitored as a category varying in direction; the landside (LS), the northerly direction (ND), the easterly direction (ED) and the westerly direction (WD). The east and west breakwaters have different orientation, but the sections remain the same on the field sheets. The reason for the sectioning is that the landside exposure on each breakwater is protected, and it is important to evaluate whether the species prefer certain sides, such as protected from wave action or unprotected from wave action. The side opposite of the land 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. This section is exposed to more impact which comes from the north east twelve-mile fetch. This twelve-mile fetch is the path of littoral transport of the sand. The east breakwater has more exposure to morning sunlight and afternoon sunlight and is subjected to strong northern winds.

The west breakwater is exposed to a 3-6 mile fetch and is protected from the strong current from the northeast. The west end is the closest to the shoreline of Deadman’s Island. The entire breakwater encompasses North, East, and West.

Figure 2: The completed breakwater at Deadman's Island. Pictometry January 2016.

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

4.3.1 Oyster growth

Success Criteria: The success criteria was met.

Since the entire reef is now the Ecosystems, comparing the species on the reef was more effective. The oysters' size ranged from 1 inch to 4 inches. The oysters in the deeper water (5-6 feet) located on the north west section of the project, seem to show the larger sizes as compared to the oysters in the shallow locations of the west and mid-east sections.

4.3.2 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). This monitoring quickly evaluates the oyster reef coverage and whether spat has settled on the old oysters or if the older oysters have fallen off the units.

It was discussed in the 2015 report that oysters will spawn when there is a ten degree temperature change. So far, this speculation is observed to be true for the oyster reef. The spat has been observed to have settled within two weeks of placement of the new Ecosystems. Also observed is some spat do not survive over the next month and tend to fall off the reef units.

The reef remnants of the old rebar system were used to "seed" the reef and provide stress to the oysters, causing them to spawn. Stressing the oysters by movement (and temperature) can cause the oysters to spawn. This method is commonly used in aquaculture. The seeding method that was used in the 2015 reef placement, may have been the catalyst to the immediate spawning, resulting in the increased population of the oysters in 2016.

4.3.3 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 by percent coverage. Random unit numbers were chosen to observe any spat which may have settled. Any purple colored shell would be considered new settlement and counted as spat. It was difficult to quantitatively count spat because it was unknown what spat was alive and what was dead. Dead spat and oysters usually stay on the reef until the byssal threads rot; then the empty shells, if not attached to a live shell will fall to the sandy bottom. If the dead oyster is attached to a live shell, other marine organisms, such as blennies, gobies and crabs will inhabit and protect their home.

4.3.4 Oyster growth rates

The growth rate in oysters met the criteria for 2016 and exceeded the total species of 2015. The year of 2015, was the first year minimum market-sized oysters showed healthy full shell growth instead of showing 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.

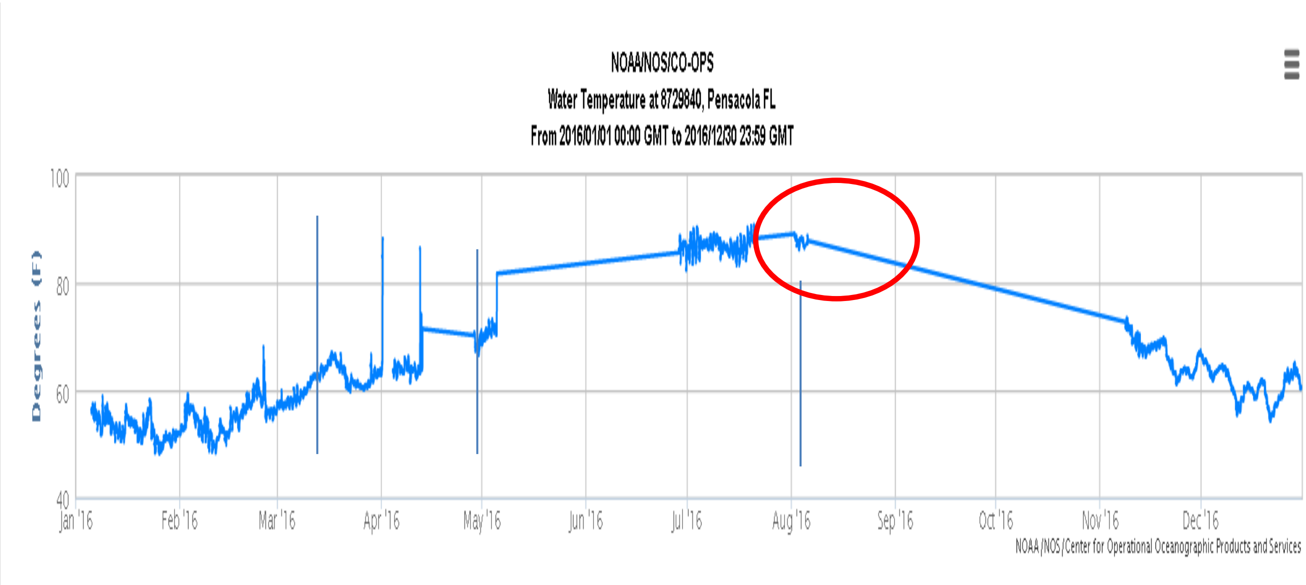


Figure 3: 2106 Water temperature. This chart was used to determine the settlement and age of the new oyster growth on the new breakwaters. The red circle estimates the times of spawning and settlement.

4.3.5 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 ppt but can survive in 8 ppt. There was a presence of oysters drills on both reefs, but the population of the oyster drills count was almost equal as 2015. This similar count could be due to an increase in species which prey on oyster drills and possibly the reef is becoming balanced. The stone crab population increased exponentially on both reefs. It was interesting to observe another predator of the oyster drill which was the Sheepshead fish. Sheepshead were found on both reefs. The west reef showed a 3.5% increase in large Sheepsheads.

Last year's monitoring discussion focused on the increase in Stone crabs, sheepshead and whether or not there was an impact on the oyster drill population. The reasoning behind this speculation is during the 2011 oyster drill boom when there were no "janitors" such as crabs or sheepshead since the oil spill in 2010. During this boom, the fish and crab population had not recovered from such a rapid mortality observed in 2010. Now we are seeing a recovery and determining whether this recovery is a natural cycle or a die off from the oil spill.

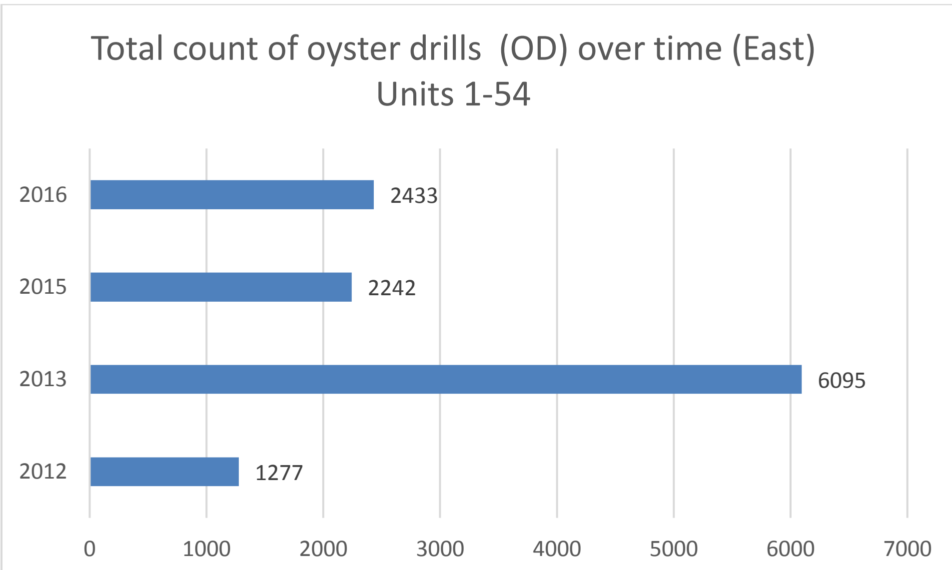


Figure 4: Total count of oyster drills over time 2012 and 2016.

4.4 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. Oyster health is observed by shucking the oysters and looking for signs of disease, thin shells, unusual spotting, and fungus. Another evaluation of oyster health is forensic analysis for pollution or unnatural chemicals in the water.

4.4.1 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 were extremely low, all tests showed no detection of any oil contamination, yet oysters (and fish) were still dying off. We also had samples of pure crude oil. The NOAA test results were the only testing methods showing they were above the maximum of chemical compounds of diesel range. This means chemical compounds of crude oil were found in the tissue of the fish and oysters instead of the basic PAH from boat pollution.

The first year since the 2010 oil spill, the reefs had a majority of minimum market size oyster (3-5 inches) was 2015 . As discussed in the 2015 report, the 2010 oysters were tested for basic PAH and no results were found. A sample of submerged oil found was split with the FDEP laboratories and shoreline team. This sample was a pure sample of crude oil. The FDEP results came back as no detection. The carcinogenic compounds found the oyster tissue during 2010 were fluoranthene which is Group 3 carcinogen, naphthalene which is a Group 2B carcinogen known to damage or destroy red blood cells, phenanthrene-Group 1 carcinogen. Phenanthrene is not listed as hazardous to humans under Clean Water Act but the duration of exposure is unknown. Pyrene which is toxic to liver, blood and kidneys was also found. The exposure rates to toxins were judged from May 2010 to the sample date of the oysters.   In the earlier stages of the oil spill (August 2010) when the reef die off and sick fish were first seen, the same chemicals, but chrysene was also found. Some of those chemicals occur naturally in the environment and can be detected in lab controls, but there is a certain detection limit which is acceptable. These concentrations were above the detection limit and some of these numbers increased with time. The 2015 and 2016 oyster tissue analysis showed no detection of any of these contaminant concentrations. However, the 2016 results did show Total Petroleum Hydrocarbon (TPH) from C9-C40 to be 101 mg/kg. This exceeds the detection limit range of 5-23 mg/kg. There was no detection in Total Saturated Hydrocarbons. In addition the compounds of chrysene, pyrene and fluoranthene were not verified but show a slight detection under the criteria range.

4.4.2 Diseases -Dermo

Another test to determine stress or a die-off in oysters is Dermo. Dermo is caused by a single-celled Protozoan parasite (*Perkinsus marinus).* Dermo is an intracellular parasite (2-4 µm) infecting the hemocytes (blood cells) of the eastern oyster (*Crassostrea Virginia)*. Dermo is not known to be harmful to humans but can be spread to other oysters and cause a massive die off. 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 11-30ppt. 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 oysters in 2016 (Figure 5). 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 60 oysters selected, similar to 2015, there were no signs of diseases or fungus.

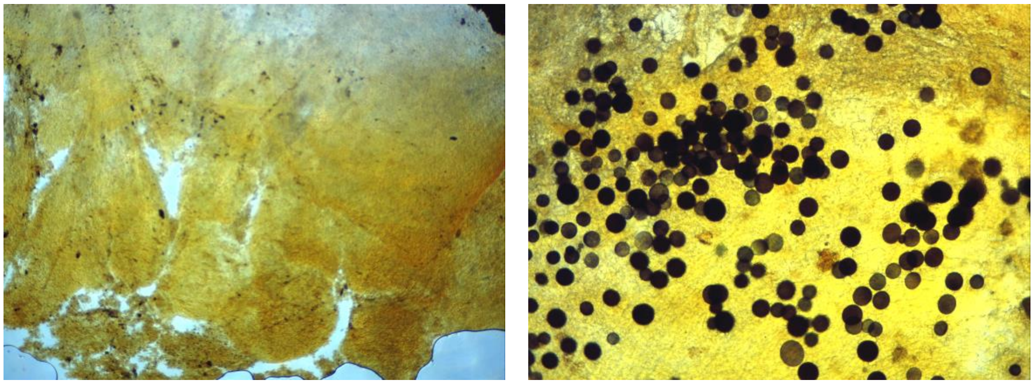


Figure 5: Oyster tissue DERMO results. (Left) Clean tissue from Deadman's Island adult oysters (right) an example of a dermo infected tissue in another bay (Photo credit Heather Reed. 2016 (left) , Dermo sample(right) credit by Dr. Bill Walton, Auburn University, 2015)

5 Abiotic Factors affecting the reef

5.1 Salinity

Salinity is an important physical factor to trend in order to understand whether the oysters will have a year of healthy growth or historically predict a possible trend of fluctuation of salinity values; possibly causing a change in oyster 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 parts per thousand (Bartol et al., 1999). At times, the maximum level of salinity would reach 32 parts per thousand yet the year’s average is still in the range of healthy oyster growth (Figure 6). In 2013, the salinity reached its highest point in the bay at 32 ppt and every year went above the maximum limit, only briefly, the lowest in 2016 at 4.0 ppt but the highest salinity values matched the values from 2013. Although these values were outside the limits, on average the salinity was at optimal levels (Table 1).

5.2 Temperature

Salinity changes can be affected by temperature. As the temperature rises the salinity increases in the bay (Figure7). The exception would be fresh water influx as observed with the floods of 2014. Observations of nearshore shallow water (ten feet from mean high water) found more oysters are susceptible to disease from stress and literally baking in the sun from hotter temperatures when exposed. Shallow water reefs less than four feet deep should not be dependent on oyster growth to create a functional and structural reef due to oyster die off. This die-off leaves a waste of exposed bags of oyster shells. The offshore distance of the breakwater and depth greater than 4 feet is found to keep the temperature and dissolved oxygen ideal for the oysters because of continual underwater exposure. Monitoring shows some oyster growth out of the water, but this exposure is normally tidal influenced and there is not a constant exposure to heat.

5.3 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 considerable flushing coming into Deadman's Island from current and wave action; the reefs are flow-thru reefs, always providing circulation. Dissolved oxygen is not a major concern for these reefs but should be monitored in case of long term low dissolved oxygen events which may affect the reef ecosystem.

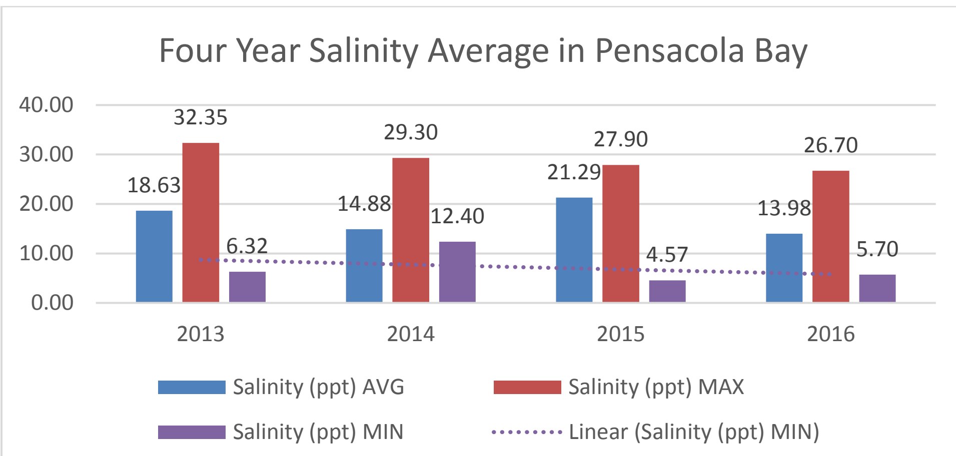


Figure 6: Salinity chart for 2013-2016. The year 2016 shows an average range between 32.35 (ppt) and min and max range 4.57-20.17 (ppt). Data source FDEP STORET.

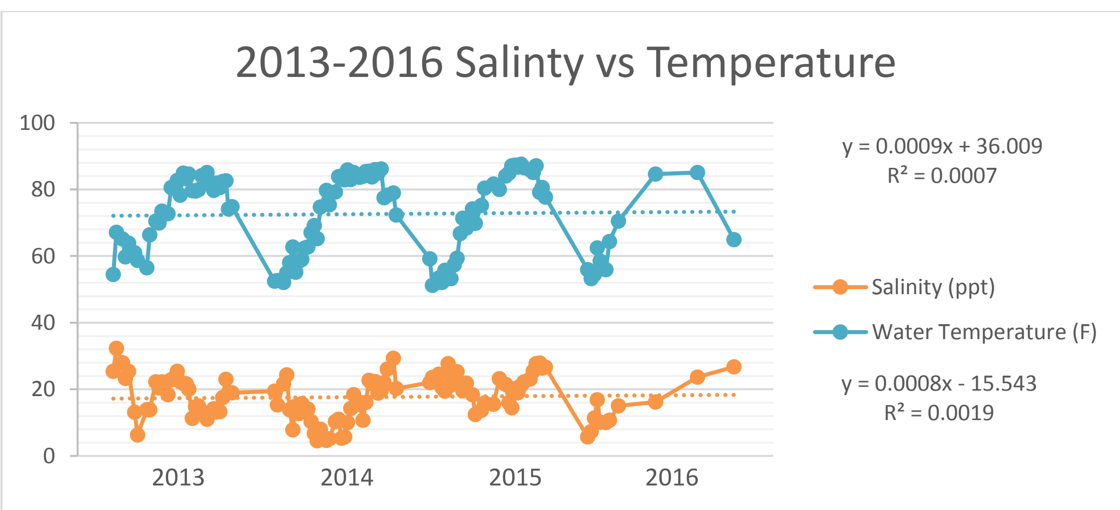


Figure 7: Water Temperature/Salinity trends from Jan 2013 thru Dec 2016 showing a steady trend of temperature vs. salinity.

Species name	Common name	2012	2013	2015 East Side	2015 West side	2016 East	2016 West
Urosalpinx cinerea	Oyster Drills (OD)	1277	6095	2242	3138	2433	4503
Urosalpinx cinerea	Egg Casing (EC)	38	28	56540	17840	51980	22920
Crassostrea virginica	Live Oyster (LO) %	43	85	32	31	30	16
Barnacles sp.	Barnacles sp %			17	31	14	23
Archosargus probatocephalus	Sheepshead	55	10	0	8	33	36
Lutjanus campechanus	Red Snapper	10	0	0	1	3	32
Lutjanus griseus	Mangrove Snapper	60	96	58	65	18	6
Zooanthis sp.	Zooanthids	13	0	0	23	6	9
Hypsoblennius hentzi	Blenny (Feather)	9	204.3	1716	2859	1786	3642
Cerianthus spp.	Tunicates	18	185.73	0	0	0	11
Menippe mercenaria	Stone crab	4	0	6325	5965	2764	3532
Pagurus longicarpus	Hermit Crab	49	161	840	547	419	315
Lagodon rhomboides	Pinfish	79	140	877	459	328	241
Chaetodipterus faber	Atlantic Spadefish	23	59	0	2	0	0
Astrangia danae	Coral	1	101	0	3	0	0
Opsanus beta	Toadfish	0	359	19	29	29	11
Brevoortia patronus	Menhaden juv*	0	100	0	2	0	0
Sabellidae spp	Featherduster worm	0	21	0	3	0	543
Cerianthus spp	Anemone	3	0	276	1479	0	15
Micropogonias undulatus	Atlantic croaker			81	18	21	18
Ischadium recurvum	Hooked mussels			12489	8490	3016	2151
Callinectes sapidus	Blue crab			136	52	9	4
Gobiosoma bosc	Naked Goby			1361	594	815	1132
Littorina littorea	Periwinkles			3703	1479	1910	6094
Total fish		236	868.3	4112	4035	3033	5118
Total oysters %		43	85	32	31	30	16
Total crabs		4	0	6461	6017	2773	3536
Land Side species total		695.02	2000	30615	11857	23137	14483
Bay Side species total		747	1844	27384	41834	22934	14309
East Side species total		196	2034	22607	37143	18870	5847
West Side species total		505	1852	6067	10420	2842	9867

Table 1: Species found on both reefs from 2012-2016 East and West breakwater reef.

5.4 Species abundance and Individuals present

The early years, 2012 and 2013 the species abundance coincide with community structure graph; there was a steady increase in 2012, 2013, 2015 and 2016 (Table 1). 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. 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. However, the East side of the breakwater is more exposed to the morning sun than the west side.

This 2016 east and west analysis does not include the entire reef of 371 units. For simplicity and to understand the species abundance on both sides, we use the same number of units (54) for the both the east and west side we have been using since 2012.

The oyster drill population increased 8 % this year on the East side and 43% increase on the west side. The number of oyster drill egg casings were also counted. On the East side there was 8% decrease in egg casings from 2015. The West side showed a 28% increase in egg casings. The idea is to try to correlate or predict if the number of egg casings found will be a similar number the following year. 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. There is a rise in the number of sheepsheads which in theory can also help control the population of drills. Unfortunately, these reefs are a good spot for fishers and recreational visitors, so anthropogenic stresses may have an impact on the fish population and in turn, the drill population.

The population of sheepshead in 2015 was for some reason, very low. The numbers increased and were almost the same in 2016 with 33- 36 sheepshead fish (Table 1). Although there was an increase in sheepshead in 2016, there was not a drastic decrease in oyster drills in 2016. This is the same with stone crab, the population of stonecrabs decreased in 2016 as the oyster drill and egg casing population increased. The 2017 data should help in understanding more about this relationship and whether there is a correlation between the stone crabs and oyster drills/egg casings.

Surprisingly, the coral was not found on the reef in 2016. In 2015, the hooked mussel, *Ischadium recurvum* was added to the list. The main predator of hooked mussels is blue crabs. The blue crab population decreased in 2016 in addition to the decline of the hooked mussels. It is still too early to link a correlation between hooked mussels and blue crabs.

6 Biodiversity

6.1 Competition and Species present

The results did not show 100% oyster coverage on most of the entire units because the top units were exposed to the air from various tides (Table 2). This long term exposure outside of the water does not allow 100% oyster growth. Coverage 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 30% coverage of live oysters and 17% of dead oysters. Barnacles comprised of 17% coverage. Monitoring of the West side breakwaters measured 76 structures. On average, out of the 76 structures, 16% coverage of live oysters and 18% coverage of dead oysters. Barnacles comprised 23% coverage.

The Shannon-Weiner Diversity index showed the mobile species on East breakwater 1.25 and the mobile species on the West breakwater is 1.25. The Simpson Diversity index to measure species richness for mobile organisms on the East breakwater side was 0.62 and species richness 0.27 for the West breakwater. The species evenness (Evar), was the same the East and West breakwater as 38%. 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.

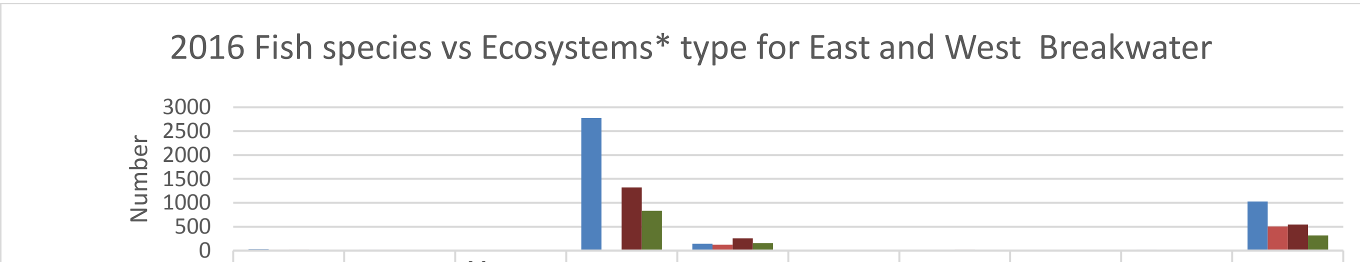
The diversity index was based on what was found on each tier of each unit of the reef only. The calculation for this index did not account for the schools of fish swimming among the reef. It was obvious the West breakwater side had more coverage of the total area of the units and a larger number of species. What is unique about the west side and the increased species richness is the ballast rock, left by historical 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, wrasses, pompano, black drum that frequent the rocky bottom on the West side as opposed to the all sandy bottom on the East side.

Species name	Common name	Proportion East %	Proportion West %
Urosalpinx cinerea	Oyster Drills (OD)	2.81	4.20
Urosalpinx cinerea	Egg Casing (EC)	59.97	21.37
Crassostrea virginica	Live Oyster (LO) %	3.67	1.92
barnacles	Barnacles sp %	1.48	2.34
Archosargus probatocephalus	Sheepshead	0.04	0.03
Lutjanus campechanus	Red Snapper	0.00	0.03
Lutjanus griseus	Mangrove Snapper	0.02	0.01
Zooanthis sp.	Zooanthids	0.01	0.01
Hypsoblennius hentzi	Blenny (Feather)	2.06	3.40
Cerianthus sp.	Tunicates	0.00	0.01
Menippe mercenaria	Stone crab	3.19	3.29
Pagurus longicarpus	Hermit Crab	0.48	0.29
Lagodon rhomboides	Pinfish	0.38	0.22
Chaetodipterus faber	Atlantic Spadefish	0.00	0.00
Opsanus beta	Toadfish	0.03	0.01
Brevoortia patronus	Menhaden juv*	0.00	0.00
Sabellidae spp	Feather duster worm	0.00	0.51
Cerianthus spp	Anemone	0.00	0.01
Micropogonias undulatus	Atlantic croaker	0.02	0.02
Ischadium recurvum	Hooked mussels	3.48	2.01
Callinectes sapidus	Blue crab	0.01	0.00
Gobiosoma bosc	Naked Goby	0.94	1.06
Littorina littorea	Periwinkles	2.20	5.68
	Total fish	3.50	4.77
	Total oysters %	3.67	1.92
	Total crabs	3.20	3.30

Table 2: The proportion of species in relation to the entire population of each breakwater section.

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 and inside the reef are counted. After a few transects, the fish are more relaxed with the presence of divers and easier to quantify. The table tops showed the presence of more fish than the closely stacked units called lillypads (Figure 12). This could give the impression more fish were found on the table tops. However; it was difficult to count organisms in some of the lilypads due to the units only having about 2-4" of between each tier, whereas, the Table tops have more space in-between each tier which makes it easier to see and count the fish.



	Sheepshead	(Other) Snapper	Mangrove Snapper (Grey)	Blenny	Pinfish	Spadefish	Oyster Toadfish	Spotfin Mojarra	Croaker	Goby
Table Tops (W)	29	19	5	2774	145	0	11	0	15	1029
Lilly Pads (W)	15	18	3	0	122	0	3	0	9	503
Table Tops (E)	21	1	11	1325	255	0	25	0	11	542
Lilly Pads (E)	11	0	12	833	159	0	10	0	8	316

Figure 8: The fish population vs. the various sections 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 show 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 Lilly pads. 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 subtidal floor. The other footing is without the pad, and only the piling is exposed. All units are secured by a separate collar 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 (Figure 9), 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 see even with flashlights.

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. As in 2015, Tier 1,2,3 of figure 9, show juvenile fish and the lower tiers show, the larger fish. The deeper in the water column the tiers have, the larger the fish. What is consistent in all years? The third tier seems to show more species (including fish) abundance. The reason could be this area keeps juveniles safe from predators. The other reason could be due to tier three and four are 90% submerged 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 a result of two theories; 1) the larger fish control the species population on the sixth tier and 2) the sand builds near these reefs and the wave action causes the moving sand to irritate some of the species. The organisms do not prefer the rough environment of the pelting sand, reducing the ideal habitat for most species.

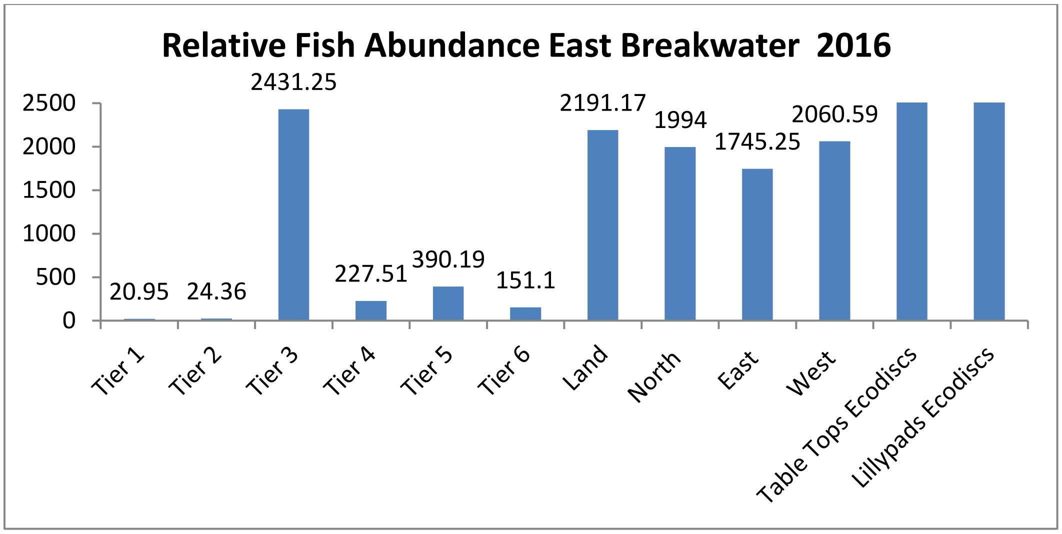


Figure 9: Total abundance of individuals on the East and West breakwater reef in relation to all tiers of each unit, all directions of Land side, north direction, south direction, east direction, west direction and on the two different structure designs of Table Top and Lillypad Ecosystems.

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. The method to determine the amount of foraging food present for the sturgeon is still being pioneered.

Twentyfive 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 identify under a microscope. The sand two feet from the breakwater, showed mostly Ghost shrimp, polychaete worms, *Mediomastus Ambisetae, and Leitoscoloplos fragilis,* lancelets, *Branchiostoma carabaum* and mysid shrimp, Mysideacea. These species are good foraging species for the Gulf Sturgeon.

10 Bathymetric Survey

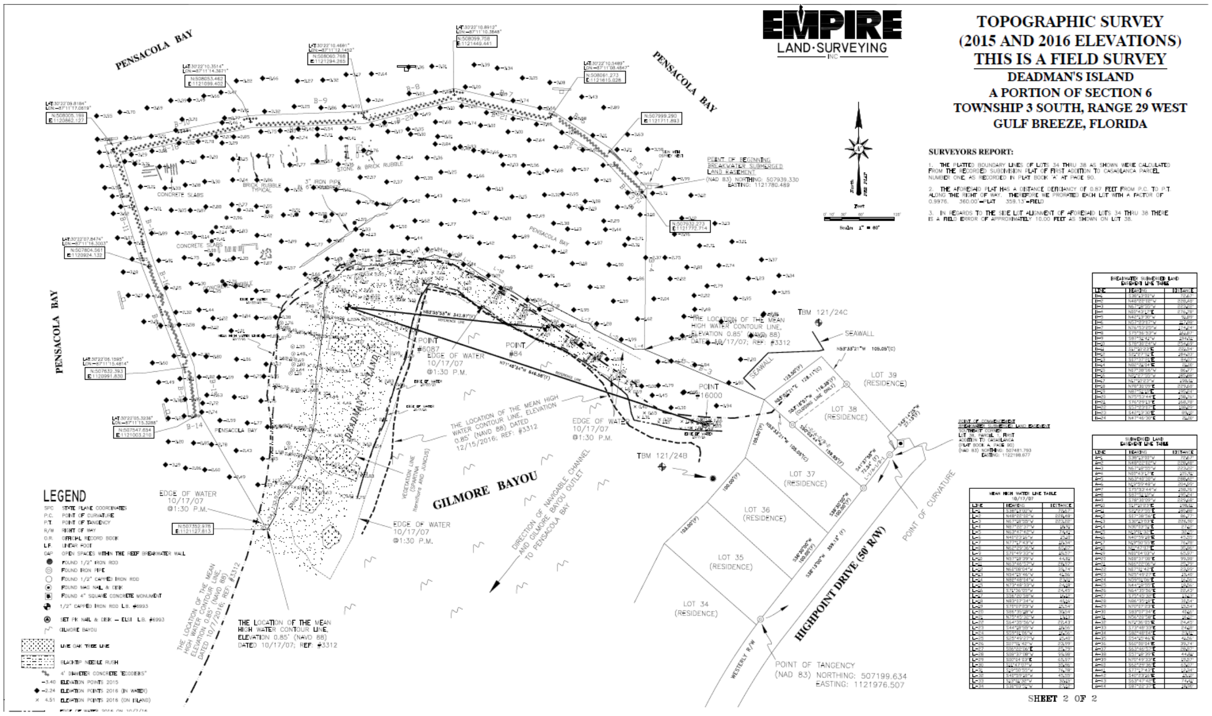


Figure 10: 2016 bathymetric survey and as-built breakwater survey

A bathymetric survey was performed by a professional surveyor in the month of October 2016. The survey was needed to monitor the sediment movement, erosion, and accretion. The survey elevation points were then compared to the 2007 bathymetric baseline survey, 2007 survey was funded by US Fish and Wildlife (Figure10). The baseline of 2007 was completed before any breakwater was placed offshore of Deadman's Island (Figure 11).

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.

Since Ecosystem 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 will be compared with 2016 (Figure11, 12 and 13)

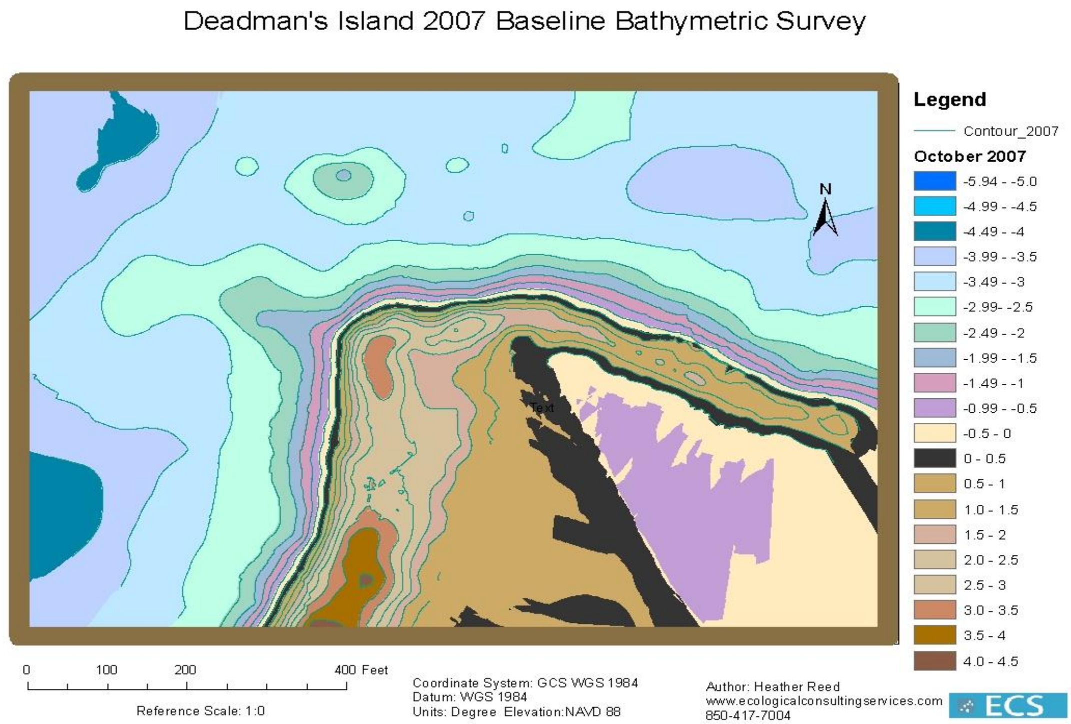


Figure 11: The 2007 Baseline survey of the bathymetry of Deadman's Island prior to breakwater placement.

Figure 12: Deadman's Island aerial taken in November 2007 from Google Earth.

10.1 Sand movement

The 2007 baseline shows a deeper depth throughout the project and in some areas (Figure 13), 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 unearthed, and the saltmarsh was in danger of being smothered and impacted by high salinity or saltwater intrusion.

With initial bathymetric observation during 2007 and 2016 , it appears sand had accreted behind the breakwater at a rapid rate. There was an evolution of events including sand placement andthe shifting and leveling of unprotected areas from wave action. The failing breakwater and northeast open section with no breakwater caused the wave action to push the sand to the east and southeast to spread around the project and accrete behind the existing breakwaters.

Sand continued to shift prior to the year 2015. At this point, there appears to be no loss of sand in the area. Yearly bathymetric surveys showed the lack of breakwater on the northwest corner (Reed, 2015) was causing sand to shift around the original location of placement of sand. Once the sand was behind the western breakwater, less shifting occurred. The northern shoreline 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%. This lack of wave attenuation has created a continual erosion of the vegetation planted for stabilization. Since the breakwater has been placed, GIS readings show very little change in the shoreline.

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 and 2016 survey the darker green and blue area (-2.49 and -2) the elevation have been reduced and is increasing in volume throughout the years behind all breakwaters (Figure13). This section remains deep from the lack of breakwater and scouring prior to 2016 on the north-western side. The 2016 bathymetric should provide better insight to how the sand will shift and move with the now complete offshore breakwater. The 2017 survey should determine whether the innovative breakwater and shoreline stabilization project was successful and could be transferable to other site-specific projects needing restoration.

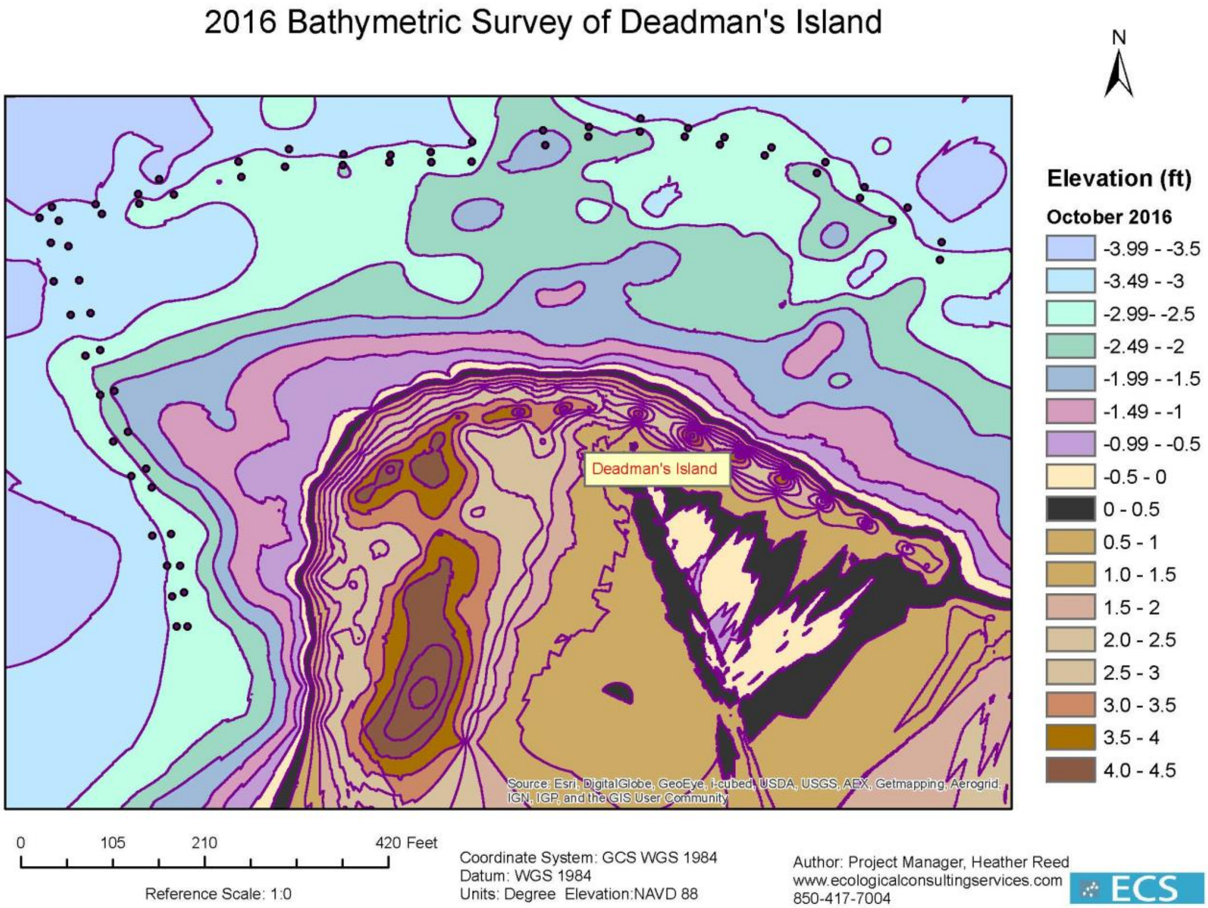


Figure 13: The 2016 bathymetric survey shows the location of the recently placed 2015 Ecosystems breakwater for reference.

11 Storms

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

The storms on March 10th, 2016, established the first concern of constant and high north winds. These storms shifted the sand and accelerated the effects from an adjacent seawall. The property adjacent to the seawall eroded at an accelerated rate. On May 2, 2016, the sand moved under a residential dock and grounded a sailboat; rendering the boat impossible to remove without damaging. In June and July 2016, additional surges and high tides followed by Hurricane Hermine (September 1, 2016) created additional erosion and scouring. Although Hurricane Hermine did not directly impact the Gulf Breeze area, it created substantial surges and high tides and also contributed indirectly to the accelerated erosion.

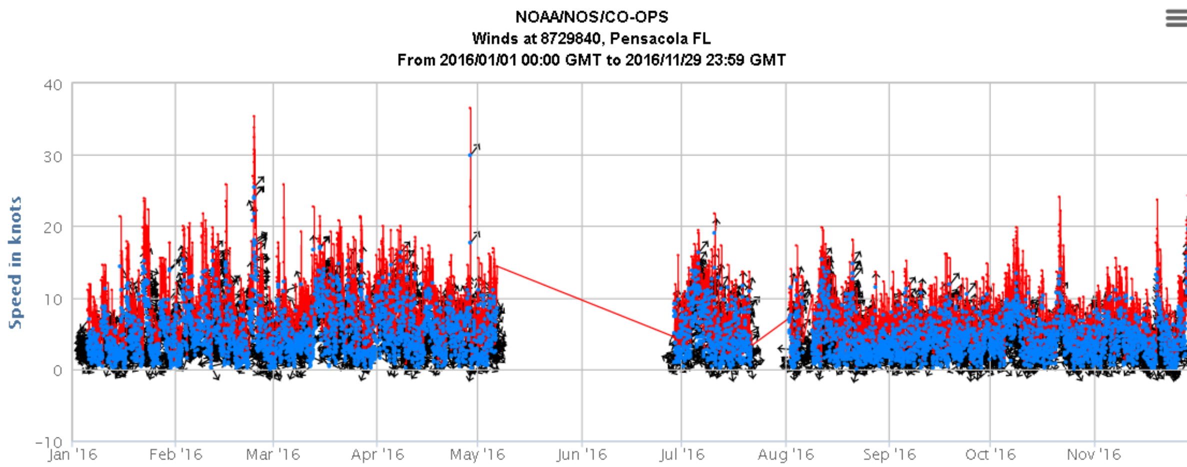


Figure 14: The high water events in 2015, due to storm the water levels were raised above mean high water (MHW) consistently. October 26, 2015, showed the highest water level of 2.14 above MHW level.

11.2 Sea Level Rise

Sea level rise seems to finally be measurable on a local scale. By reviewing historical tide data of 2013, 2014, 2015 and 2016 that shows the actual tides versus predicted tides, we can verify from the field data, the actual tides were much higher than the predicted tides (Fig, 15, 16 and 17).

The green color represents the actual tides for that day or month. The actual high tides were much higher than the predicted tides throughout the entire year. The predicted tides are from models based on the last 100 years. In most cases, not only was the high tide greater than normal but the low tide in some months represented more of a high tide and remained above zero high water. In other words, the verified data, which is green, shows the low tide were absent at a time when salt tolerant plants needed to recover from the lengthy duration of high tides.

In the months of March through May, it shows the higher tides are 1.5 higher than the average. This boundary is indicated by the orange tideline. The lower tides are a half a foot higher than the average low tide. This suggests in the month of March throughout May, the brackish vegetation along the shoreline may have suffered throughout Pensacola Bay from salt-water inundation. This salt-water inundation would not allow the plants to recover from the months of extremely high tides.

This saltwater inundation was also observed in nearby areas of Pensacola Bay. Extremely high tides and north winds in April transported sand in areas of no breakwater and smothered the upland dune vegetation. The dunes eroded, causing a breach into the saltmarsh. An adjacent seawall is also causing more scouring and loss of land. This high tide event accelerated the problem. In other areas around Deadman's Island, during the unforgiving high tides, sand shifted and smothered the upland plants, eroded living shoreline and moved the isthmus twenty feet into Gilmore Bayou.

Throughout the months of January,February, April, May and June, the tides were higher than normal from 2.52 feet to 1.0 foot.

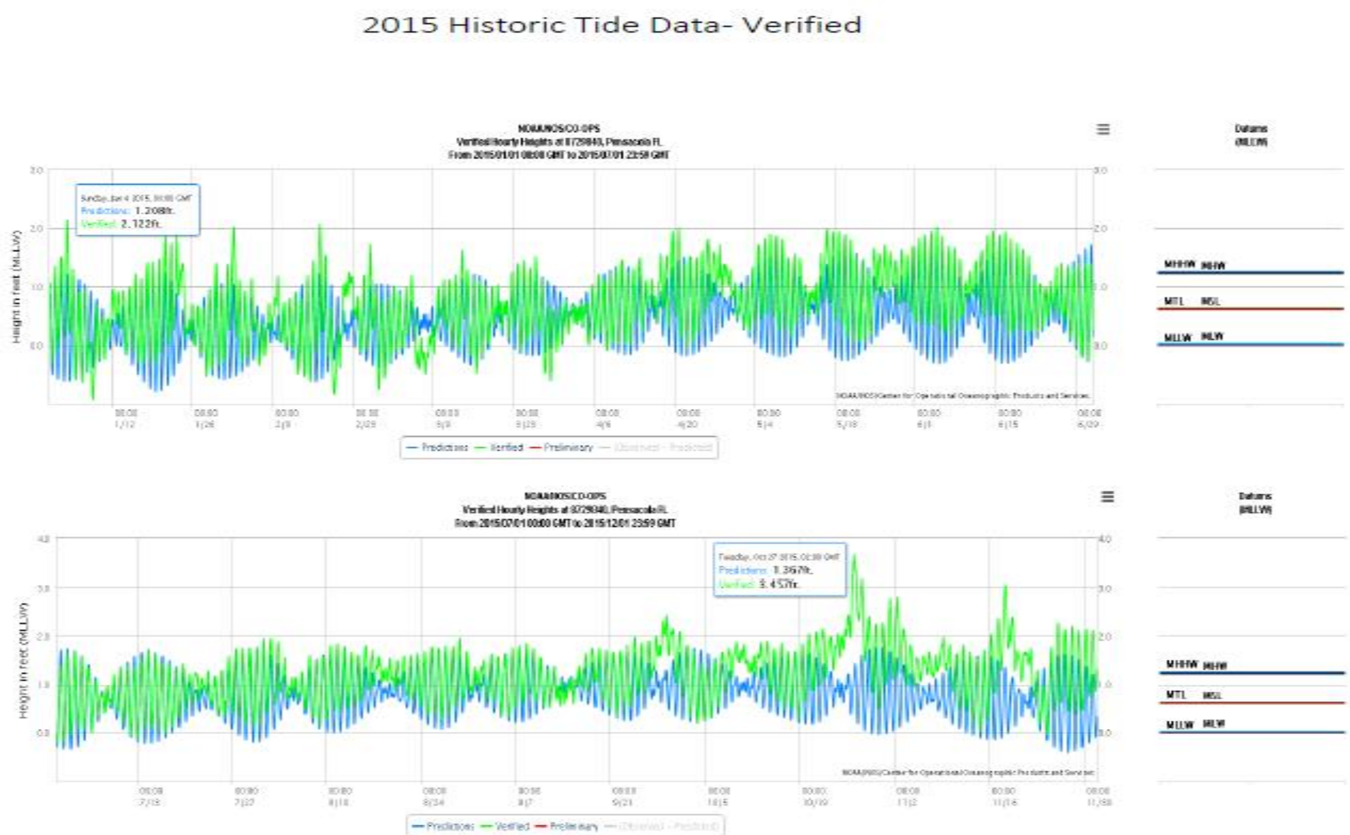


Figure 15: 2015 Historic Tides data from Station # 8729840. The blue lines are the predicted tides given, and the green lines are the verified tides which were the actual tides In some cases from January to July, the tides were .69 feet higher than normal tide (Top). From July to December the tides were also approximate .85 feet above normal except a few storms in October and November raising to 2.45 feet above normal (Bottom).

In April, May and June 2015, low tides were also higher than normal and never allowed a normal low tide (Figure 15). In all months of 2015 after July, the verified high tides ranged from 1 to 2 1/2 feet above normal tide. During the months of November and December where there are extremely low tides are expected was more similar to an average summer tide, 1/2 to 1 foot higher than the normal low tide.

2014 Historic Tide Data- Verified

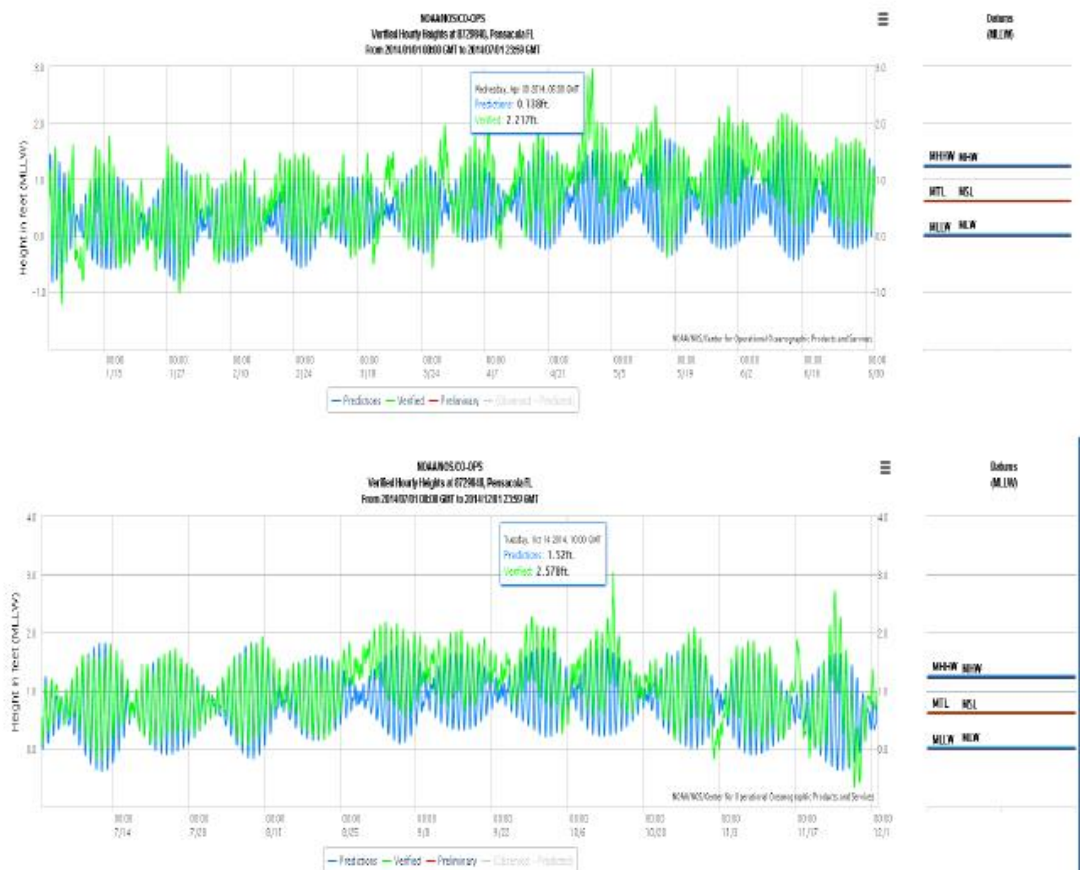
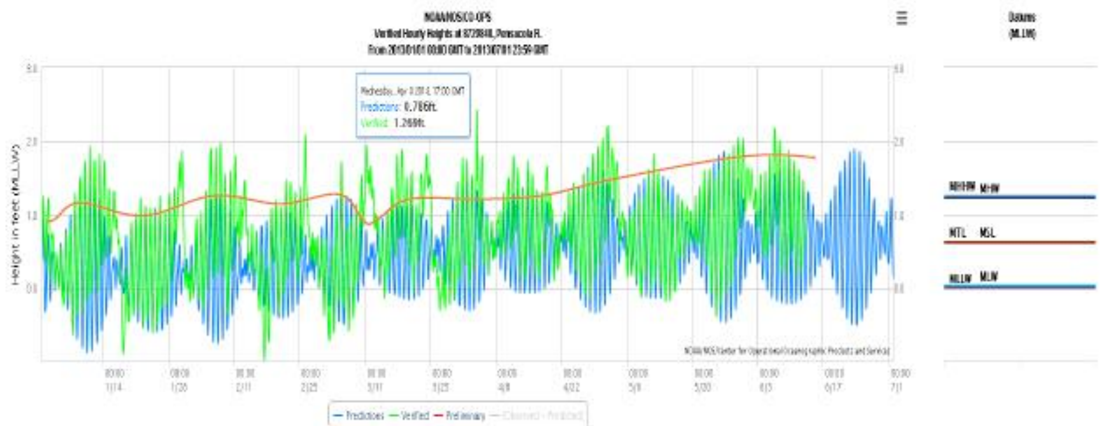


Figure 16: 2014 Historic Tides data from Station # 8729840. The blue lines are the predicted tides given, and the green lines are the verified tides which were the actual tides. In some cases from January to July, the tides were 2.079 feet higher than normal tide. From July to December the tides were also approximate 1.058 feet above normal.

2013 Historic Tide Data- Verified



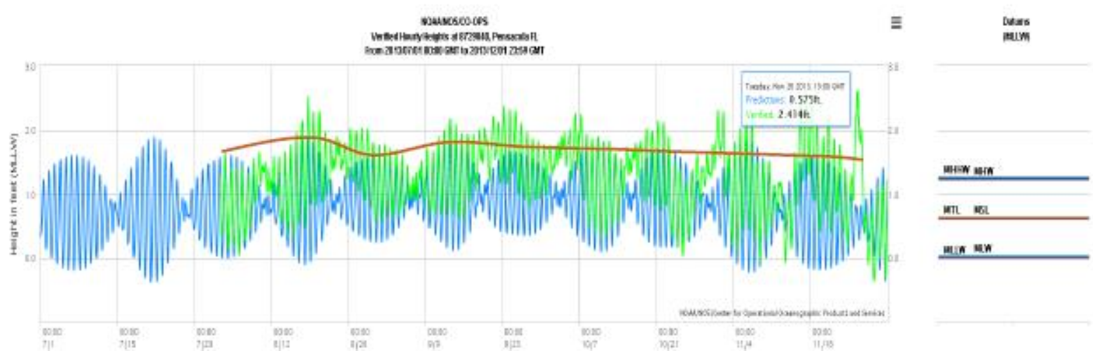


Figure 17: 2013 Historic Tides data from Station # 8729840. The blue lines are the predicted tides given, and the green lines are the verified tides which were the actual tides. The orange lines show the difference between the verified and the predicted. In some cases from January to July, the tides were 1.19 feet higher than the normal tide. From July to December the tides were also approximate 1.839 feet above normal.

12 Measurements: Shoreline Vegetation Survival, Mortality and Planting

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)

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

12.1.1 Test planting results

Test plantings occurred through community volunteer events along the shoreline throughout the summer and after the breakwater was placed. The shoreline vegetation behind the west end breakwaters seems to have stabilized. Moreover, the east end has not shown stabilization due to heavy wave action and lack of protection.

13 Future Project Needs

The breakwater footprint is now complete. The previously placed 16,000 cubic yards of sand that has shifted along the shoreline appears to have stabilized. Vegetation and the protective shoreline lost over the last few years can now be replaced. The dune pilot project shows additional 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 2017. The project proposes to place 500 feet living shorelines comprised of a combination of bagged oysters shells and limestone rock, ten feet of the mean high waterline (shoreline) and plant emergent vegetation along 500 feet of the isthmus. This project includes five years of monitoring data including bathymetric surveys and ArcGIS mapping.

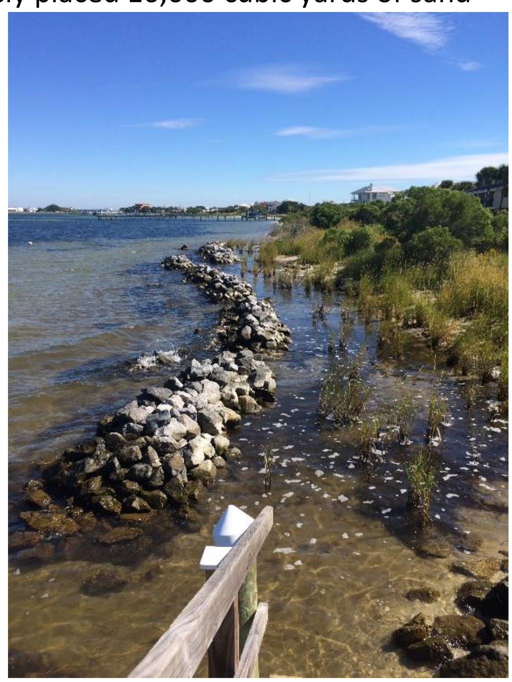


Figure 18: Another ECS restoration project and future example of the proposed isthmus breakwater project at Deadman's Island.

The cause of the erosional threat is from a combination of the lack of sediment for re-nourishment, permitted activities, storms and scouring. This combination caused the breaching of the isthmus and saltmarsh being smothered by sand. This final project will completely restore and protect the remainder of Deadman's Island.

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A special thanks for the funding for this project from Estuary Habitat Program,US Army Corps of Engineers, Mobile District, Mike Malsolm.

A special recognition and thanks to Dr. Jan Kurtz, Dr. Robert Menzer, Biologist Donald Ray, Ric Moore, Cathy Saunders, Dr. Bill Walton of Auburn University Shellfish Laboratories, Rick Custureri, Peter Tereszkiewicz, Nathan Mckinney, Ken Junk, Joe Concannon for their valuable contribution to this report.

Report citation : *Reed, Heather. 2016. The 2016 Monitoring report of City of Gulf Breeze Deadman's Island restoration project, Gulf Breeze, Santa Rosa county, Florida, for the US Army Corps of Engineers, Estuary Habitat restoration program. Ecological Consulting Services Inc. 35pp.*

Appendix

1.)Vicinity map

2.) Bathymetric survey

3.) Analytic lab results