2018 MONITORING REPORT

CITY OF GULF BREEZE DEADMAN'S ISLAND RESTORATION PROJECT

For the

U.S. Army Corps of Engineers

ESTUARY HABITAT RESTORATION PROGRAM

GULF BREEZE, SANTA ROSA COUNTY, FLORIDA

By Heather Reed, Project Manager

Ecological Consulting Services, Inc.

2018

Contents

Special recognition and thanks to Ric Moore, Amber Marthis, Ashlie Johnson, Caroline Polder, Julie Peterson, Zach Black, Dr. Robert Menzer for their valuable contribution to this report.

Executive Summary

Deadman's Island in Gulf Breeze, Florida, Santa Rosa County, is a remarkable coastal ecosystem located in Pensacola Bay. Deadman's Island is one of the few places that has a variety of ecological habitats of the dune, saltmarsh, oyster reef and pine forest located within one area, including a variety of historical and cultural resources. Due to the Hwy 98 bridge construction, dredging activities, a 12-mile fetch impact, and neighborhood seawalls, Deadman's Island has experienced documented accelerated erosion since the 1940s. This erosion has unearthed and exposed many historic structures including an unmarked cemetery and shipwrecks dating back to the 1500s. This erosion has also threatened historic *Juncus sp*. saltmarsh and destroyed 100-year old marine oak trees (Morgan, 1993). For several years the restoration project has been constructed through phases as funding becomes available.

The purpose of this report is to provide the monitoring data of the construction activities for the restoration project funded by the Army Corps of Engineers (ACOE) Estuary Habitat Restoration Grant. In addition to the ACOE Estuary Habitat Restoration grant, there was multiple funding to the project from the National Fish and Wildlife Foundation, private donors. The City of Gulf Breeze, Gulf Breeze High School, Navarre Middle School, Pensacola Catholic High School and Socialize With Education SMART (Student Monitoring Area Restoration Techniques) program has provided cash and in-kind services towards planting, cleanups and monitoring. This report provides details of the monitoring results and describes if/how success criteria were met.

The monitoring of 2018 showed the continued success of the construction projects with only minor maintenance needs. Several groups of volunteers from the local community and schools assisted in maintenance planting during the fall months.

1.0 Project History

Deadman's Island has been a victim of erosion since the beginning of hardening the shoreline through seawalls and the construction of the three-mile bridge in the 1940s. The bridge interrupts the littoral bridge and blocks the sediment transport where land on the west side of the bridge is not receiving the sand which normally re-nourishes the shorelines. The seawalls continue to scour the adjacent property that does not have a seawall and the homeowners of the impacted property have no choice but to place a seawall and start a "domino effect" to another property. A shoreline change has been observed throughout the years and has been described in detail in earlier ACOE monitoring reports and presentations (Reed 2013, 2015).

In 2005, Hurricane Dennis exposed several coffins, and human remains. The State Historic Preservation Office informed the City of Gulf Breeze that they need to start preventing the erosion which is causing unearthing of historic structures, mainly human remains. In an effort to stop the erosion and prevent further exposure of human remains, in 2008, 850 feet of the oyster breakwater (ReefBLKS) were placed within the 1,450 linear feet permitted footprint. The oysters flourished on the Reefblk and created an effective breakwater until 2011 when the structure fell apart.

Through comparing 2009 pre-oil spill monitoring data and 2011 monitoring data, the oyster coverage went from 95% to 1% coverage. The 2010 Deep Water Horizon oil spill caused delays in construction of breakwater; due to the project site being blocked and surrounded by the oil boom, additional breakwater could not be placed as planned. The delays resulted in additional erosion to the area and other areas on Deadman's Island. In 2011 and 2012, a new breakwater called "Ecosystems" made by Reefmakers was deployed. This footprint now includes outside breakers. Including the outside breakers, 530 feet of the 1450 ft modified footprint was placed on the southwest and northeast location. A 250 foot opening on the northwest end was left to complete the entire breakwater footprint. In 2013, of a square shape prototype of the Ecosystem breakwater filled 50 feet of the remaining 250 feet opening.

Not anticipating a complete die-off of oysters, the ReefBLKS began to lose 90% of the shells in the bags during 2012 from tumbling by wave actions and falling through the mesh containing the oysters. This die-off caused the 850 feet of Reefblk breakwater to become non-functional as a wave attenuator. This non-functional reef has caused 16,000 cubic yards of newly placed sand from summer of 2012 to shift and slowly erode. As the barriers containing the sand caused wear and breakdown, the sand is washed from inside the project area. In 2015, the old breakwater was removed, disposed of, and replaced with the newer Ecosystems stacked vertical breakwater and 200 feet of the breakwater located in the barren area was deployed to finish the permitted 1,450-foot footprint of the State land lease.

In late 2016 and early 2017, 16,000 cubic yards of sand was moved from the existing dredged disposal area located on Deadman's Island and placed on the northern point areas where the sand shifted and eroded due to the Reefblk breakwater losing function in 2012. In addition to the breakwater project, an osprey nest was relocated on the signage reef pilings at Deadman's Island. This project was not funded by the ACOE.

The 2017 eastern shoreline protection project protects the remainder of Deadman's Island; this project addresses the easterly section of the isthmus only. The isthmus is the sandbar between the mainland and the larger land mass of Deadman's Island (Figure 1). The breaching of the isthmus was caused when the isthmus shifted past the existing seawall. Once the upland sandbar eroded south, past the seawall, the erosion rate increased and scoured the adjacent living shorelines. This erosion caused the isthmus connection to breach; this event created an emergency situation and was repaired by the City of Gulf Breeze in 2017. Deadman's Island is listed as John H. Chafee Coastal Barrier Resources System (CBRS) in the state of Florida. So as a recognized conservation CBRS site FEMA funding was unavailable for repairs from the storms.

In 2018, maintenance plantings continued as well as coastal/underwater cleanups and reef monitoring. The additional project and funding which rebuilt the isthmus with sand and rock have also been shown a successful project. The storms did knock over large riprap, but overall the vegetated berm that was placed behind the rock held up well with only a few intense water blowouts of the established root systems.

1.1 Project Purpose

The purpose of the project is to protect the 10-acre peninsula, an existing salt marsh habitat and historical and natural resources while increasing the biological productivity of the Gulf Breeze marine area. 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 dune. The reef structures were constructed to protect the area by reducing the amount of wave energy that reaches the shoreline. An incidental benefit of this project is to protect numerous cultural resources and artifacts identified at the site. Approximately 16,000 cubic yards of sandy material and vegetation protect and cover historical resources and create a small peninsula that adjoins the land. To reduce anthropogenic stressors on the project, the restoration area was separated by a dune fence. In summary, the project protected and stabilized the shoreline and increased productivity and diversity of flora and fauna indigenous to the Florida areas.

1.2 Project Goals 2011-2018

1. Repair the indirect impact during the oil spill timeframe and place 16,000 cubic yards of sand and stabilize with vegetation (completed 2017)
2. Remove the degraded 850-foot long oyster ReefBLK^{TM} structure. Complete the remaining breakwater by installing new breakwater units (Ecodiscs and pilings) to decrease the wave energy, reduce erosion and stabilize the site. (completed 2015)
3. Protect exposed cultural resource site by covering them with sand and minimizing future erosion (completed 2016)
4. Create a nearshore island wetland using a local sand source (completed 2016)
5. Protect, conserve, and restore seagrass beds (completed 2017)
6. Create sand dunes by constructing them on the nearshore island (completed 2014)
7. Install Gulf sturgeon monitoring equipment (2 of requested four receivers are installed)
8. Increase the overall biological productivity of the Gulf Breeze aquatic and shoreline area (ongoing since 2011)
9. Repair south end dunes to protect *Juncus* salt marsh (ongoing- funding dependent)
10. Control erosion and stabilize the shoreline by planting emergent vegetation
11. Monitor, maintain and study the site for five years once all construction is complete (ongoing)

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

According to GPS surveys, the 2015 breakwater structures have stabilized the shoreline on the north and south-west side, directly behind the breakwater. The structures replaced the ReefBLK which was damaged during the time period of the 2010 oil spill.

In 2016, the tides continued to rise higher than the tide charts predicted and have been an ongoing problem. The tides are higher than initially predicted during the 2007 permitting process. The height of the breakwater was determined by the 2007 mean high water level and tide trends. The higher tides caused the water to rise over a portion of the breakwaters. Due to the wave height, the breakwaters could not attenuate the wave action, and the shoreline was vulnerable to increased wave action and erosion in some areas on the north end. The vulnerability caused the shifting of the newly placed sand and washed out some of the new vegetation planted on the north end. Few of the Ecosystems units were manually reset by lifting the tiers to match the height of the entire breakwater system. As tides continue to rise, the height of the breakwater may become a concern. As for now, the effectiveness of the vertical wave attenuation system continues to be monitored.

The 2018 storms caused water to rise completely over the breakwaters at times. Strong storm events caused a change in the tidal height which shifted the sand and washed out the vegetation on shore. This washout is especially apparent on the northwest point of the project site. Some breakwaters were set to an even height to match the height of the other breakwaters to provide better wave attenuation during higher tides.

2.0 2018 Summary of Monitoring Results

2.1 Monitoring Goals.

- Establish valuable baseline data that can be used to compare with post-implementation data to see if the restoration has the desired effect.
- Determine the effectiveness of the project features in reducing the rate of erosion as compared to historical rates of erosion.
- Determine the effectiveness of the project features in improving habitat and population increases for shellfish, finfish and birds.
- Determine sediment characteristics and their change over time.
- Determine the ecological health of shoreline vegetation by monitoring species composition, distribution, and area covered over time.

2.2 Description of Field Work Summary and Results

Success criteria were determined by the 15 page modified Deadman's Island monitoring plan of 2015.

The plan was modified from the Part I monitoring plan from lessons learned and according to funding availability. Underwater monitoring of the existing breakwaters occurred daily and was weather dependent from July 1 to October 30, 2018. To compare previous years' data with the same number of units, 102 units of the breakwater reefs were randomly selected for monitoring. The visibility of the water was 1-5 feet, predominantly 1-3 feet. In addition to the subsample of 102 randomly selected reefs to compare with the previous years' data, the entire reef was also monitored.

Reference Site: The existing Ecosystem reef breakwaters at Deadman's Island will be used as a reference for monitoring of oyster production and ambient water quality parameters. The Ecosystem breakwaters were placed during the fall of 2011 and were monitored yearly until FY2016; the data collected during that time serve as baseline. Monitoring of the new reefs began in FY2017 and will end in FY2021.

Modifications- Deleted from the plan:
The following tasks were deleted from the plan either through lessons learned or funding availability.

a. Water Quality Monitoring: Will test the ability of the new breakwater to serve as a virgin living oyster reef to change ambient water quality (Functional). Samples will be collected via surface grab samples at an approximate depth of 0.15 meters below the surface.

Sampling parameters include Biological Oxygen Demand (BOD), Chlorophyll *a*, Total Suspended Solids (TSS), Color, Turbidity (NTU), Fecal Coliforms, Total Coliforms, Enterococcus, Nitrates, Nitrites and Total Phosphorus. Two water quality samples will be taken twice a year for a period of five years.

Success Criteria: Sampled parameters would be compared to the Clean Water Act (CWA) action limits and samples previously taken. Results below reported action limits would be deemed successful. Ambient water quality conditions should increase as oyster production is established. This was deleted in the Part 1 section.

Although it sounds good on paper, it is difficult to measure oyster filtration in an open system such as a bay. It is unknown how much oysters are filtering in an open bay. There is much current and flushing and although a water sample can be tested, the source of filtering would have changed with the current.

It is difficult to realistically evaluate these parameters on a reef that is located in an open system and therefore they were deleted from the plan. The tests listed are better in a lab in a closed system, but then again the lab is a controlled system unlike the changing dynamics of the bay. Stress on the oyster can also limit the amount of filtration from the oyster. Tissue testing is normally performed to measure toxin uptake on the oysters since oyster retains polyaromatic hydrocarbons (PAH) from pollution and could also restrict filtering. Due to lack of funding the tissue testing was also discontinued. However, this is an important test, and there is good information from the previous testing and could be viewed as a post-oil spill "baseline" as well as an environmental pollution baseline for another study.

Modification: It has been found the health of the oysters in an open system can be best determined by temperature, salinity and freshwater sources (rainfall, watersheds). Salinity, temperature, storms and rainfall data is collected through instruments and also other data from the corresponding year.

b. Benthic Monitoring: Sediment will be characterized by analyzing grain size and percent organics (Structural). Petite Ponars will be used to sample at designated stations for benthic macroinvertebrates in areas where structures will be placed. Each station will have three separate replicate samples that will be individually sampled, giving the most statistically valid number of benthic composition and diversity (Functional). Samples will be submitted for statistical analysis using the Shannon Weaver Diversity Index. Two samples will be taken twice a year for a period of five years.

Success Criteria: The success of the benthic community will be evident as oyster and fish production, diversity and abundance increase. Decrease or increase in sediment accumulation will be measured using permanent stakes gauging changes in elevation. Comparisons will be made against baseline benthic data collected in 2008 during the initial construction of the oyster reef.

This is a difficult success criterion: This test was also discontinued because the benthic traps and sediment were either buried or removed, so it was difficult to measure underwater changes in depth with stakes.

Modification: measuring from the bottom of the existing tiers to the subtidal floor below is performed instead. The existing tiers are fixed in the sand and marked underwater. If the slab is covered or has disappeared there is obvious subsidence or accretion. Grab samples are taken and documented if any organisms in the sand are found. Organisms are counted under a microscope.

2.2.1 Oyster Spat Settlement, recruitment, predation, and health inspection

Success criteria met- there is 100% live and dead oyster coverage on almost all the tiers. Success Criteria: 60% coverage of oysters within the first year, 100% coverage of oysters by year five.

Oyster Growth Rates: **Success criteria met**

A cash stock of oysters will be marked and measured (Functional), and other stations will be used by quantitative underwater ecological surveying techniques. Sampling will occur twice a year for a period of five years.

Success Criteria: The size of the marked oysters and those at the other measurement stations will increase over time. The first year the oyster size will be 1-2 inches and by year four 60% of the oyster will be 3-4 inches in length.

Oyster Predation: **Success criteria not met**

Evaluation will be done throughout random stations and random point count methods - using the point count method of the quantitative underwater ecological surveying techniques (functional), predators will be compared to the live/dead oyster count. Sampling will occur twice a year for a period of five years.

Success Criteria: The number of predators on the ecosystem will be less than or equal to the number of live oysters.

Oyster Health: **Success criteria not met** – tissue testing not performed and live oysters is not 80% more than dead oysters

Due to lack of funding, laboratory testing of the oyster tissue was not continued in 2018. Evaluation will be done throughout random stations using the point set method of the quantitative underwater ecological surveying techniques (Functional). Sampling will occur twice a year for a period of five years.

Tissue testing: Tissue testing will be cross-reference with mortality counts. Tissue tests will be performed measuring the presence of total polyaromatic hydrocarbons and the oyster disease Dermo which is affected by the parasite *Perkinsus marinus.*

Success Criteria: The number of live oysters will be 80% more than the number of dead oysters.

2.2.2 Shoreline vegetation monitoring

Measurements:

1. Survival/mortality percent coverage increase/decrease (Functional)

2. Species composition identifies the species of shoreline vegetation within the sampled area and determines the percent contribution of each species to the cover (Structural).

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

Success Criteria: Percent coverage and density will increase the first two years and stabilize the shoreline and sustain itself with no additional planting within four years.

Success criteria met - There has not been any additional planting along the shoreline at the north end or the spoil site at the south end of Deadman's Island because the shoreline is stabilized from the additional planting.

2.2.3 Finfish surveys

Success criteria met

Evaluation will be done throughout random stations- using the visual census method of the quantitative underwater ecological surveying techniques (Functional).

Success Criteria: A gross inventory of fishes will be conducted and compared to previous baseline surveys. Success would show an increase in richness and density/abundance. Oyster production is directly tied to this monitoring metric with an increase in production leading to larger and more numbers of fish utilizing the area.

2.2.4 Wetland creation

Success criteria met- wetland bogs are still present at the site

Measurements:

1. Survival/mortality percent coverage increase/decrease (Functional)

2. Species composition identifies the species of shoreline vegetation within the sampled area and determines percent contribution of each species to the cover (Structural).

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

Success Criteria: Percent coverage and density will increase the first two years and stabilize the shoreline and sustain itself with no additional planting within four years.

2.2.5 Reef Structural Integrity

Measurements- Reefs structure remains intact, pilings stay in place and does not roll in the sand
Success criteria met

2.3 Sand Accretion from Storms

Success criteria met on the north end behind the east breakwaters but not met behind the west breakwaters

Monitor the decrease or increase in sand accumulation and depth behind the breakwater. Monitoring will occur after every hurricane or large storm. Sediment erosion device (sediment trapping tent/net) measured quarterly for the first year and after storms. After the first year, monitor twice yearly every year for the next four years (Structural).

Measurement method: permanent stakes with measurements taken at the time of placement and two-weeks after placement, monthly for three months and twice a year thereafter for five years (Structural). Measurement of depths and wave attenuation in front of and behind the structures will be the first year after placement of structures and at the end of the five year monitoring.

Success Criteria: The stakes will show a no difference, increase or decrease in shoreline erosion, depth or accretion due to the project's performance.
The stakes are missing but there are GPS of the stakes, and the shoreline is mapped

2.4 Summary of Damage from Storms

Overall, the reef project held up well with 30 out of 374 tier 1 and tier 2 units damaged.
It is essential to straighten and replace some of the broken reefs to protect the shoreline and hard work of the restoration project. It is also important to plant vegetation that was smothered and inundated under the saltwater long term.

3.0 Monitoring Description and Results

3.1 Underwater Qualitative measuring techniques

Monitoring was performed when visibility was at least 1.5 feet and using an underwater flashlight. Monitoring was conducted by using shallow reef hookah rigs with supplied air and regulators. The depth of monitoring was 3 to 6 feet. Monitoring techniques such as percent coverage, point count and scale measurements were performed underwater.

3.2 East Breakwater, West Breakwater vs. Entire Breakwater

There are 371 breakwater units. Each breakwater unit is monitored and labeled on the field sheets in four sections according to orientation to the land; the landside (LS), the northern direction (ND), the eastern direction (ED) ,the western direction (WD) and (BS) Bay side facing the Bay. The east and west direction have a different orientation due to "L' shape of the reef, but the sections remain the same on the field sheets. The reason for the sectioning is because the landside exposure on each breakwater unit is protected. The opposite side, Bay side, of the reef is exposed to the open water and fetch wave impact (Figure 1).

The east side breakwater is closer to residential property, is exposed to a 12-mile fetch, and is in the path of littoral transport of sand from the northeast. The east side breakwater has more exposure to morning and afternoon sunlight and is subjected to fierce northern winds. The west side breakwater is exposed to a 3 to 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, south, east, and west.

In the past years, since the breakwater was not complete. The monitoring compared the west section and the east section; however, since the remaining breakwater was completed in 2017, breakwater unit sections are randomly selected equally throughout the entire reef.

Figure 1: The completed breakwater at Deadman's Island

3.3 Monitoring Results of Oyster growth rate, spat settlement, recruitment, predation, and health

3.3.1 Oyster Growth Rate

Success Criteria: The success criteria were met.

Since the entire breakwater reef is now the Ecosystems units (Figure 1), comparing the species on the reef was more effective. Recruitment of spat was evident by the presence of the small number of living oysters present on the reef. The oyster sizes ranged from 0.25 to 5 inches. The oysters in the deeper water (5-6 feet) seem to show the largest size (5 inches) as compared to the oysters in the shallow locations, average size 1.5 inches (measured at depths of 3-5 feet).

3.3.2 Oyster Spat Settlement

There was about 1 inch of oyster spat covering 70% of the reef this year. It was difficult to quantify how many of the new recruitment of oyster spat were alive due to a light algae covering the purple color of the live spat. However, high percent coverage of new spat shows evidence of spawning earlier in the year.

3.3.3 Oyster Predation

Using the point count method of the quantitative underwater ecological surveying techniques 102 random units were selected from the data to evaluate oyster predation from oyster drills (Figure 2).

Oyster reefs provide numerous benefits ranging from water quality to providing a high-income industry due to oyster consumption. It is necessary to protect these reefs/ecosystems to further continue the benefits oysters provide throughout our nation's coasts. There are many predators of oysters on the reefs, but the most abundant threat to oyster sustainability is oyster drills, *Stramonita haemastoma,* which are a common oyster predator observed inhabiting the reefs.

Oyster drills prefer salinity above 15 parts per thousand (ppt) but can survive in 8 ppt. During the summer months, the salinity usually is the highest. Salinity was measured from July to October during the months of monitoring. Unfortunately, databases such as EPA STORET to cross-reference salinity and other water quality parameters was decommissioned on June 29, 2018 (www.EPA.gov, 2018) and the State of Florida FDEP STORET has discontinued their water quality monitoring program. Summer salinity values ranged from 16 ppt to 21 ppt. This salinity was ideal for oyster drill growth. Since oyster drills are the most significant threat to the reef, it is essential to understand any correlation between drills and other predator type species on the reef to understand which species is the largest threat to the reef.

Five species of predators to the oyster drill were observed inhabiting the reef: Stone Crab (*Menippe mercenaria)*, Hermit Crab (*Pagurus longicarpus)*, Blue Crab (*Callinectes sapidus)* (Sally Crab or mud crab (*Rhithropanopeus harrisii*), and sheepshead (*Archosargus probatocephalus)*

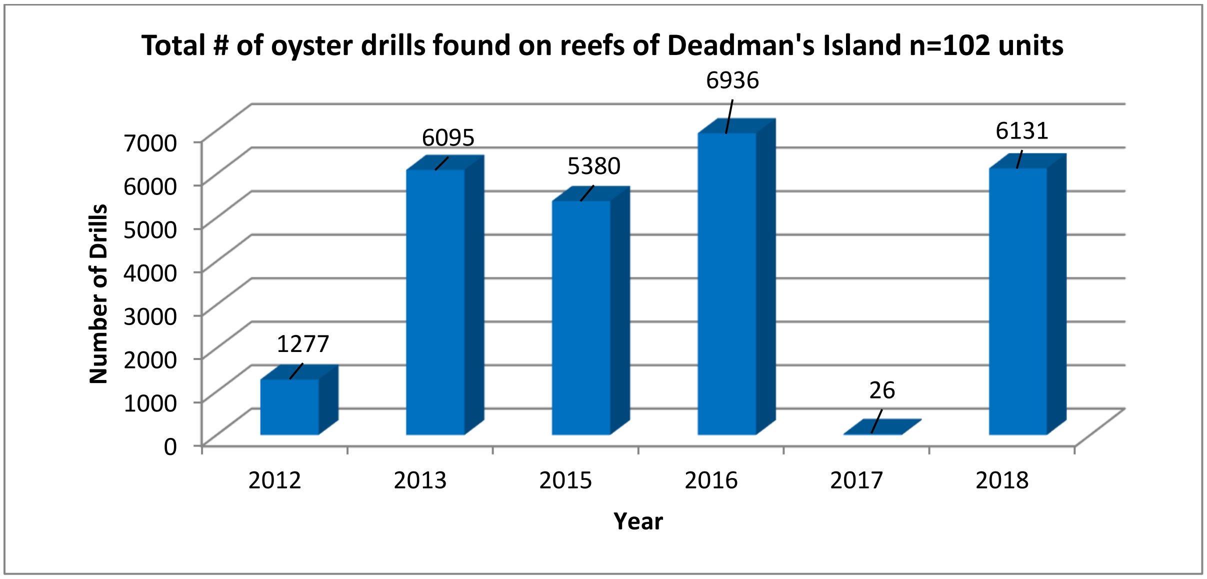


Figure 2: Total count of oyster drills over time.

In the case of oyster drill predation, a healthy oyster reef ecosystem would depend on the number of oyster drills present and the number of overall predators maintaining the stability and balance of the ecosystem. The more oyster drill predators found inhabiting the reef may likely result in fewer oyster drills observed. If oyster drills are exceeding the number of other predators needed to keep the reef sustainable, an increasing number of oyster drills observed in relation to the number of predators found can be expected. Hypotheses based on this sample data are as follows:

H_0: There is no significant correlation between any of the predators and oyster drills

H_1: There is at least one significant correlation between any of the predators and oyster drills

The final model for Multiple Linear Regression shows the oyster drills as the dependent variable. With a p-value of less than 0.0001, the model for oyster drills is considered statistically significant. When removing any influential outlying observations, the final linear regression model shows there is an R-Squared value of 0.9987. 99% of the variability of oyster drills can be accounted for with the predictors (Sally Crab, Stone Crab, Hermit Crab, Blue Crab, Blenny) found for this data set. Each predictor is found to be statistically significant as each probability or p-value is less than alpha (0.05). When observing the oyster drills in relation to their predator numbers, it may determine how many oyster drills are present in relation to an increase in each predator. Parameter estimates for each predictor (predator) are as follows:

- For every one observation increase for a Sally Crab, -0.80371 oyster drills are predicted to be present within the reef
- For every one observation increase for a Stone Crab, 1.34553 oyster drills are predicted to be present within the reef
- For every one observation increase for a Hermit Crab, 3.17246 oyster drills are predicted to be present within the reef
- For every one observation increase for a Blue Crab, 6.94095 oyster drills are predicted to be present within the reef
- For every one observation increase for a Blenny, 2.55617 oyster drills are predicted to be present within the reef.

Using 95% confidence intervals, the range of values found in the sample data regression line can be determined (Table 1). The confidence intervals for each predictor (predator) are as follows:

- Sally Crab: -5.197442507, 5.41563800
- Stone Crab: 0.44112891, 1.60530654
- Hermit Crab: 0.09610656, 1.51698562
- Blue Crab: 5.38350069, 18.21865697
- Blenny: 3.08043173, 3.71968482

Each predator has been found to be statistically significant according to each of their associated p-values which are less than 0.05. The p-values for each predator corresponding to oyster drills are as follows:

- Sally Crab: 0.0081
- Stone Crab: <.0001
- Hermit Crab: <.0001
- Blue Crab: 0.0154
- Blenny: <.0001

The sample data for oyster drills fit the Multiple Linear Regression model well where each predator displays a statistical significance influencing how many oyster drills may be observed throughout the reef for each predator found. The R-squared value also determines this is true, as variability with the oyster drills is extremely small. We can reject the null hypothesis and conclude that there is a correlation between each predator (Sally Crab, Stone Crab, Hermit Crab, Blue Crab, Blenny) and the oyster drills.

Table 1: Linear regression of oyster drills and competitive parameters

Parameter	Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits	
Intercept	0.10910647	2.69851072	0.04	0.9678	-5.19742507	5.41563800
Sally_Crab	-1.00772785	0.27118302	-3.72	0.0002	-1.54100024	-0.47445546
Stone_crab	1.02321772	0.29600746	3.46	0.0006	0.44112891	1.60530654
Hermit_Crab	0.80654609	0.36127717	2.23	0.0262	0.09610656	1.51698562
Blue_Crab	11.80103333	3.26348398	3.62	0.0003	5.38350069	18.21856597
Blenny	3.40005827	0.16253850	20.92	<.0001	3.08043173	3.71968482

3.3.4 Oyster Health

Evaluation of health was performed throughout random stations. Visual inspections were performed instead of laboratory testing. There was not any concaved shells or fungus on random samples.

3.3.5 Live Oyster Coverage

The data was obtained daily using snorkels and hookah rigs. The live and the dead oyster percent coverage was counted. Recordings took place in the mornings when the water was the calmest, and the visibility was good. Most of the reefs were on tabletop structures, and some were on Lilypads. Each reef had several tiers on them. The different tiers were in different depths of water and created different habitats for other animals. The top tier was mostly out of the water except at high tide and held very small and very few (if any) oyster shells on them. Oysters located on this tier were mainly dead and were empty half shells. The tier right below the top tier (2) was covered entirely with shells. The oysters were either all dead or mostly alive depending on the location. The oysters were still very small on the first three tiers. The deeper the tiers (4-6), had less coverage of oysters; however, those present on the deeper tiers were larger in size and alive.

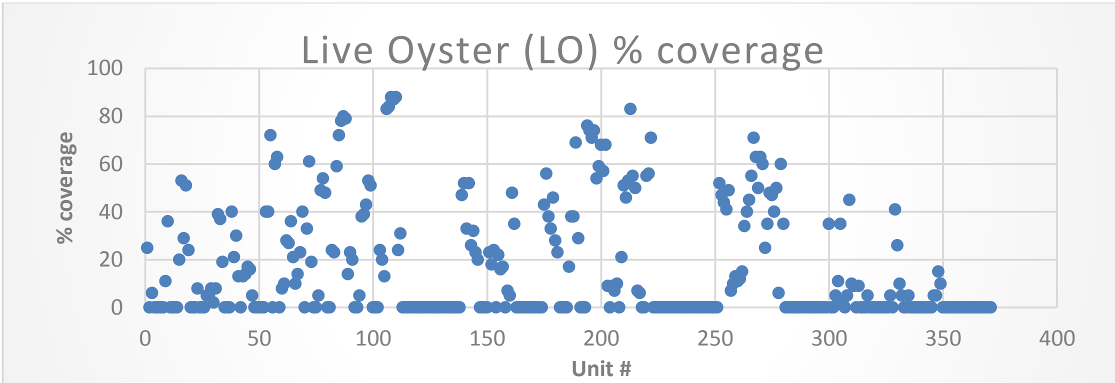


Figure 3: Graph of oyster coverage on the entire reef

For monitoring and recording live oyster (LO) coverage data, each unit number represents a single oyster reef structure. Several reefs have high LO coverage, but the majority of the reefs have zero or low coverage (Figure 3). Reef structures 1-100 were on the east side, structures 101-250 were on north/Bayside, and structures 251-371 were on the west/bay side. The wave action was the strongest on this part of the reef. The waves constantly impacted reefs 250 to 374 and the flow of water was noticeable between some the reefs; the percent coverage decreases on units 250 to 374, and more units in this range have no coverage.

The east part of the reef, unit #1-100, showed the highest LO percent coverage. These were the most protected with less intensity of wave action. Overall the LO percent coverage of the entire reef was 25%. The east and north sides also had more marine organisms on and around them than the west side.

The second and third tiers had the most coverage whether the oysters were dead or alive (Figure 5 -11). The bottom tiers had more water and sediment flow, so it was harder for the smaller oysters to attach and maintain settlement. With more coverage, more habitat is created for other animals.

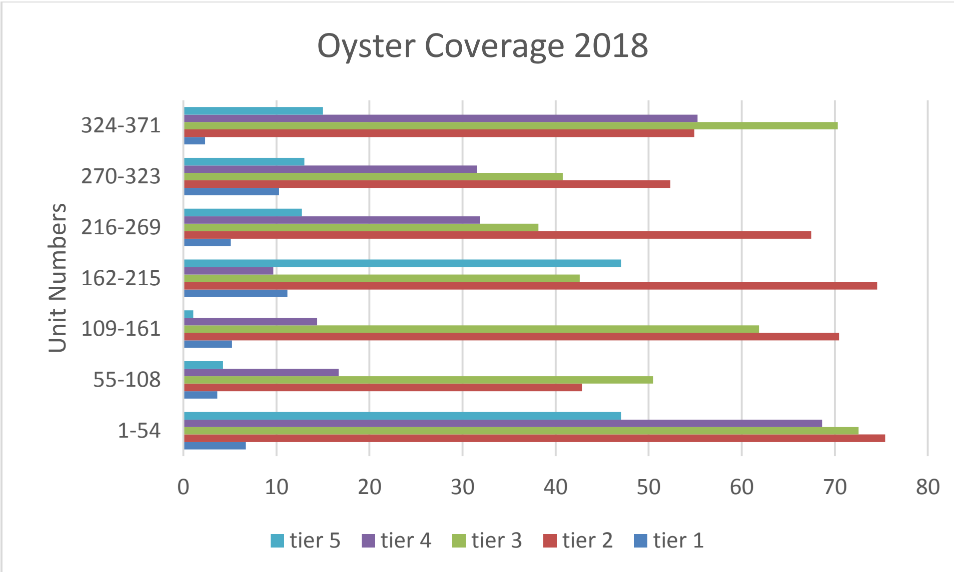


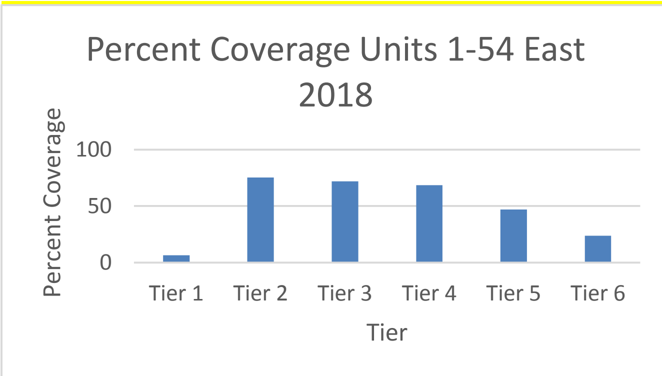
Figure 4: Chart of the oyster coverage among the different tiers of all units

3.3.5.1 Percent coverage of all organisms on tiers 1-6

To understand the functionality of the vertical oyster reefs as opposed to a horizontal reef, we studied the differences of coverage between each tier of each unit (Figure 4). Horizontal reef usually lay on the bottom, and the vertical reefs are vertical in the water column. Vertical reefs are good for deeper water, and horizontal reefs are better for shallow water. If placed in the wrong area horizontal reefs can easily bury, and vertical reef can quickly be inundated with larvae floating in the water column by the current. Depending on the location, each reef can be beneficial depending on the goal of construction.

Each breakwater at Deadman's Island has 4-6 tiers depending on the depth and depending on the purpose of the placement location of the breakwater is to accrete sand or maintain the existing depth.

The reef is numbered, and as explained in previous reports, each section is unique due to physical characteristics. Units 1-54 are the farthest eastern section of the reef (Figure 5). Units 55-108 are the mid-east section, meaning the long row of breakwaters are the middle, but on the east side, and are usually a shallow depth (Figure 6). Units 109-161 are the midsection and have a shallow depth of 3 feet (Figure 7). Units 162-215 are the mid-west section; this section is also in the middle, but on the western side, and gradually gets deeper (Figure 8). Units 216-269 are called northwest Section the most in-depth sections, ranging from 5-6.5 feet and are usually colder sections of the reef (Figure 9). The largest of the oysters are found here. The west section is comprised of the 270-323 units and has the round and square prototypes of the reefs (Figure 10). The southwest units are 324-371; this area contains ballast rock and sometimes tropical fish species. The southwest section is also closest to the land and has the warmest temperature (Figure 11).



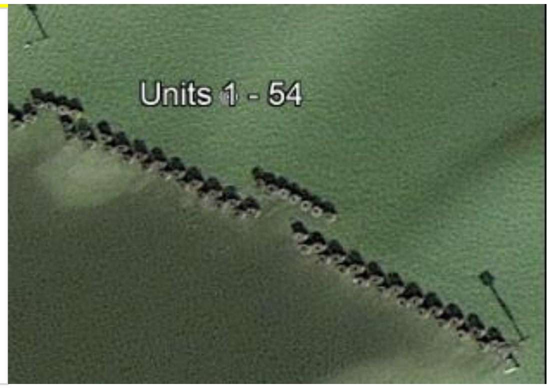
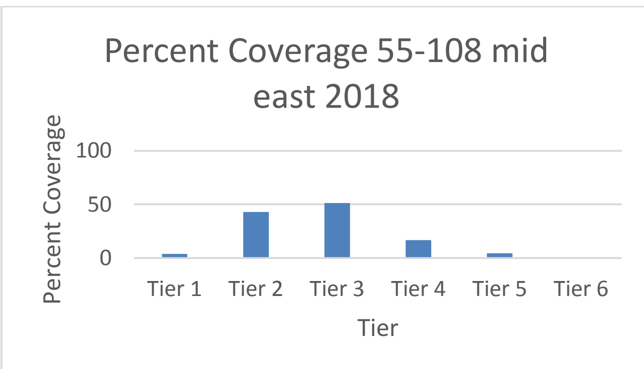


Figure 5: Percent coverage chart (left) of all organisms on the tiers of the eastern reef units 1-54 (right)



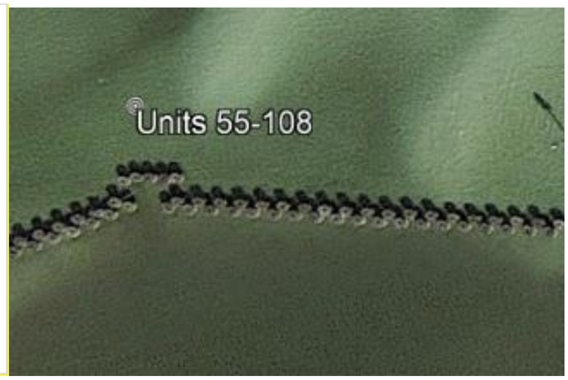


Figure 6: Percent coverage chart (left) of all organisms on the tiers of the mid-eastern reef units 55-108 (right)

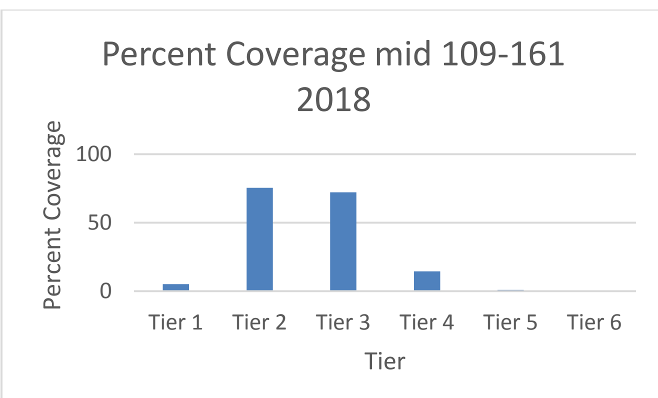


Figure 7: Percent coverage chart (left) of all organisms on the tiers of the middle reef units 109-161 (right)

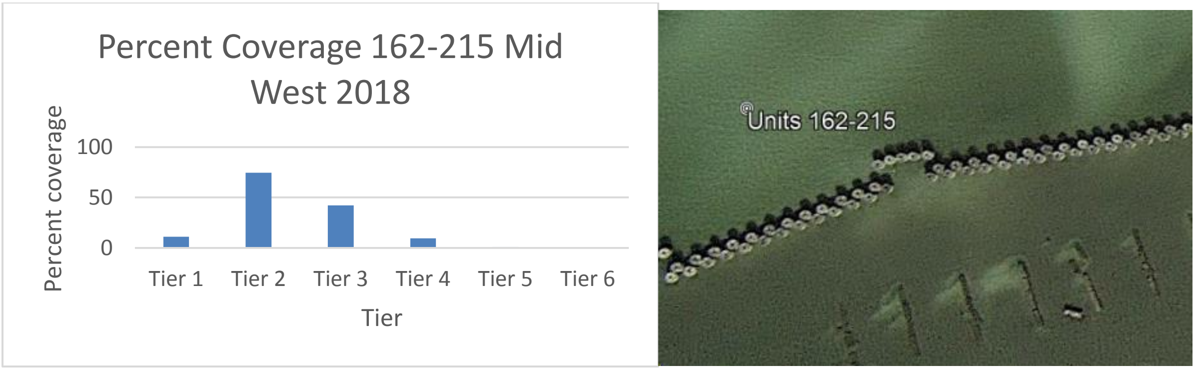


Figure 8: Percent coverage chart (left) of all organisms on the tiers of the mid-west reef units 162-215 (right)

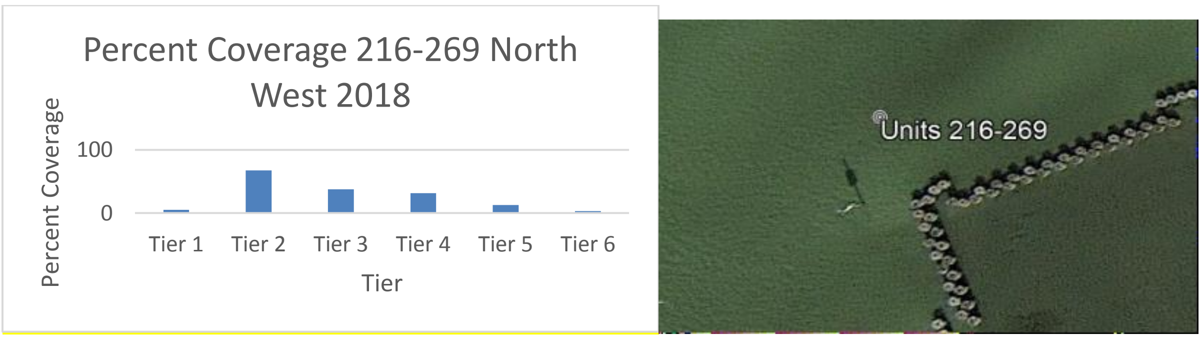


Figure 9: Percent coverage chart (left) of all organisms on the tiers of the northwest reef units 216-269 (right)

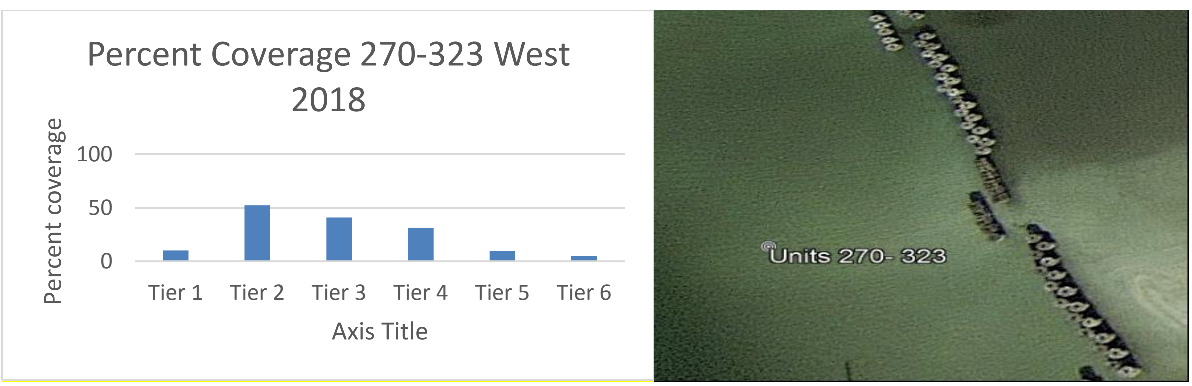


Figure 10: Percent coverage chart (left) of all organisms on the tiers of the western reef units 270-323 (right)

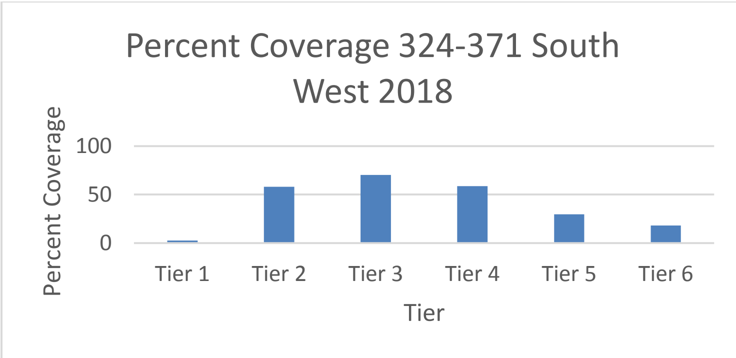


Figure 11: Percent coverage chart (left) of all organisms on the tiers of the southwest reef units 324-371 (right)

3.3.6 Overall percent coverage of all organisms on individual tiers

Tier 1 is ideally exposed out of the water, but the graph shows there is some coverage (Figure 12). This result shows the units are submerged at times due to the presence of organisms. Tier 2 and 3 show the most coverage (Figure 13 and 14), as well as Tier 4 (Figure 15), but the bottom two tiers, Tier 5 (Figure 16) and 6 (Figure 17) show a decline in percent coverage.

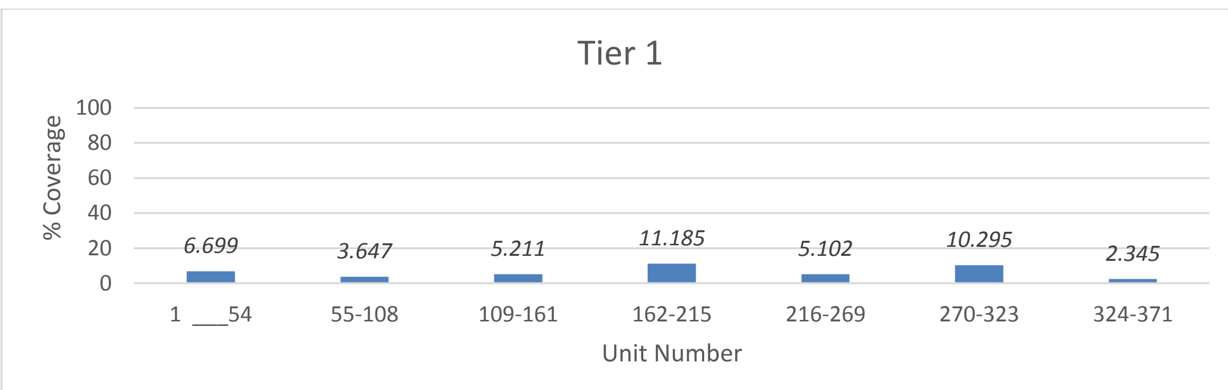


Figure 12: Percent coverage comparison between tier 1 and section east through southwest (1-371).

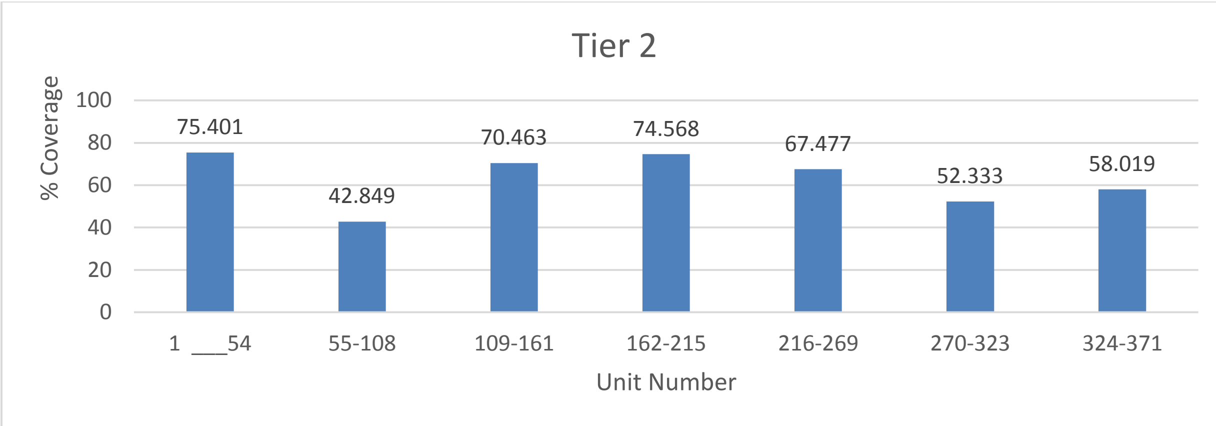


Figure 13: Percent coverage comparison between tier 2 and section east through southwest (1-371).

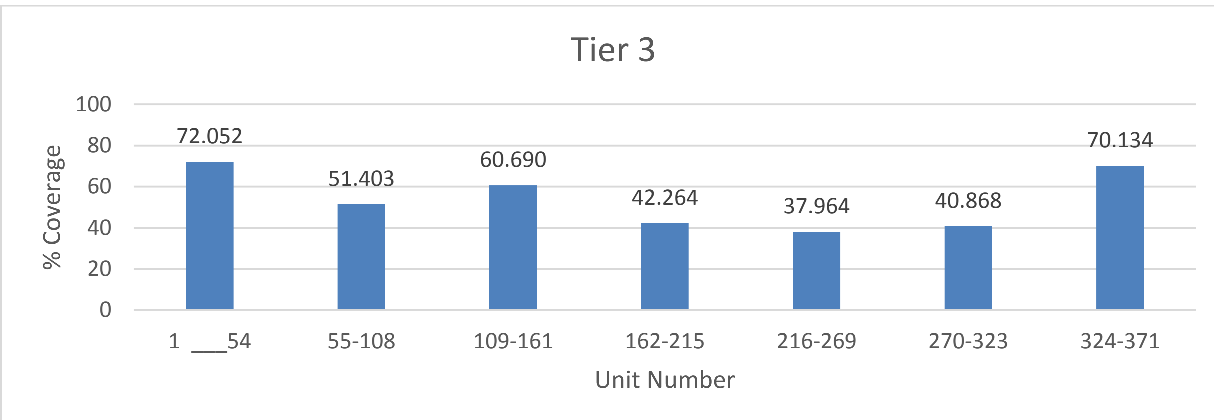


Figure 14: Percent coverage comparison between tier 3 and section east through southwest (1-371).

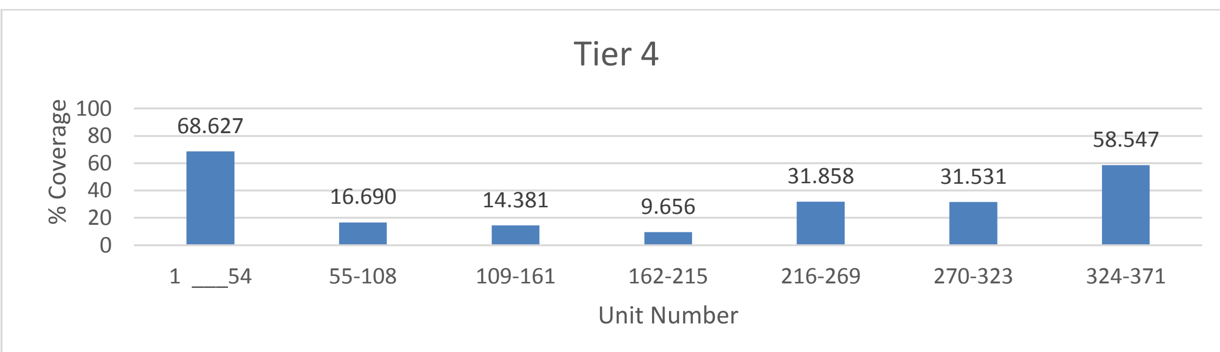


Figure 15: Percent coverage comparison between tier 4 and section east through southwest (1-371).

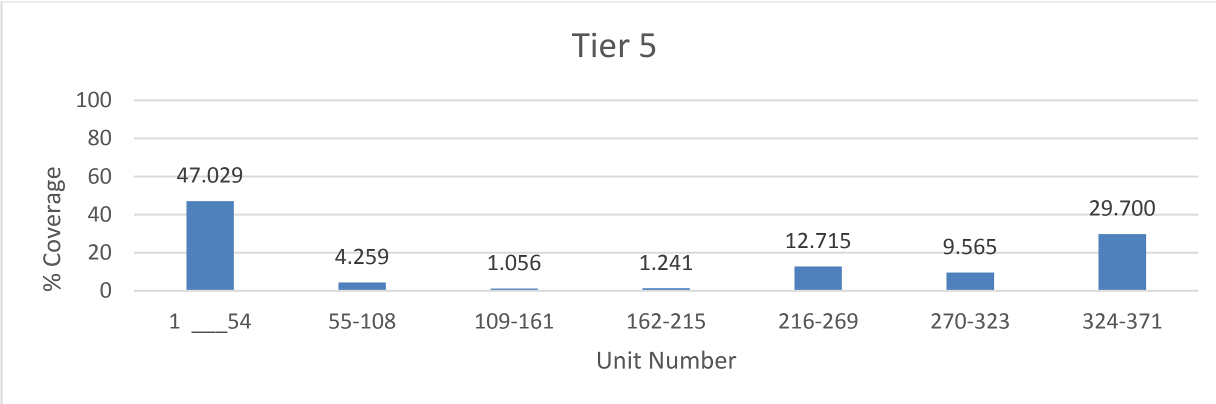


Figure 16: Percent coverage comparison between tier 5 and section east through southwest (1-371).

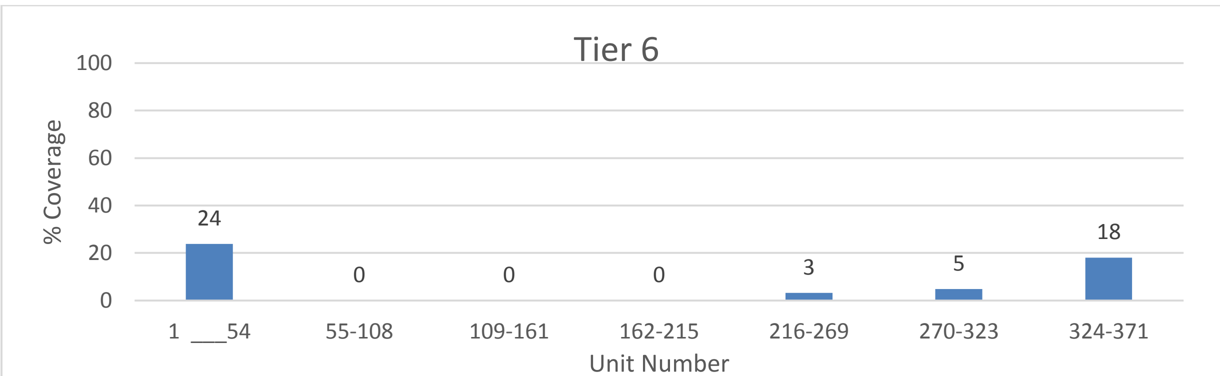


Figure 17: Percent coverage comparison between tier 6 and section east through southwest (1-371).

4.0 Environmental factors affecting the reef

4.1 Storm Events - Hurricanes and Tropical Storms

The 2018 storms impacting the project were Alberto, Gordon, and Hurricane Michael (Figure 18). Fortunately, these storms were not direct and were east of the project site, but it did raise sea level, increase precipitation and caused high winds (Figure 19 and 20).

Figure 18: 2017 radar pictures of 1. Tropical Storm Alberto 2. Tropical Storm Gordon and 3. Hurricane Michael

4.1.1 Tropical Storm Alberto

Tropical Storm Alberto was the first storm of the 2018 Hurricane season; Alberto developed on May 25 near the Yucatan Peninsula. As it entered the Gulf of Mexico, Alberto intensified and transitioned into a tropical cyclone. Alberto reached its peak intensity, with maximum sustained winds of 65 mph (100 km/h) and a minimum pressure of 990 mbar on May 28, 2108 (Figure 18). The storm caused coastal flooding along the United States Gulf Coast, most significantly in Florida where the storm moved onshore (Wikipedia- National Hurricane Center, 2018). Alberto mainly shifted the sands around Deadman's Island. There was no significant damage except some minor scarping and trash debris. This storm started the decline in salinity measurements and creating turbid waters for June.

4.1.2 Tropical Storm Gordon

Tropical Storm Gordon struck the coast at 70 mph (60.82 knots), under of hurricane strength, near Pascagoula, Mississippi, late Tuesday on September 4, 2018. Forecasters reported radar spotted possible tornadoes spun off by the storm overnight in southern Alabama and the Florida panhandle. Parts of the panhandle had received more than 10 inches of rain in 24 hours as of midday Wednesday (National Hurricane Center, 2018). Even though the site were on the east side of the storm, the site did not receive very high winds so very little damage was done to Deadman's Island reefs and shoreline.

4.1.3 Hurricane Michael

Hurricane Michael started in the Yucatan Peninsula on October 8, 2018. On October 9, 2018, at 3 pm the storm turned into a Category 2 hurricane and was 360 miles south of Panama City Beach. On October 10, 2018, as Category 3 at 3 am, Hurricane Michael was 220 miles SSW of Panama City, Florida; at 11 am on October 10, 2018, the storm became a Category 4 hurricane and was 105 miles SSW of Panama City. The hurricane not only impacted the Gulf coast from the south but strong winds from the north impacted the outer counties.

In Gulf Breeze, Santa Rosa County, Florida, Hurricane Michael brought in winds as high as 40 knots with gusts as high as 61 knots along the north side of Deadman's Island Gulf Breeze (NOAA RADAR, 2018). These high winds started and were maintained from 1 pm on October 9 to 7 pm October 10, 2018. The winds were from the north and northwest. The water level rose above the reef structures. The storm damaged the top tier of 30 reefs. The force of storm surges caused 30 reef sections to crack or break off completely. On the east isthmus, the large Class II category rocks blew over, and few were washed about 6 feet landward. The water completely covered Deadman's Island and the vegetation. The storm piled about 9-12 inches of sand 70 to 100 feet on shore; this sand build up was beneficial to the project.

The Category 4 hurricane Michael raised the tides of Pensacola Bay and destroyed many docks and washed them onshore to Deadman’s Island. The storm broke dock sections from area resident homes and washed up on Deadman's Island. Other large miscellaneous debris was found. The 500 feet of chained barrier curtain tied to piling to protect the new plants along the shoreline was buried. The curtain was ripped and some parts destroyed, washed ashore or were buried in the sand. The cleanup effort is slow and costly. The entire west side dunes were scarped and destroyed all previous planting efforts.

4.2 Rainfall

The year 2018 received less rain than the previous years (Figure 19). Last year the inland rains were 64.62 inches (FDACS, 2018). This year’s rainfall from January to August was 38.30 inches. The highest rainfall was in July 8.24 inches (Figure 19).

Knowing the amount of rain helps determine whether water quality impacted the coastal areas by increased turbidity levels which reduce light exposure, salinity, and runoff. These factors can affect growth, food chain dynamics, predation, and the overall microbial community survival.

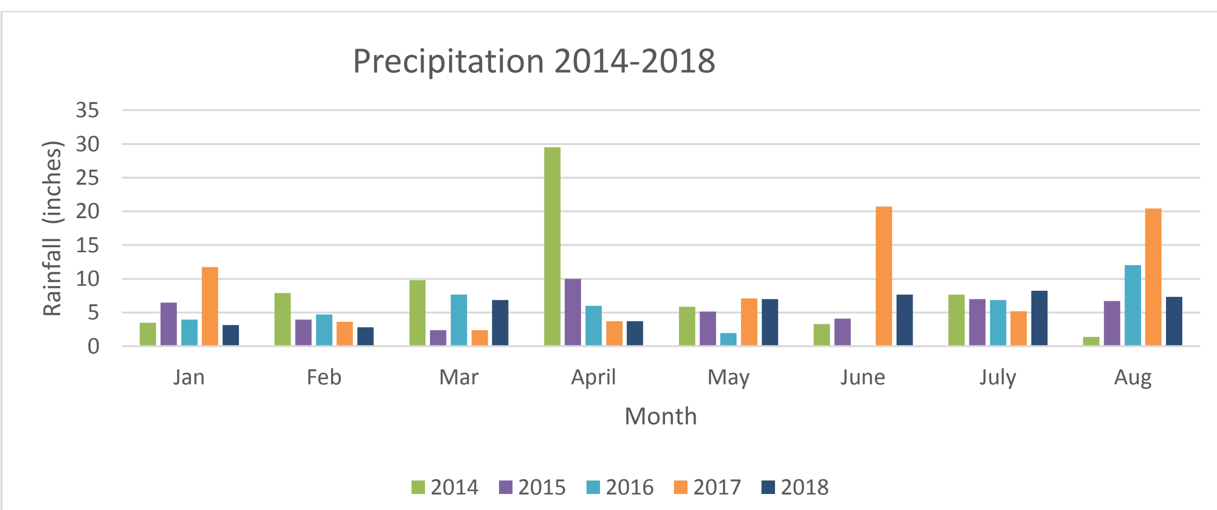


Figure 19: Precipitation near Deadman's Island.

4.3 Wind direction

Wind direction is measured in degrees clockwise from due north. Consequently, a wind blowing from the north has a wind direction of 0°; a wind blowing from the east has a wind direction of 90°; a wind blowing from the south has a wind direction of 180°, and a wind blowing from the west has a wind direction of 270°. The highest gusts were from the north which directly impacts the northern and eastern reefs where the most damage was observed. The constant wave impact is from the west-southwest and there are a few damaged units but not from the north. Normally, erosion to the shoreline usually occurs from the west.

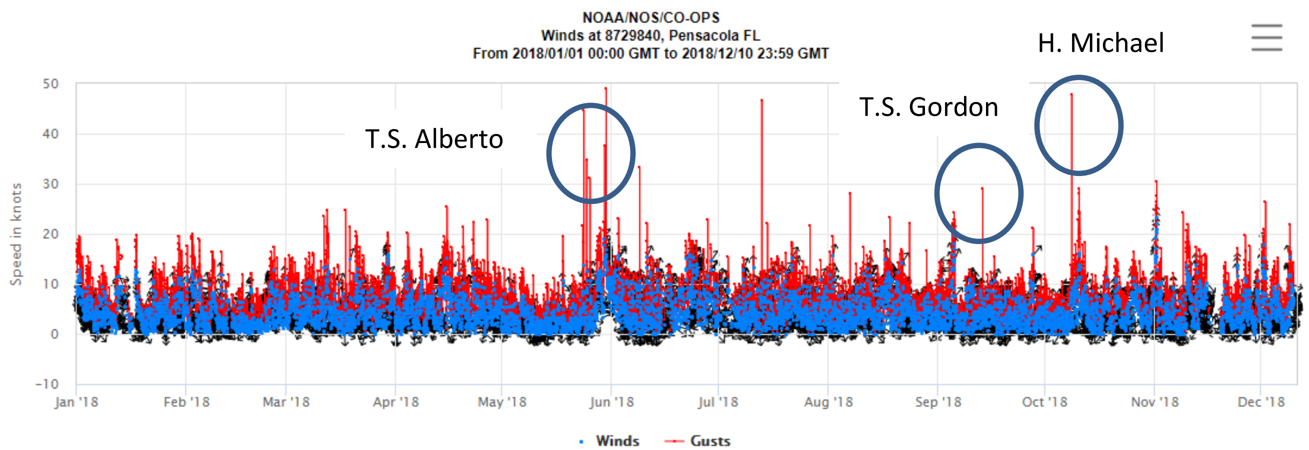


Figure 20: A chart of the winds showing the timeframe of the major impacts to Deadman's Island reefs

4.4 Sea Level Rise

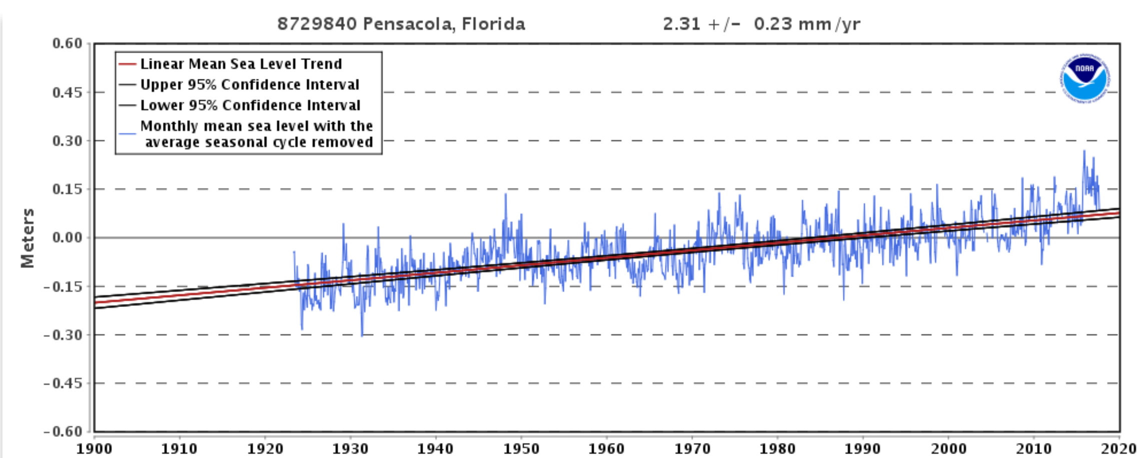


Figure 21: the 100-year average trend of sea level rise of Pensacola, Florida.

As mentioned in the previous year's report, sea level rise seems to be measurable on a local scale. In comparison to the 2013-2018 tides and monitoring reports, the tide charts show a sea-level rise. Field validation shows the predicted tides are much lower than the actual tides. This fluctuation causes problems for daily field planning, especially for boat launching since Deadman's Island is boat access only.

Historically and currently, the verified tides (green) depicted on the National Oceanic and Atmospheric Administration (NOAA) tide charts are shown higher than the predicted tides (blue) (Figure 22). In some cases, from January to October, the tides were 0.5 to 1 foot higher than normal tide. At times it was higher than 2 foot, but these tides correlate with the storms in May, September, and October.

4.4.1 Number of high water events/ significant storms 2018

As shown in Figure 22, the actual tides continue to rise above the predicted level initially indicated on charts by NOAA. This fluctuation makes it difficult to plan for tide dependent projects. Although two tropical storms and one hurricane affected the Gulf region, the trend of sea level rise continues throughout the months where there were no storms (National Hurricane Center, 2018).

The predicted tides are from sea level rise models based on the last 100 years (Figure 21). In most cases, not only was the high tide greater than average, but the low tide from some months, represented more of high tide and remained above 1.0 foot above normal (Figure 22). In other words, the verified data in the charts, which is green, shows the low tide was absent during the time when salt tolerant plants needed to recover from the long duration of high tides.

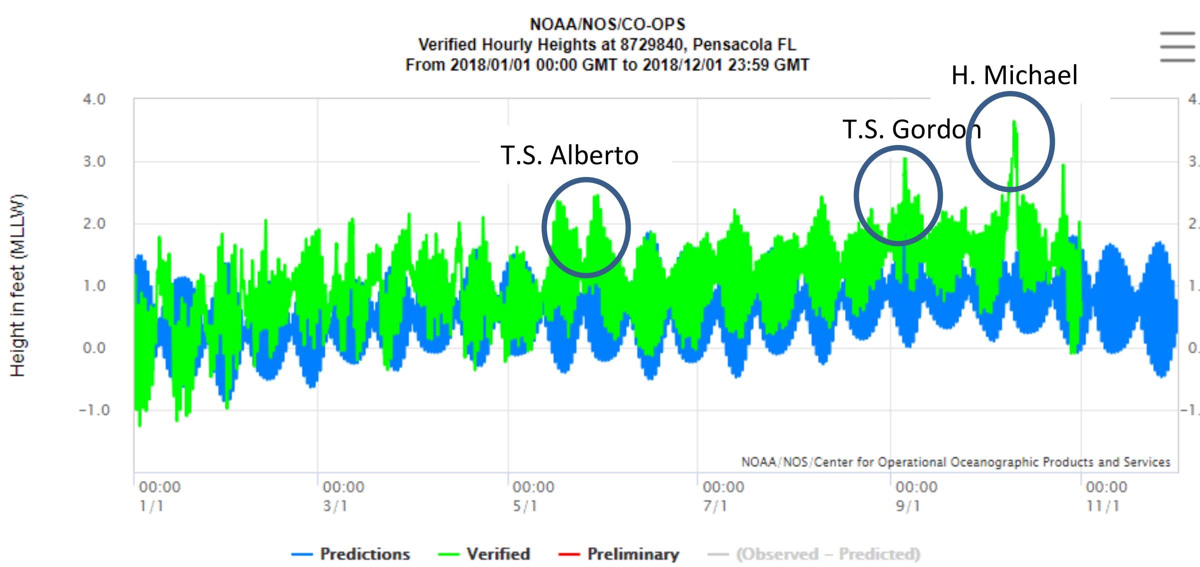
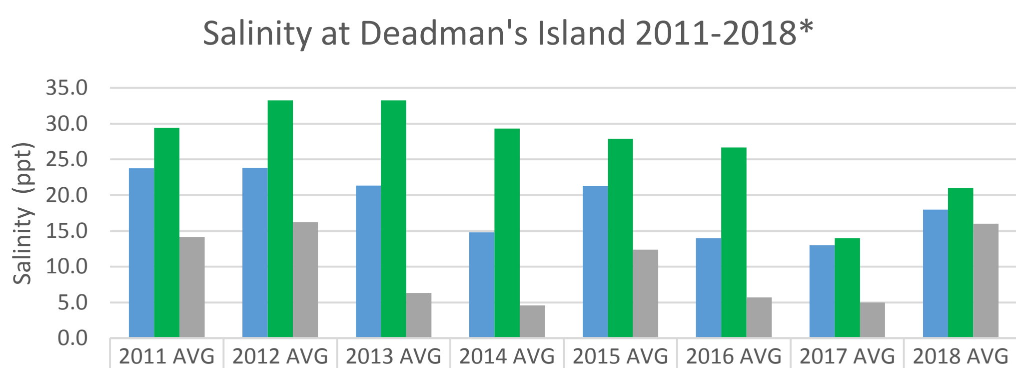


Figure 22: The actual and predicted tides levels of 2018. The blue lines are the predicted tides given, and the green lines are the verified tides which were the actual tides.

4.5 Salinity



	2011 AVG	2012 AVG	2013 AVG	2014 AVG	2015 AVG	2016 AVG	2017 AVG	2018 AVG
Avg	23.8	23.8	21.4	14.8	21.3	14.0	13	18.0
Max	29.4	33.26	33.26	29.3	27.9	26.7	14	21
Min	14.16	16.23	6.32	4.57	12.4	5.7	5	16

Figure 23: Salinity chart for 2011-2018. *The salinity of 2018 does not represent the entire year. Salinity levels represent July, August, and September of 2018.

Salinity is the most important physical factor to understand whether the oysters have a healthy year or predict a possible change in growth. Salinity influences the health of the oyster and its predators. Higher salinity accommodates most of the predators of the oysters (Savarese, 2005). Oysters can grow and spawn in intermediate salinity such as 5-25 parts per thousand (Bartol et al., 1999). Historically, the salinity reached its highest in the bay at 32 ppt in 2013, and every year went above the maximum limit only briefly; the lowest salinity was observed in 2015 at 4.57 ppt. In 2018, salinity ranged from 16-21 ppt from July to September (Figure 23). As observed in the previous years, the increase in salinity correlated with the increase in oyster drills, which are most abundant when the salinity is high.

4.6 Temperature

There were several temperature fluctuations throughout the year which could have induced spawning. The temperature chart shows the large temperature fluctuation in late January, March, September, and November (Figure 24).

Water temperature can change and impact salinity levels. As shown in previous reports as the temperature rises, the salinity increases in the bay (Reed, 2013). The exception would be the fresh water influx as observed with the floods of 2014 causing low salinity levels and multiple heavy precipitation events in 2017 (Figure 19). 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 exposure causing “baking” in the direct sunlight from increased temperatures. The offshore distance of the breakwater keeps the temperature and dissolved oxygen ideal levels for the oysters because of frequent underwater exposure. Monitoring shows some oyster growth above the mean high water, but this exposure is tidally influenced.

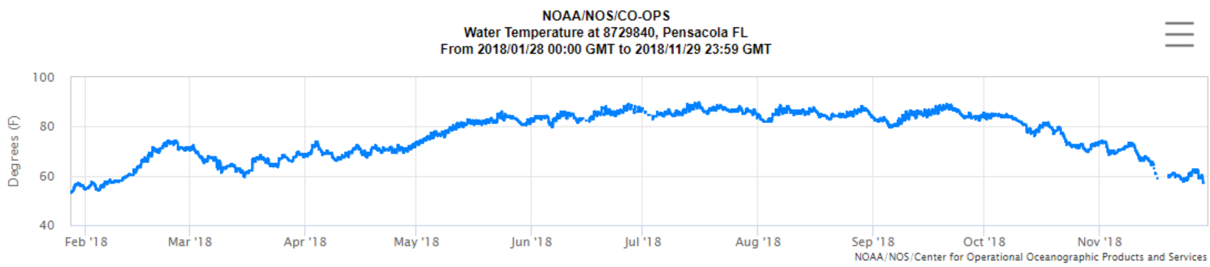


Figure 24: 2018 Water temperature. NOAA Air Temperature, Pensacola FL. January to December 2018

5.0 Community Structure

5.1 Species abundance and Individuals present

Figure 25 Pinfish, *Lagodon (*above) and Figure 26 (below): Wrasse (*Halichoeres bivittatus*). Photo credit Ashlie Johnson

During the early years of 2012 and 2013, the species abundance coincided with community structure. The previous years' data showed a steady increase from 2012 through 2015 of species abundance. Usually, a stable ecosystem is observed to have a constant change in species abundance numbers. A certain number of species increased significantly on various sides of the reef. Again, the point to understand for reef orientation, 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. Certain species seen around the reef were not counted in the data as reef species. For example the Pinfish (*Lagadon sp.*) was counted as a reef species (Figure 25) due to its presence inside the Ecosystems. The wrasse (*Halichoeres bivittatus)* (Figure 26) is not found on the reef and is not counted as a reef species but is noted as an inhabitat near the reef because the wrasse prefer the habitat of sand and rocks along the east side instead of inside the Ecosystem reefs.

In the previous years, flucuation in number of species such as the oyster drills may be changing the community structure. The oyster drill populations appear to fluctuate on the entire reef. The flucuation included both the Reefblk and the Ecosystems. There was an increase in the oyster drill population of 4.7 from 2013-2015. By 2015 there was a 65% decrease in numbers. However, the egg casings increased over 2000 times. As with the 2014 floods, the salinity in the year 2017 was extremely low. This low salinity caused the lowest number of drills in all the years. This decrease coincided with the same drop in numbers as with 2014.

In 2015, another species which also has seem to change community structure and competition with oysters is the hooked mussel, *Ischadium recurvum,* was first seen on the reef and was added to the data collection. Hooked mussels prefer the low salinity ranges. In 2017, the highest number of hooked mussels were observed. Although hooked mussels are symbionts on the reef, there is still a competition for space with the oysters. The main predator of hooked mussels is the blue crab. More blue crabs were found on the reef in 2018 and less hooked mussels. It was difficult to determine any correlation between the blue crab and the hooked mussels due to the vast size of the reef.

6.0 Fish Surveys

Fish surveys are conducted throughout the monitoring event using the visual census method of the quantitative underwater ecological surveying techniques. Fish swimming in the vicinity of the reef and fish inside the reef were counted such as the juvenile sheephead (Figure 27). After a few transects, the fish are more relaxed with the presence of divers and more accessible to quantify. Certain fish were not counted as part of the reef because there were either baitfish or the fish that preferred the habitat next to the reef such as the ballast rocks.

Figure 27: Juvenile sheepshead. Photo credit: Caroline Polder

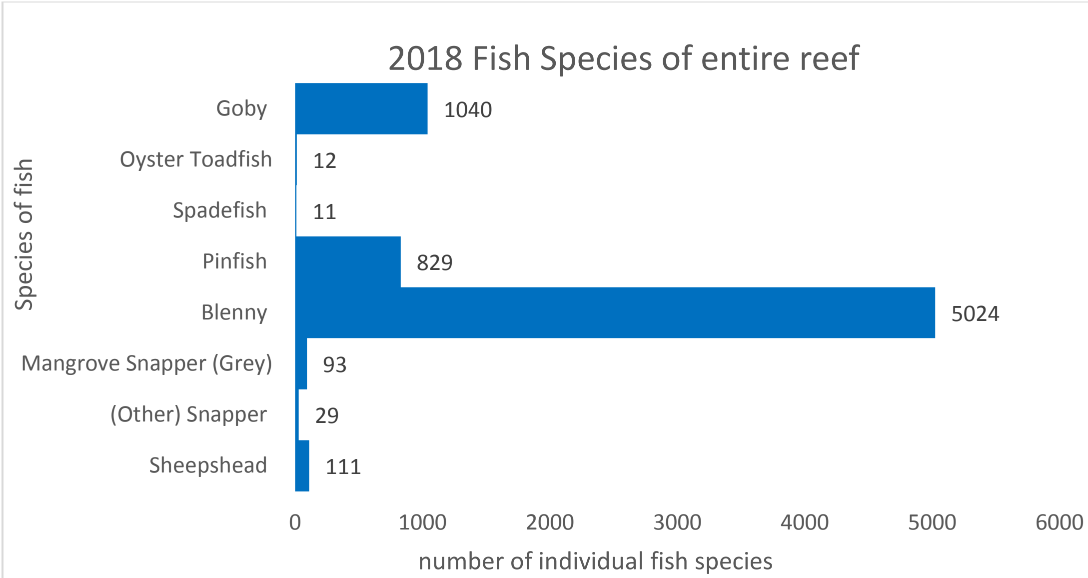


Figure 28: Chart of the fish species throughout the entire reef at Deadman's Island

6.1 Species Richness and Diversity

Community evenness is found to shift much earlier than species richness before a species die off, its abundance is likely to decline gradually. The early shifting may lead to a variation in evenness if the decline is not uniformly affecting all species in the system. Tracking community evenness may give early warning signals of what is going on in the community. The abundance of oyster drills and egg casings can be an indicator of the possible results of oyster mortality the next year. This tracking can also be the same for synergies between species such as the predators of the drills, such as stone crabs (Figure 29) or sheepshead (Figure 27). A reduction in evenness would lead to a decline in the function rates as the beneficial support between the species declines. Unfortunately, these numbers can be disturbed by overfishing of these species and lead to false results of certain evenness scenarios.

If the function lessens (or improves) and dominated by the output of one species (dominant) and this species performance is below the average, a decrease in evenness due to the increased dominance of this species and the function rates will decline. Using a species not typically disturbed by humans, the main predator of the reef, the oyster drill, shows an increase of drills in 2018 (Table 3). The proportion of oyster drills and egg casings between 2017 and 2018 may predict a decline in evenness on the reef. Unless there is a high rain which lowers the salinity, there will be much less live oyster coverage on the reef in 2019.

In 2018, the entire reef was counter. One hundred and two units were randomly chosen to compare with 2017 and previous years; however, to get a better idea of the evenness and richness of the reef we calculated the proportion (Table 2).

Table 2: Species proportion table comparing richness between the same species between 2017 and 2018

Species name	Common name	2017 n=102	2018 n=102
Urosalpinx cinerea	Oyster drills (OD)	0.65	16.05
Urosalpinx cinerea	Oyster Drill Egg Casing (EC)	4.67	15.87
Archosargus probatocephalus	Sheepshead	0.06	0.29
Lutjanus griseus	Mangrove Snapper	0.27	0.06
Zooanthis sp.	Zooanthids	0.02	0.00
Hypsoblennius hentzi	Blenny (Feather)	1.14	3.70
Menippe mercenaria	Florida Stone crab	4.75	1.59
Pagurus longicarpus	Hermit Crab	7.05	1.27
Lagodon rhomboides	Pinfish	4.75	0.70
Chaetodipterus faber	Atlantic Spadefish	0.00	0.01
Opsanus beta	Toadfish	0.06	0.01
Ischadium recurvum	Hooked mussels	69.86	4.07
Callinectes sapidus	Blue crab	0.00	0.07
Gobiosoma bosc	Naked Goby	2.68	0.60
Littorina littorea	Periwinkles	8.41	5.62
	Total fish	9.14	5.38
	Total eastern oyster % cover	0.01	0.01
	Total crabs	11.80	2.93

Table 3: Species abundance on the reef of Deadman's Island from 2015-2018 n= 102 and 2018 of the Entire reef

Species name	Common name	2015 n=102	2016 n=102	2017 n=102	2018 n=102	Entire reef 2018
Urosalpinx cinerea	Oyster drills(OD)	5380	6936	248	6131	21548
Urosalpinx cinerea	Oyster Drill Egg Casing (EC)	74380	74900	1784	6060	24576
Barnacles sp.	Barnacles sp % coverage	8	37	11	24	33
Archosargus probatocephalus	Sheepshead	1	69	24	36	111
Lutjanus campechanus	Snapper sp	123	35	61	7	29
Lutjanus griseus	Mangrove Snapper	23	24	105	22	93
Zooanthis sp.	Zooanthids	4575	15	6	0	0
Hypsoblennius hentzi	Blenny (Feather)	4575	5428	435	1412	5024
Cerianthus spp.	Tunicates	0	11	1	0	0
Menippe mercenaria	Stone crab	12290	6296	1813	607	2222
Pagurus longicarpus	Hermit Crab	1387	734	2692	484	1683
Lagodon rhomboides	Pinfish	1336	569	1813	266	829
Chaetodipterus faber	Atlantic Spadefish	2	0	1	4	11
Astrangia danae	Coral	3	0	0	1	1
Opsanus beta	Toadfish	48	40	24	5	12
Sabellidae spp	Feather duster worm	3	543	47	0	0
Cerianthus spp	Anemone	1755	39	0	0	0
Micropogonias undulatus	Atlantic croaker	99	39	4	0	0
Ischadium recurvum	Hooked mussels	20979	5167	26679	1555	6676
Callinectes sapidus	Blue crab	188	13	1	28	101
Gobiosoma bosc	Naked Goby	1955	1947	1025	228	1040
Littorina littorea	Periwinkles	5182	8004	3210	2146	8380
Total fish		5147	8151	3492	2055	7149
Total live oysters % coverage		63	46	2	3	4
Total crabs		12478	6309	4506	1119	4006
Total #species		59906	35909	38189	13007	47760

7.0 Observations

During the monitoring events, several observations were made that would require additional monitoring techniques to quantify, but observations also validate some of the data found, for example, the Florida Stone Crab. The stone crab is very important to have on the reef for the survival of the oysters and ecosystem. Although the stone crab is known as a predator to oysters, they have been observed eating algae off the reefs and also oyster drills.

7.1 Florida Stone Crabs (*Menippe mercenaria)*

Several observations were made through monitoring the reefs during the summer of 2018. An outstanding number of 2,222 Florida Stone Crabs (*Menippe mercenaria*), were recorded throughout the entire reef (Figure 29). These reefs showed either dead oyster coverage, live oyster coverage or both. It is unsure if the high number of stone crabs were affecting the live coverage and spawning rates of the oysters on the reef.

The stone crabs were mainly noticed on the deepest tiers. Each reef had either four to six tiers, and the stone crabs were on tiers three and lower with the occasional one found on the top two tiers. Most of the stone crabs observed in June through mid-July seemed to be juvenile crabs that were using the dead oysters as coverage from other predators such as Blennies sp., Gobies sp., Blue Crabs (*Callinectes sapidus*) and other organisms. These juvenile crabs seemed to be just seeking structure rather than eating the live oysters. Occasionally, it would be noticed that the juveniles would pick at algae growing on the reefs trying to find some nutrients to grow and survive.

Figure 29: Juvenile stone crab on the reefs of Deadman's Island. Photo credit by Ashlie Johnson

The reefs were also home to larger adult stone crabs these adult crabs were noticed during all months of research. Also, adult stone crabs in August were observed carrying eggs, which can signify that the crabs may come to the reefs to spawn their young. Observations showed most of the adults seemed to be less concerned about the researchers being in the water than the juveniles.

The adult stone crabs were observed eating oyster drills, Blue Crab (*Callinectes sapidus*) and fellow Stone Crab (*Menippe mercenaria*) body parts. A few times the crabs were observed eating live oysters. Stone crabs were noted eating more oyster drills than any other species. The oyster drill's main source of nutrients comes from algae and live oysters, which could be damaging to the reefs if the population is not controlled; the stone crabs and a few other organisms that feed on oyster drills help control the drill's population levels, which in turn benefits the health of the reefs.

From long term observations, stone crabs appear to be beneficial to the reefs. These crabs appear to help provide the amount of control of oyster drill populations that is needed to let these reefs thrive in the Pensacola Bay. Most of all, the crabs observed seem to have their small territory with no other active competition. There was observed mating of *Menippe mercenaria* in July and August. The vast amount of space and structure between the reefs make a great nursery grounds for many organisms, including the stone crab.

7.2 Oyster drills

One observation mentioned several times throughout this, and previous monitoring reports, is the Deadman's Island reefs show diverse communities in various sections of the reef.   While pinfish (Figure 25) was plentiful across all reefs, live oyster counts changed a great deal by depth and placement in the bay, for instance after unit 300, on the west side, there wasn't a significant increase in the percentage of live oysters in proportion to 2017 (Table 2).

Figure 30: Oyster drill located on the reefs of Deadman's Island. Photo credit: Ashlie Johnson

The fluctuation in the abundance of oyster drills (Figure 30) has been the most interesting. It was hypothesized that the stone crab population could compensate for a large oyster drill population thus allowing for a balanced and healthy ecosystem.

To determine whether the hypothesis was correct or not, the amount of live oyster coverage on each reef to the number of oyster drills on each reef was measured (Figure 31). Unit 50 showed a significant spike in live oysters; there was also a significant spike in the number of oyster drills on those reefs. The charts showed that even when there was a high amount of oyster drills on a reef the number of live oysters found was still high even though their main predator was living there. Observations showed there was a consistent number of crabs throughout the reef (Figure 32).

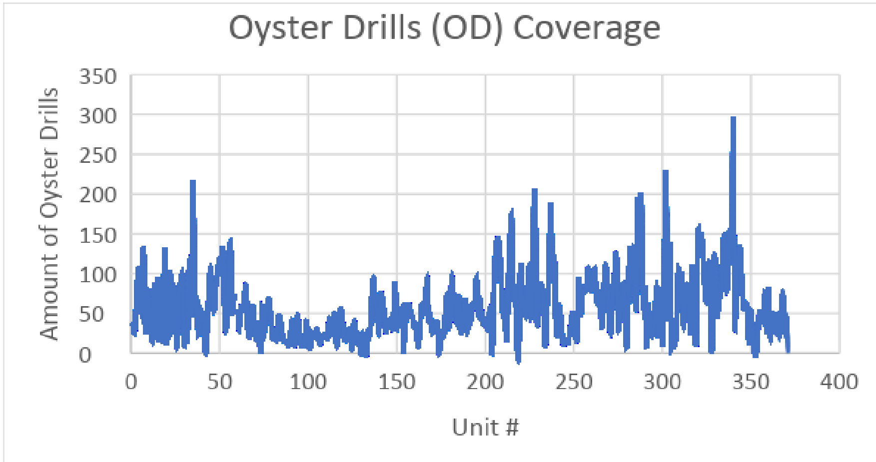


Figure 31: Graph of the presence of oyster drills on the entire reef.

It was concluded that the amount of oyster drills to crabs may show a realistic balance as a food source. For each crab, there are ten oyster drills (or less) throughout the 371 reefs as a whole.

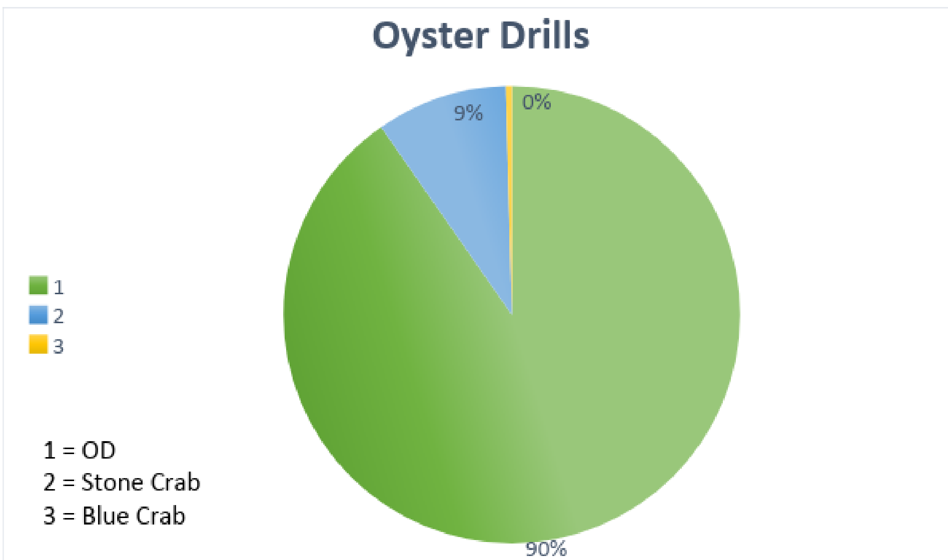


Figure 32: Chart of the presence of oyster drills vs invertebrate predators to oyster drills

7.3 Additional observations

Although in the 0.001% range, Corals and sponges (Figure 33) have appeared throughout the years at Deadman's Island reefs but only to disappear the following year. It is unknown why at this point. At this point, the presence is documented but because the presence is low, it was not added to the reef species table in 2018.

Currently, the main threats to Deadman's Island are tropical storms and anthropogenic impacts. This summer had a few major tropical storm systems come through Deadman's Island as mentioned in Section 4.0, but a few of the reef structures had tilted slightly due to storms moving through the area before our monitoring began. Other observations were negative anthropogenic impacts on the project; we consistently found fishing line on the top tiers on the reefs, sometimes the line was caught on more than just one reef and stretched down to the reefs surrounding it. Fishing lures were also recovered on the top tier of the reefs throughout the structures.

Another negative anthropogenic impact observed was the amount of pollution and waste products found on the reefs, the island, and in the Pensacola Bay; almost every other day plastic water bottles, chip bags, glass bottles, and other various types of waste were found. The marine life such as the stone crab is the least of Deadman's Island reefs impacts. These crabs, believe to be a nuisance to the reefs, may help the reef sustain a healthy equilibrium. The negative anthropogenic impacts in the area are much more cause for concern for the reef and peninsula’s sustainability.

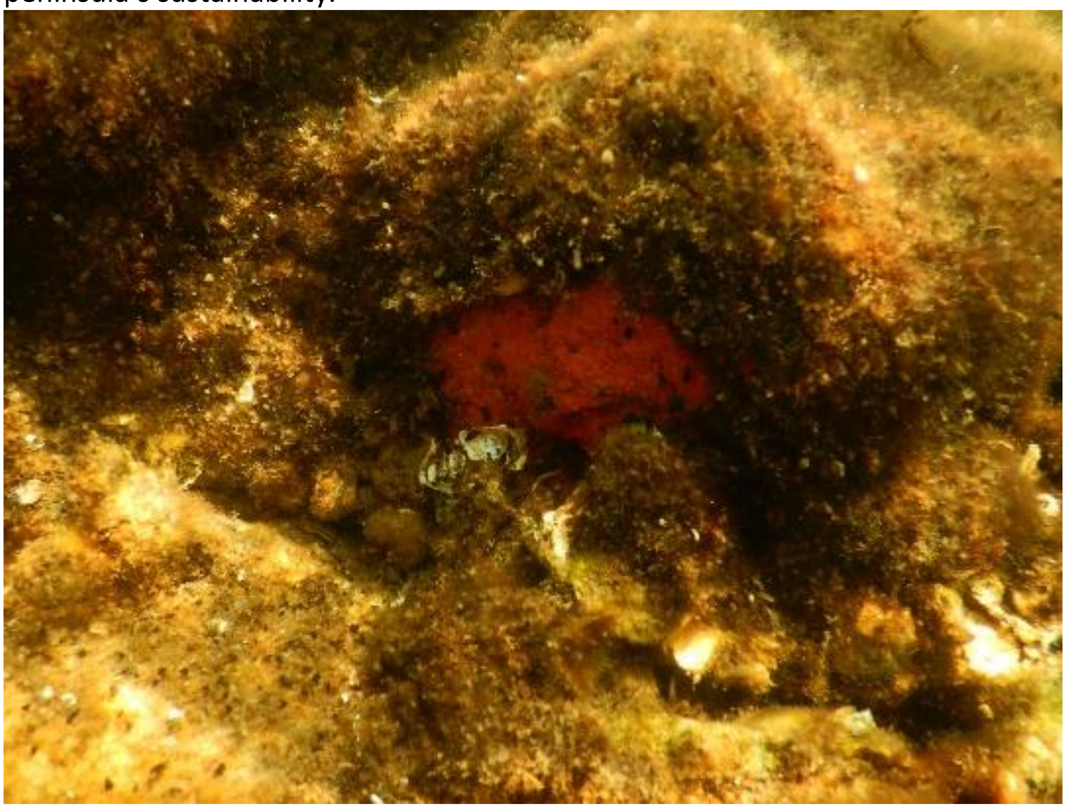


Figure 33: Sponges are becoming a common species on the reefs of Deadman's Island

8.0 Shoreline Erosion/Change

A bathymetric survey was not performed this year due to lack of funding. Instead, shoreline erosion was measured with GPS surveys, and a map was created to show the change in the shoreline. Since 2017 had new construction and sand placement, it is believed the sand would continue to shift and would not have settled to equilibrium inside the reef in only a year. Therefore, a bathymetric survey may not be representative of the actual depth until the sand settled.

The GPS map of the 2018 shoreline change showed there was an erosion of the shoreline (Figure 34). Since the breakwater footprint construction was completed, it was confusing about what caused any erosion (besides the apparent storms). Observations show the reefs were submerged many days; it was possible the wave action rolled over the reefs and caused additional erosion to the shoreline.

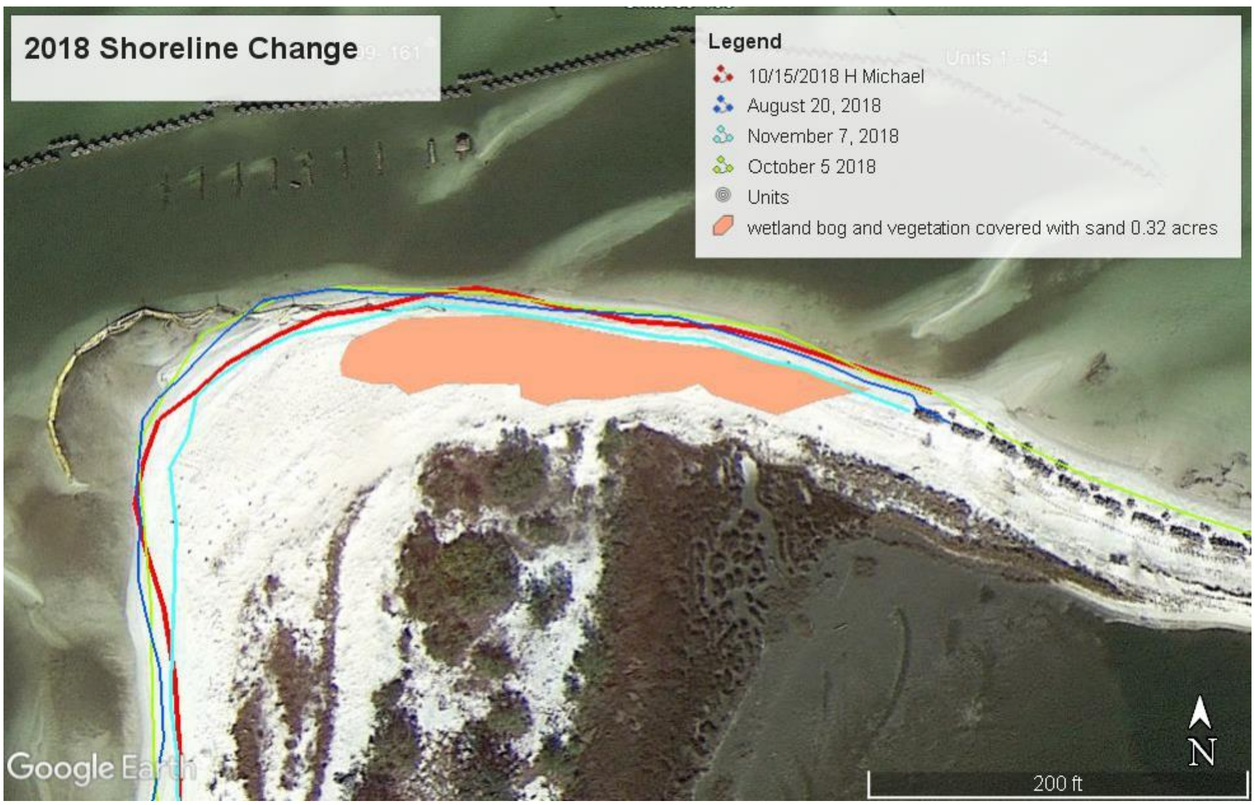


Figure 34: Shoreline change documenting the erosion, sand shifting, impact and accretion throughout the summer and fall of 2018

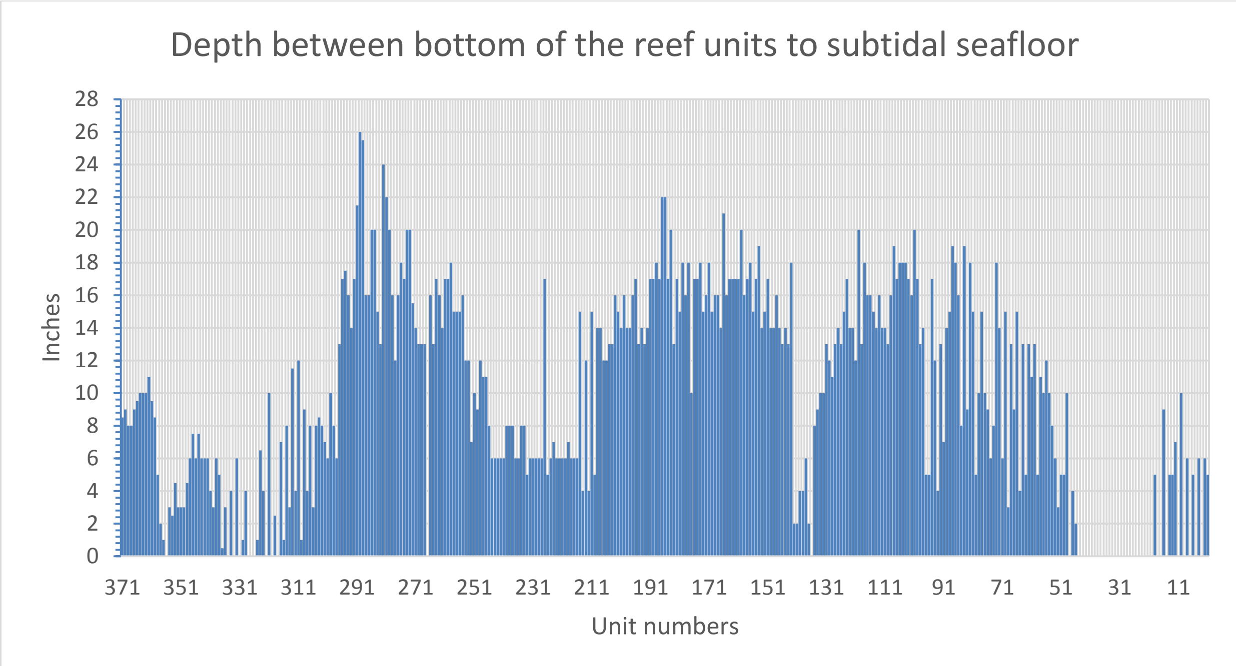


Figure 35: Chart showing space distance between the bottom tier of the reef units and subtidal floor

As mentioned in the 2017 report, the 2017 aerials show whitecaps on the landward side of the reef (Figure 36). Further studies of tide datum showed the date of the aerial was during a supermoon and high tide (NOAA.gov 2018). When the water rose above the reefs, the shoreline would be impacted. With the higher than normal tides, a majority of the reefs were rarely observed out of the water. The 2018 study of measuring any gaps between the bottom of the unit and subtidal floor found that although the reefs as being submerged and not effectively attenuating the waves to protect the shoreline, the current underneath the reef may also have contributed to the erosion (Figure 35).

Possible subsidence (sinking of the structures) was measured from reference points on the units. The units are placed over the top of a Pearson piling, which is unbreakable according to manufacture studies. What is observed is the pilings can tilt and lean if repositioned. This leaning is what happened in 2017 from storms. When placed in 2015, some of the units were raised off the subtidal bottom to compensate for the higher tides. This was when the erosion was first seen, and barriers were left to protect the shoreline. The entire time it was believed the erosion was caused by wave action washing over the tops of the unit and this is true. However, some erosion was also observed when the water was not washing over the units. In theory, there should not be any erosion once the footprint of the reef was completed.

The obvious causes of the erosion were ruled out: subsidence, accretion, too much spacing between tiers, and too much flow-through the units. Flow-through was measured with dye and a flow meter. Those results show normal and mild flow through on a day demonstrating high wave impact to the reef.

No subsidence was found because the tier units sit on a collar above the sand. There are a few pilot units where a pad was placed underneath a unit and there were no oyster shells. These units have since accreted sand which was the intention. To measure the accretion, the distance between the bottom tier and sediment were measured. It was found found some of the units had more scouring underneath the piling, sometimes up to 2 feet was measured between the bottom of the tier and the top. This is where the problem was found. The current was strong under the reefs.

The chart in Figure 35 represents the entire reef, and each reef unit is numbered 1-371. The chart shows dark blue spaces representing the number of inches of space between the subtidal floor and the bottom the unit. The dark blue spaces are the gaps under the reefs. Currently, some reefs are closer to the floor and block the strong underwater current.

These changes in gap spacing have led to a dramatic washout of the subtidal floor, leading to a large gap between the floor's surface and the lower tier of the reef structure. This has also led to dramatic shoreline loss along the north end of Deadman's Island. A recommendation is adding an additional two tiers to the top of the reef structure as well as adding a collar onto the bottom occur to salvage the reef structure as it currently stands.

Measurements show the number of units that are submerged or are leaning to one side were impacted by storms and not leaning before the storms. If the tides continue to rise and the wave action continues to beat above or below the reef structure, then the structure will inevitably lean toward the shore and fail to be a significant breakwater. In the 2018 monitoring season, 30 units were submerged. Thirty structures of 371 were impacted. There is currently only 8.1 percent of the reef that is documented as submerged, which is due to the higher tides rising and lowering from day to day.

Measurements show the gap between the final tier of the reef structure and the floor of the bay underneath. A large widening gap appears to be forming and at some gaps in the reef are as large as 26 inches (Figure 35). This gap is allowing the strong currents to pass beneath the structure to where it washes out the sediment and causes an eddy affect to the shoreline and eroding the shoreline directing in front of the gapped units.

Since the reefs are offshore, it is ideal to have each reef at least 1-2 feet above the water, but as determined by the FDEP permit and rules this was not allowed. It is hopeful in time, projects such as the Deadman's Island reef show better science to help change the rules and statutes for more effective offshore wave attenuators and better use of future funding.

8.1 Isthmus Protection Project

An additional project of 2016-2017 rebuilt the isthmus on the north end with sand and rock. There was a breach on northeast end which opened and threatened marshes and living shorelines. The project underwent an emergency repair (Figure 36) to stop the breach. The project has appeared successful. A few things to mention, there are several methods of erosion defense on this project. The rocks were placed upland to allow time for the sediment and plants to become established. It was anticipated if there was more starving of sediment to this project, erosion would occur and the once upland coastal protection structures would become a breakwater. This erosion did occur as anticipated. A majority of the Class II rocks are in the water. Behind the rocks are 13 species of plants and all planted with a purpose according to elevation, location to the water and whether the plants are deep-rooted or shallow, saltwater tolerant, upland and wetland etc. A large berm was created behind the more shallow elevation for the deep-rooted upland species and behind the berm is a large mat of *Spartina alterniflora* to stabilize the shoreline of the marsh. This stabilization will provide strength during high storm surges and prevent wash out and especially breaching (Figure 37).

This has also been shown a successful project, primarily through storm evaluation. The storms did knock over large riprap, but overall the vegetated berm that was placed behind the rock held up well with only a few intense water blowouts of the established root systems.

Figure 36: 2017 Aerial of Deadman's Island. Blue arrows show the whitecaps of the current from the northeast.

Figure 37: 2018 Post-restoration of the sand transport and placement and also the isthmus repair.

9.0 Future Needs

As recommended, two tiers need to be placed on top of the tiers that sit lower in the water to offset sea level rise and remain a consistent height throughout the entire reef. The north end still needs funding to remove the pilings used to place the barriers in 2013 and also transport the marine debris associated with the removal of material placed in 2017. The southwest end of Deadman's Island endured much scarping from rogue waves, storms and anthropogenic stressors of visitors. A project to rebuild the dunes is needed to restore the dunes. There were many episodes of the general public impacting the dunes by sliding down the dunes and exposing the root systems. The dune was roped off to inform visitors not to slide and destroy the dunes. Most of the educational field trips and volunteer projects have been geared to inform the general public about how easy it is to destroy something and how hard it is to rebuild it.

Figure 38: vegetation planting success of wetland bogs and upland

As monitoring continues and lessons are learned such as the wetland bogs in Figure 38, these projects can easily be transferred to other areas to determine best practices for restoration projects along the Gulf Coast and U.S.

References

Bartol IK, R Mann, and M Luckenbach. 1999. Growth and mortality of oysters (*Crassostrea virginica*) on constructed intertidal reefs: effects of tidal height and substrate level. J. Exp Mar Biol. Ecol. 237:157-184.

Florida Department of Agriculture and Consumer Services FDACS Precipitation Data 2018. https://www.freshfromflorida.com/Divisions-Offices/Florida-Forest-Service/Wildland-Fire/Fire-Weather/Forecasts/Year-to-Date-Rainfall

Houser, Chris 2007 Historical Shoreline Erosion: Deadman's Island Dr. Chris Houser, Department of Geography, Texas A&M University updated and sent 8/20/2007 (3pg)

Morgan, James. 1993. Erosional changes between 1940 and 1992 and resulting impact on Deadman's Island, Gulf Breeze Peninsula, Florida.

Moran, Kilgen, Dugas. 1989. The Ecology of oyster reefs of the Northern Gulf of Mexico and open file report.U.S. Fish and Wildlife Report, Dept. of Interior.

Reed H. 2011, Monitoring and Detection of Gulf Sturgeon During a Bridge Deconstruction Project in Pensacola Bay, Gulf Breeze Florida. A Technical report for Tetra-tech and the City of Gulf Breeze.

Reed, Heather. 2013. The 2013 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.

Reed, Heather. 2017. The 2017 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.

Reed, Heather. 2015. The 2015 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.

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.

Savarese, Michael 2005. Influence of salinity on the habitat use of oyster reefs in three Southwest Florida estuaries. Journal of Shellfish Research

Tropical Storm Alberto (2018) - Wikipedia. N.p., n.d. Web. 25 Jan. 2019 <https://en.wikipedia.org/wiki/Subtropical_Storm_Alberto>.

NOAA Website for meteorlogical data http://tidesandcurrents.noaa.gov/ Accessed 2018
https://tidesandcurrents.noaa.gov/map/index.html

NOAA Radar information accessed From National Hurricane Center 2018

www.EPA.gov, 2018 Accessed November 2018

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

Report citation: Reed, Heather. 2018. The 2018 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. 36 pp.

Appendix

1.) Vicinity map
2.) Reef Map