State of Louisiana

Coastal Protection and Restoration Authority of Louisiana (CPRA)

2014 Operations, Maintenance, and Monitoring Report

for

Bioengineered Oyster Reef Demonstration Project (LA-08)

State Project Number LA-08
Priority Project List 17

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Cameron Parish

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Preface

This report includes monitoring data collected through December 2013.

The 2014 report is the 1st report in a series of two reports. This 2014 OM&M report is a progress report for year two of this five year demonstration project. The final OM&M report is scheduled for 2017.

I. Introduction

The Bioengineered Oyster Reef Demonstration (LA-08) project was proposed on the 17th project priority list of the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) and is co-sponsored by the National Oceanic and Atmospheric Administration/National Marine Fisheries Service (NOAA/NMFS) and Louisiana's Coastal Protection and Restoration Authority (CPRA). It is located on the Gulf of Mexico shoreline in southeast Cameron Parish on the Rockefeller Wildlife Management Area and Game Reserve (Rockefeller Refuge) (Figure 1). The total length of this shoreline protection demonstration project is approximately 565 feet (172.2 m) and is comprised of two, 215 ft (65.5 m) reef sections separated by a 130 ft (39.6 m) gap.

Both historically and recently, the Gulf of Mexico shoreline along Rockefeller Refuge has steadily retreated at a high rate. The Barrier Island Comprehensive Monitoring Program (BICM) reported that the Rockefeller Refuge shoreline eroded 34.9 ft/yr from the 1884 to 2005 and 52.4 ft/yr from the 1999 to 2005 which were the highest rates west of the Atchafalaya River (Martinez et al. 2009; Figure 2). From Feb 2010 to Mar 2013, the shoreline eroded 42 ft/yr along the Control reach for LA-08 based on shoreline morphology measurements collected during the monitoring period of an adjacent project, Rockefeller Refuge Gulf Shoreline Stabilization Demonstration Project (ME-18) (HDR 2011). The beach along Rockefeller Refuge has diminished to a thin layer of shell hash over old marsh platform, and the waves wash ashore onto the marsh. The shell hash is reworked by waves and rolled onto the marsh vegetation along the shoreline where it smothers the vegetation. The soil weakens as the roots die, and the waves erode the shoreline as the shell hash is rolled further inland by the waves. This pattern is exacerbated in the mid-winter to late spring during higher water levels when persistent south winds feed frontal passages to the north (Pers. Comm. P. Trosclair, LDWF Rockefeller Manager). In addition, the water bottoms along the shoreline are old marsh platform and have very low weight bearing capacity. A geotechnical report for ME-18 classified the top 20 feet of soil as very soft clay with an allowable bearing capacity of 290 pounds per square foot (psf) (Fugro Consultants LP 2004) which is too weak to hold the amount of rock used in traditional breakwaters (CHE 2009).

To address shoreline erosion issues along the weak soils of the Rockefeller Refuge coastline, LA-08 is testing the Oysterbreak™ system patented by Oyster Restoration Advancement Technologies, L.L.C. (ORA Tech). The Oysterbreak™ system in an artificial reef composed of interlocking, concrete rings designed to provide habitat for oyster colonization; the rings are 5 ft in diameter, 6 inches wide, and 20 inches tall. The Oysterbreak reef is less dense than traditional rock breakwaters because of the void space of the rings. Rings were designed to decrease density by increasing void space to solve the weight bearing issue and were built wide to compensate for not being able to build tall. Secondary design consideration was to provide oyster habitat for reef colonization which may increase wave attenuation by closing the void space and offsetting elevation deficits as the reef segments settle. In addition, the design includes a comparison of OysterKrete© versus standard weight concrete to test for differences in oyster colonization between different construction materials. OysterKrete© is a concrete designed by ORA Tech to attract oyster colonization and improve survival.

The State of Louisiana's Master Plan (CPRA 2012) identified Gulf Shoreline Protection (Calcasieu River to Rockefeller, 004.SP.05a) "through rock and low wave-action breakwaters … to preserve shoreline integrity and reduce wetland degradation from wave erosion" (CPRA 2012). The LA-08 demonstration project will contribute information towards determining the best type of low wave-action breakwaters. As per the LA-08 fact sheet, the goals of the LA-08 demonstration project are to test and to evaluate if the Oysterbreak™ is a cost effective technique for protecting poor load bearing reaches of Gulf of Mexico shoreline (LCWCRTF 2009).

Figure 1. The Bioengineered Oyster Reef Demonstration Project (LA-08) consists of two reef segments on the Gulf of Mexico coast of Rockefeller Wildlife Refuge. The Reef Breakwaters (Oysterbreak™ segments) are each 215 ft long; the OysterKrete segment is to the west, and the standard weight concrete segment is to the east.

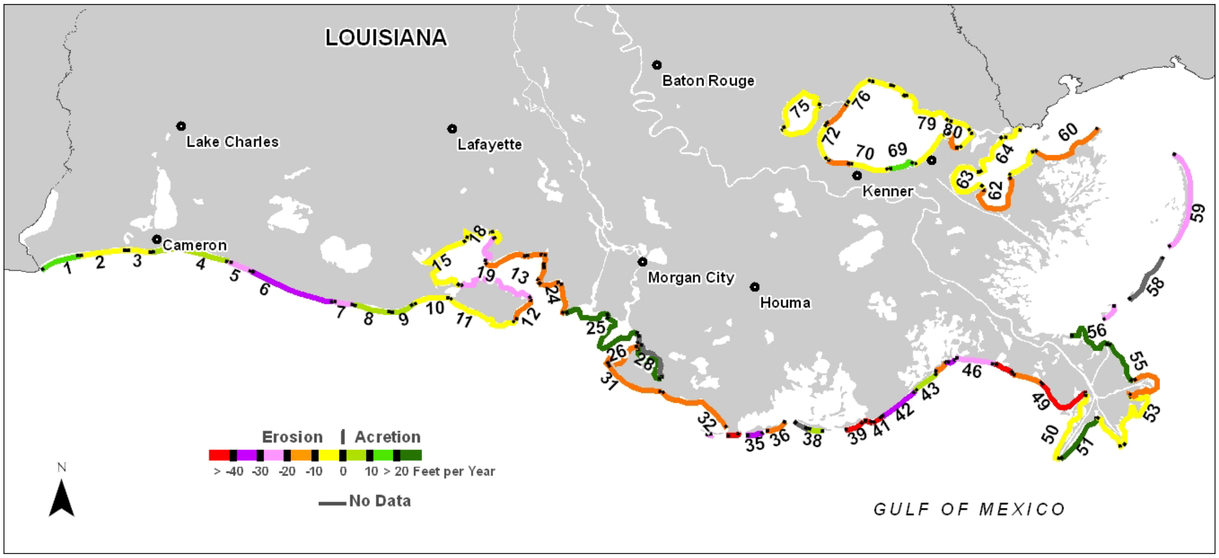

Figure 2. Shoreline movement rates across Louisiana from the mid 1880s to 2005 analyzed by BICM (from Martinez et al. 2009)**.** Reach six is the Rockefeller Refuge shoreline.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The Bioengineered Oyster Reef Demonstration Project consists of two, 215 ft segments of artificial reef separated by a 130 ft gap. No operations, maintenance, repair, and/or rehabilitation is planned for this demonstration project.

b. Inspection Results

c. Maintenance Recommendations

d. Maintenance History

<u>**General Maintenance:**</u>

III. Operation Activity

a. Operation Plan

There are no water control structures associated with this project that require manual operation; therefore, no Structural Operation Plan is required.

b. Actual Operations

There are no active operations associated with this project.

IV. Monitoring Activity

a. Monitoring Goals

The goals of LA-08 are to:

1. Reduce shoreline erosion behind the reef segments.
2. Determine which construction material (OysterKrete v Standard Weight Concrete) performs better towards reaching Goal 1.

The objectives of the Bioengineered Oyster Reef Demonstration project are:

1. Reduce wave transmission reaching the shoreline by 50%.
2. Provide habitat for oyster settlement.

b. Monitoring Elements

Topographic and Bathymetric Surveys

Shoreline erosion is being assessed by conducting a series of topographic and bathymetric elevation surveys over time in the Oysterbreak area and the control area. Elevation changes of the reef segments, marsh, and water bodies both landward and seaward of the reef positions are being tracked along survey transects perpendicular to the shoreline. Elevation data are collected at a minimum of 5 ft intervals or closer if necessary to define distinct morphologic features and changes in Oysterbreak structure profile. Transects start 100 ft landward from the averaged shoreline contour continuing into the Gulf of Mexico:

- 11 transects at the control area, 1,200 ft into the Gulf of Mexico on 200 ft spacing
- 24 transects at the breakwaters, 5 extending 2,000 ft into the Gulf of Mexico
- Perimeter and longitudinal section on the breakwaters to detect scour around and between the reef segments (Figure 3).

Elevation surveys were conducted preconstruction in October 2011, as-built in February 2012, and post construction Year 1 in July 2013 and Year 2 in July 2014 (not presented in this report). A final survey is scheduled for summer 2016, and a survey will also be conducted following a large storm if needed. Horizontal coordinate (x UTM, y UTM) and elevation (z, NAVD88 ft) data from the transects were uploaded to ArcGIS to construct elevation grids of each area. Surveys were collected in different Geoids (As built Geoid 03, post-construction Geoid 09, CRMS0600 water level Geoid 99) so elevation corrections based on survey datasheets from the secondary surveyor monument (ME18-SM-01) were applied to the datasets to convert all elevation to Geoid 09. Because of uncertainties involved with data conversions, more attention should be paid to the data trends than the specific quantities. Soil volume change over time was calculated from the differences in elevation between area grids for each time period. Changes in soil volume were then compared between areas. The Oysterbreak area was subdivided into areas that focused on the different reefs, and two equal areas were subdivided from the Control area. To assess shoreline movement, a line feature was created through the highest point along each transect to delineate the shoreline crest for each time period. Change rates for time intervals were calculated using Digital Shoreline Analysis System (DSAS) version 4.0, an ArcGIS application. Transects, spaced 5 m apart, based on the reef segments being 65 m long, were established for the shoreline reaches, and change rates (m/y) were calculated between dates of interest for each transect (Thieler et al. 2009). The transects were grouped by shoreline reaches of interest immediately behind each Oysterbreak, the gap between the breaks, and the control area (West and East). Shorelines delineated from aerial photography were not available for this report; however, they will be used for the final OM&M report. Structure settlement was calculated by subtracting the Year 1 from As-built elevations of the top row of rings on the landward and seaward edges of the reef segments.

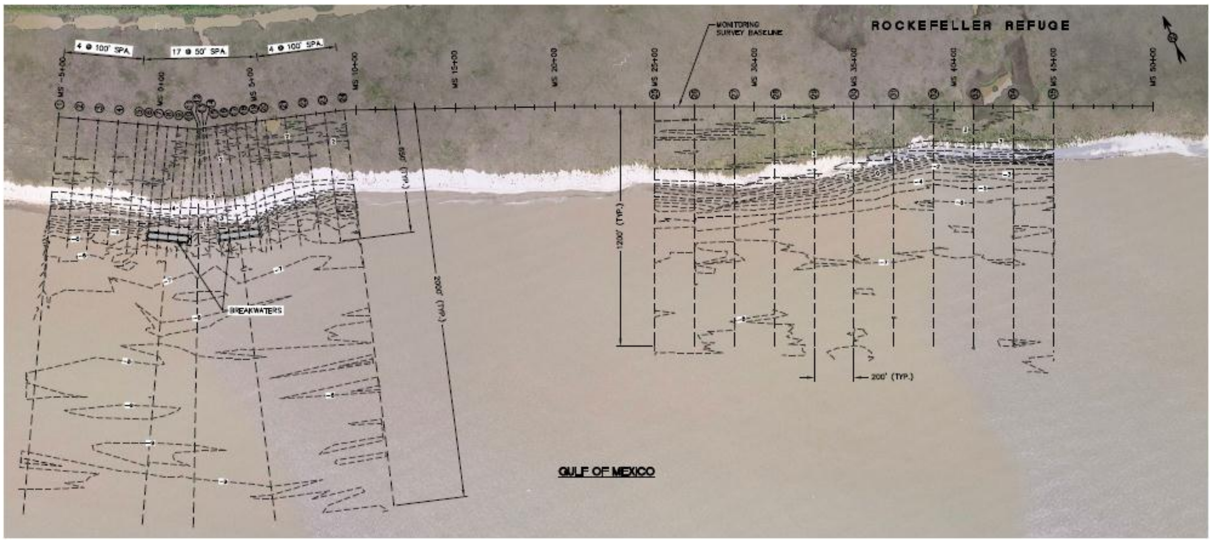

Figure 3. Approximate locations of topographic and bathymetric survey transects for the Bioengineered Oyster Reef Demonstration project (LA-08). The aerial photography was taken on March 24, 2012.

Wave Attenuation

The capacity of the Oysterbreak reef segments to dissipate waves is assessed by comparing wave transmission nearshore behind each Oysterbreak and from the control area. The erosive energy of waves on the shoreline was quantified by the transmission coefficient (Kt) which is the relationship of significant wave heights (Hs) from a point near the shoreline relative to the significant wave height from a seaward point: Kt = Hs nearshore / Hs offshore.

Four gauges were deployed for one month (07/08/2012 to 08/06/2012) to collect wave height data:

- 1 gauge seaward of the reef section at the -6 ft NAVD88 contour to measure incoming waves
- 1 gauge behind each Oysterbreak section (2 gauges) to measure broken waves
- 1 gauge in the control area to measure unbroken waves at a similar distance from the shoreline as the gauges behind the breaks.

Both Oysterbreaks were designed to have a transmission coefficient of 0.5, ie. attenuate wave energy by 50%, during average conditions of water level at 1.10 ft NAVD88 and significant wave height of 2.6 ft (CHE 2009); however, the Standard Weight Oysterbreak to the east was constructed approximately 0.5 ft higher than the OysterKrete Oysterbreak to the west and should be expected to break taller waves. The data were grouped by water elevations and significant wave heights of the incoming wave. Wave transmission coefficients are compared among the nearshore locations and to the design specifications. In addition, wave attenuation, $(1 – Kt) \times 100$, is compared between the Oysterbreak reef sections after removing attenuation attributable to the wave approaching the shoreline which was determined at the control.

Wave gauge deployment was planned for spring 2012 for a diversity of water level and wave height conditions; however, equipment issues delayed deployment until the summer which has calmer, more consistent conditions. Wave data was collected in April - May 2014 but was not included in this report; the final deployment is scheduled for spring 2016.

Wave gauge deployment/retrieval, data collection, data processing, and preliminary data interpretation was conducted by T. Baker Smith, Inc.; see Appendix A Hydrodynamic Data Collection Report for more details about the wave gauges, data collection, and data processing methodologies. Data analysis and interpretation was performed by the Lafayette Regional Office of the Coastal Protection and Restoration Authority of Louisiana.

Oyster Monitoring

Oyster and biological encrustation is monitored to (1) quantify the oyster settlement and colonization on the Oysterbreak reef segments and (2) test OysterKrete against standard weight concrete in its ability to enhance settlement and colonization of oysters on the Oysterbreak reef segments. Three elements of oyster monitoring will be conducted over the course of the project: oyster recruitment, biological accumulation, and oyster biomass productivity. Monitoring of oyster larvae (spat) recruitment to cylinders composed of the different ring materials and preliminary biological accumulation on rings are included in this report; oyster biomass production of the reefs is scheduled to be monitored in winter of 2015/2016. The current oyster monitoring was conducted by Dr. Earl Melancon of Nichols State University as a subcontractor to T. Baker Smith, Inc.; the full report is in Appendix B. Methods and results are summarized in the body of this report.

The amount of oyster larvae (spat) and other organisms that attach to spat settlement surfaces (cylinders composed of the different concrete types used to construct the reef rings) were planned to be quantified in two sets over two years. The initial set of spat cylinders were deployed on April 19, 2012 soon after the reef construction and was retrieved on March 13, 2013. Each spat cylinder composed of either OysterKrete or standard weight concrete was suspended vertically in a weighted cage with a standard spat plate attached to the underside of the top of the cage. The cages were deployed on the gulf bottom tethered to PVC poles in pairs (OysterKrete/standard weight concrete) along the landward (2 pairs) and seaward (2 pairs) sides of each reef segment and one pair between the reef segments for a total of 10 pairs. Unfortunately, the unprotected cages along the seaward edge and between the reefs were destroyed by gulf conditions prior to retrieval. Cages protected by the reef either settled into the gulf bottom or experienced varying amounts of sedimentation that affected the cylinders. The remaining cylinders were not suitable for density comparisons between the cylinder types; however, enough oysters were present for shell length frequency analysis which is used to interpret the timing of oyster recruitment by determining the modal length. The modal length is the peak size range within the size frequency histogram. The second set of oyster spat monitoring was deployed on March 13, 2013 and retrieved on October 28,

2013. Based on previous experience, the five cages were deployed only along the protected, landward side of the two reefs for a total of 10 cages. For additional weight, a pair of cylinders was placed vertically in each cage along with a pair of settlement plates attached to the underside of the top of the cage. Each cage was wedged between two bottom rings on the marine mattress and tethered to PVC pipe. Shell length frequency analyses were conducted for the spat plates and the cylinders to describe the recruitment trend. Oyster and barnacle density were compared between cylinder types.

Biological encrustation on the Oysterbreaks was sampled from the top layer of rings on March 13, 2013 and Oct 28, 2013 during low water levels. Two rows of rings, windward to leeward, were chosen to represent different elevations along each reef; five sample locations were randomly chosen on each row. Because the reefs were constructed at slightly different elevations, collecting comparable rows of rings representing tidal inundation was a challenge. Higher rows of rings were sampled on the lower, OysterKrete Oysterbreak than the higher standard weight Oysterbreak in an attempt to match water levels on each Oysterbreak; however, sampling was limited by water inundation throughout the day of sampling. Sampling consisted of scraping encrusted material within a $1/16^{th}$ m^2 quadrat off the top surface of a ring. Oysters shell lengths were measured to develop population shell length frequency for each Oysterbreak during both time periods to assess oyster growth. Overall biomass per row sampled for each Oysterbreak was determined from the March 2013 data set. Mean shell length and the shell size distribution by row for each Oysterbreak were calculated from the October 2013 data set.

b. Preliminary Monitoring Results and Discussion

Topographic and Bathymetric Elevation Dynamics

From the end of construction in February 2012 to July 2013, settlement of the Oysterbreak structures was <0.1 feet overall which is within the measurement error within and between elevation surveys. The planned crest elevation of the reefs was 1.1 ft NAVD88 matching mean sea level of the Gulf of Mexico in this area; however, Oysterbreak – East was constructed to 1.36 ft NAVD88 while the Oysterbreak – West was constructed to 0.94 ft NAVD88 because of natural water bottom variability. The difference between crest elevations (0.48 ft) causes water inundation differences between the reefs, especially when the crest elevations are close to water levels. The Oysterbreak – West was completely submerged 48% of the time while the east Oysterbreak – East was completely submerged 15% of the time during 2012-2013 based on water levels at CRMS0600 located near LA-08 (Picture 1 and Figure 4).

Picture 1. Oblique photograph taken during low water (~0 ft NAVD88) by Louisiana Department of Wildlife and Fisheries about a year after construction of the Oysterbreaks at the Bio-engineered Oyster Reef Demonstration project (LA-08). Note the elevation difference between Oysterbreak - West composed of OysterKete© (lower) and Oysterbreak - East composed of standard weight concrete (taller) based on water innundation. Also, note the tombolo behind Oysterbreak - East that formed during construction.

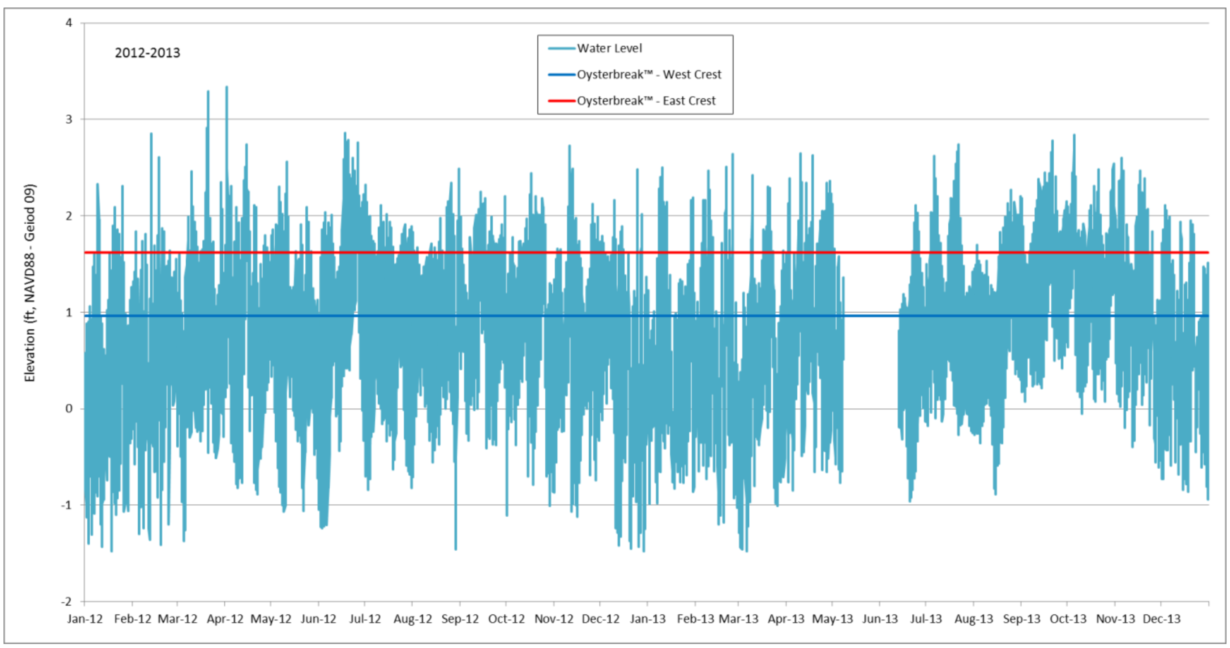

Figure 4. Water elevation collected from nearby CRMS0600 and crest elevations of the West and East Oysterbreaks™. Note the difference in crest elevations and the corresponding difference in water inundation between the Oysterbreaks™.

Surface Elevation change comparisons between the preconstruction survey conducted in October 2011 and the post construction survey conducted in July 2013 reveal differences between the Oysterbreak and Control areas and within the Oysterbreak areas; post construction was compared to preconstruction rather than as-built surveys because a tombolo formed behind the eastern Oysterbreak during the construction period. The control area experienced > 1 meter of loss along the shoreline whereas loss was reduced in the Oysterbreak area (Figure. 5). The Oysterbreak area had more elevation loss offshore from the reefs than the control area; however, we are unsure if this is a project effect. Within the Oysterbreak area, the higher Oysterbreak - East (standard weight) experienced less loss than the lower Oysterbreak West (OysterKrete) area as the tombolo added soil volume behind Oysterbreak - East. Soil loss is evident within the gap between the reefs and around the outer ends.

Shoreline loss corresponded with the soil volume change patterns (Figure 6). From preconstruction to post construction (Oct 2011 - July 2013), the shoreline erosion rate along the entire Oysterbreak area (12 ft/y; 1.6 m/y) was 69% less than the Control area (40 ft/y; 12.3 m/y). Preconstruction was included because tombolo formation behind Oysterbreak - East during construction. Within the Control area, the shoreline change map shows the variability of erosion in a given time period from as little as 1 ft/y to as much as 6# ft/yr) . Within the Oysterbreak area, reduced erosion behind the Oysterbreak - West and tombolo formation behind Oysterbreak – East are evident as erosion continues around the ends of and within the gap between the reefs (Figure 6). Relative to the Control shoreline (40 ft/y; 12.3 m/y), erosion behind the taller, Oysterbreak - East (5 ft/y; 1.6 m/y) was reduced by 86% while erosion behind the shorter, Oysterbreak – West (9 ft/y; 2.7 m/y) was reduced by 78%. Erosion along the gap between the reefs (20 ft/y; 6.2 m/y) was 50% less than the Control area (Figure 6).

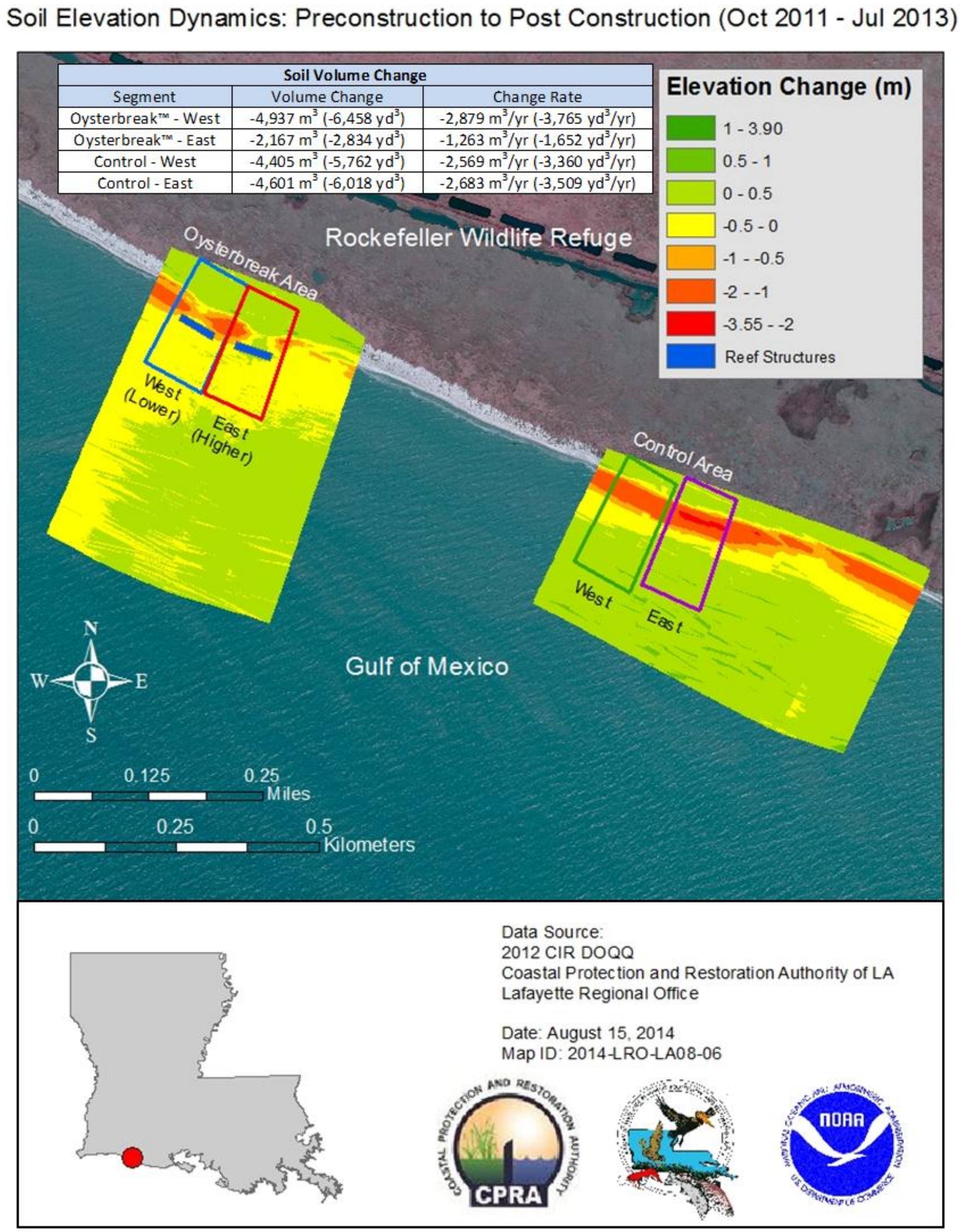

Figure 5. Soil elevation dynamics in the Oysterbreak™ and Control areas of the Bio-engineered Oyster Reef Demonstration Project (LA-08) from October 2011 to July 2013.

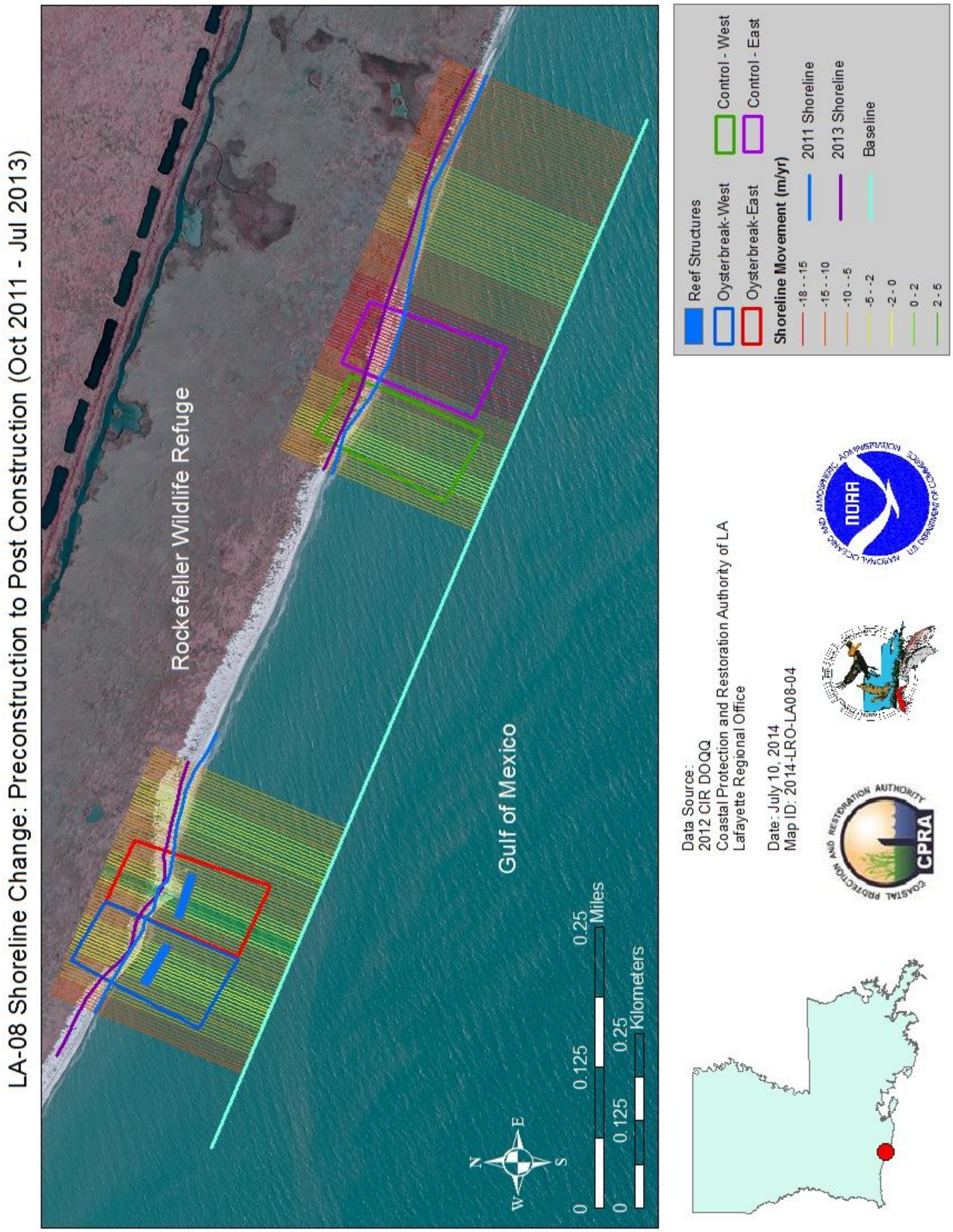

Figure 6. Shoreline change in the Oysterbreak™ and Control areas of the Bio-engineered Oyster Reef Demonstration Project (LA-08) from October 2011 to July 2013.

Wave Attenuation

The Oysterbreaks did reduce wave heights from incoming waves compared to the control. Overall, combining averages of all water levels and incoming wave heights, waves were reduced 36% as they approached the Control shore (natural slope), 66% by Oysterbreak - West, and 72% by Oysterbreak - East (Figure 7). Compared to the natural bottom slope of the Control, Oysterbreak - West improved wave reduction by 30% while Oysterbreak – East improved wave reduction by 36%. The difference in wave reduction between the Oysterbreaks is attributed to the crest height difference between the lower West and the higher East Oysterbreak (Figure 4).

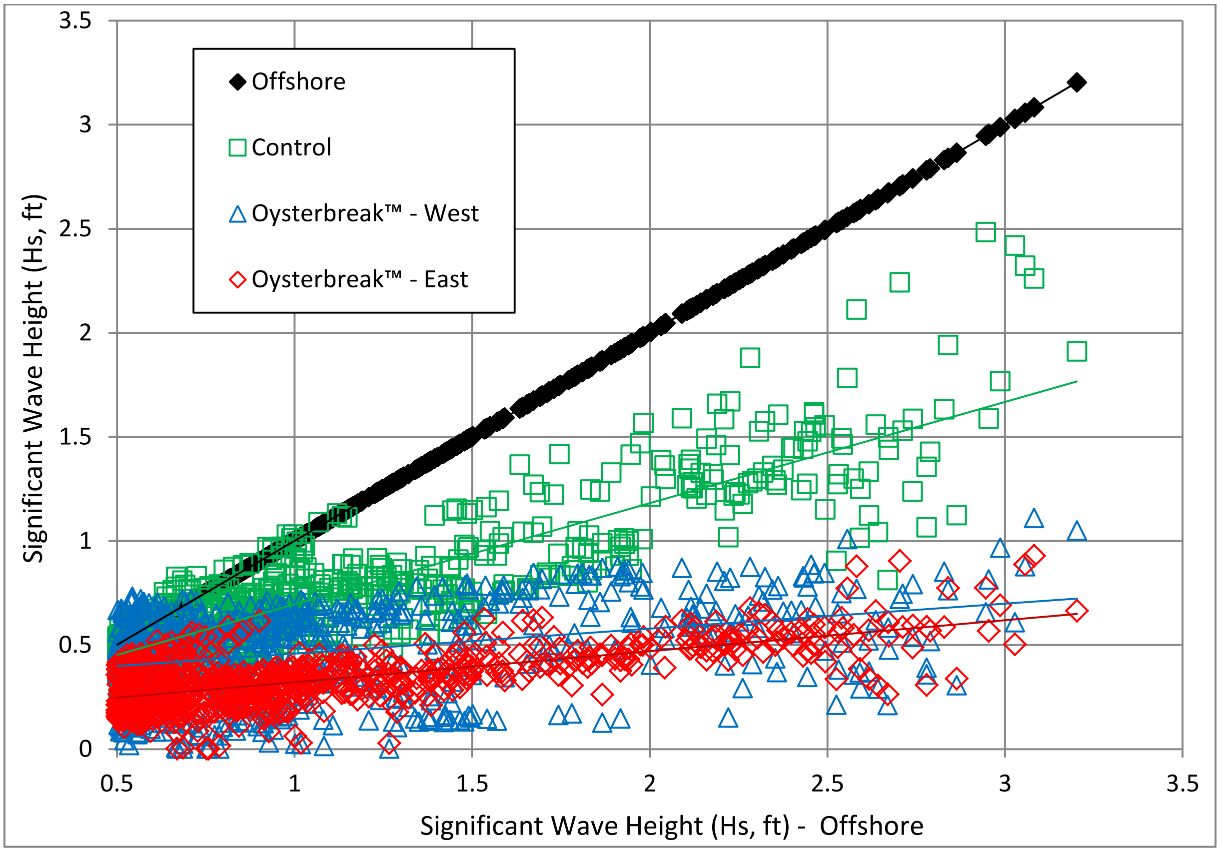

Figure 7. Significant wave heights were collected from wave gauges deployed within the LA-08 area soon after Oysterbreak™ construction (July 08, 2012 – August 06, 2012). The offshore gauge measured the incoming waves (black) while gauges behind the lower West and higher East Oysterbreaks and the Control measured waves remaining near the shoreline.

The proportion of wave height arriving to the nearshore location from an incoming wave, commonly referred to as the Wave Transmission Coefficient (Kt), is a standard metric to describe wave breaking. Wave heights that reach the shore are determined by water level, incoming wave height, and the water bottom surface dictated by the natural slope of the Control and different crest elevations of the Oysterbreaks (Figure 8 A and B). In general, less waves are transmitted through shallower water. In the shallowest water (< 0 ft NAVD88), waves are disrupted by both Oysterbreaks but are reduced less as they deflect around the taller Oysterbreak – East rather than going through as occurs over the shorter, partially submerged

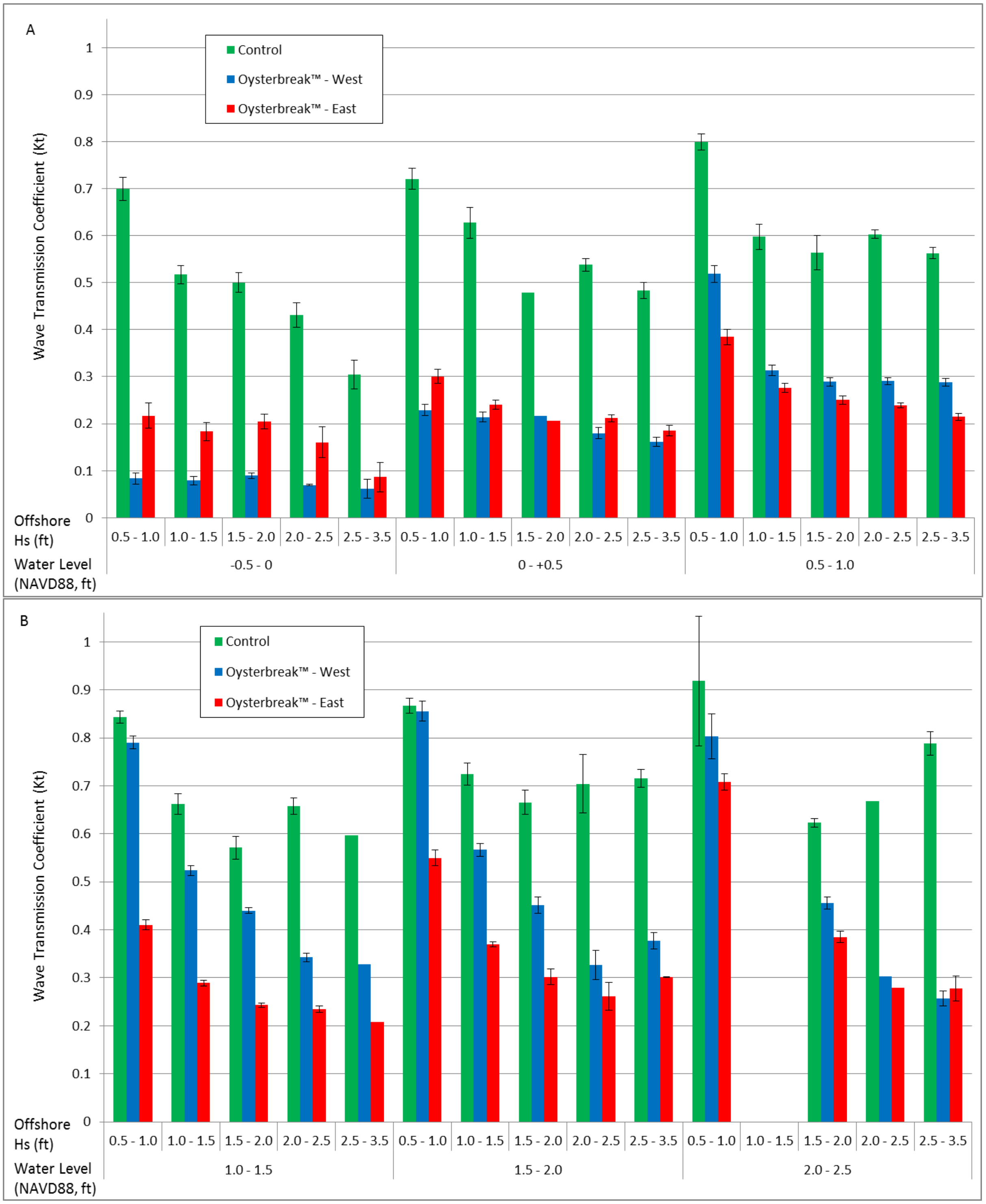

Figure 8. Wave transmission coefficients (Kt) are grouped by incoming wave heights (Hs) within 0.5 ft water level ranges (A is -0.5 – 1.0 ft, NAVD88; B is 1.0 – 2.5 ft, NAVD88). The bars represent different water bottom condition near the shoreline: the Control has a natural slope; Oysterbreak^{TM} – West is lower (crest elevation = 0.94 ft NAVD88); Oysterbreak^{TM} – East is taller (crest elevation = 1.36 ft NAVD88). The values are means and standard errors of each grouping.

Oysterbreak - West (Picture 1). When both Oysterbreaks are partially submerged (0 – 1 ft NAVD88), Kt is reduced relative to the Control and similar to each other (Figure 8A). During more typical water levels (1.0-2.0 ft NAVD88), Kt is reduced more by the taller Oysterbreak - East; the difference between reefs lessens as the wave heights increase. When both Oysterbreaks are substantially overtopped by water level (+2 ft NAVD88), Kt is more comparable (Figure 8B).

As per the modeling conducted for planning of LA-08, the success criteria for the 40 ft wide Oysterbreak with a crest elevation of 1.1 ft NAVD88 (average water elevation) was a Kt of 0.5, or 50% wave attenuation, at the modeled conditions of water level at 1.10 ft NAVD88 and significant wave height of 2.6 ft (CHE 2009). Similar conditions were determined for the constructed crest elevation of the West and East Oysterbreaks. Water level ranges ± 0.5 ft of the crest elevation and a minimum significant height of the incoming wave were set to find enough waves for comparisons of the Oysterbreaks under different conditions (Table 1A). Both Oysterbreaks exceeded the success criteria of Kt < 0.5, or wave attenuation > 50%, for model conditions and adaptions for the constructed conditions (Table 2B). Based on Modeled conditions, the higher, Oysterbreak – East reduce wave heights 10% more than Oysterbreak – West. Based on crest elevation conditions of each Oysterbreak, the eastern is 5% more effective than the western Oysterbreak. The higher Oysterbreak - East had 52% more wave reduction than the Control based on conditions representing Oysterbreak – East's constructed elevation; however, the lower Oysterbreak – West did not improve wave attenuation over the Control > 40% for any of the three conditions (Table 1B)

Table 1A. Water level and incoming wave heights were used to determine wave transmission performance criteria as conducted during LA-08 Planning. Adjustments were made based on constructed differences of the West and East Oysterbreaks™ from the model and to find waves to match the conditions.

Oysterbreak	Number of Waves	Elevation (ft NAVD88): Oysterbreak Crest	Elevation (ft NAVD88): Water Level Range	Incoming Significant Wave Height (Hs, ft)
Model	10	1.10	1.05 – 1.15	> 2.00
West	8	0.94	0.89 – 0.99	> 1.84
East	3	1.36	1.31 – 1.41	> 2.00

Table 1B. Wave transmission and attenuation at Control (Con), Oysterbreak™ - West (West), and Oysterbreak™ - East (East) locations are used to evaluate the performance based on model and constructed conditions. The success criterion is < 0.5 for Kt or > 50% for attenuation. Difference from Control provides an adjustment for wave reduction that occurs naturally. The highlighted values are used to compare West and East Oysterbreaks™ in their respective "Ideal" conditions.

Oysterbreak	Wave Transmission (Kt)			Wave Attenuation (%)			Difference from Control Kt, Wave Attenuation (%)	
	Con	West	East	Con	West	East	West	East
Model	0.62	0.33	0.23	38	67	77	0.71, 29	0.61, 39
West	0.60	0.31	0.24	40	69	76	0.71, 29	0.64, 36
East	0.78	0.38	0.26	22	62	74	0.60, 40	0.48, 52

Oyster Monitoring

Twenty months after construction, both Oysterbreaks are providing habitat for oyster settlement with no significant difference between construction materials; Oysterbreak – West is composed of OysterKrete, and Oysterbreak – East is composed of standard weight concrete. The final phase of oyster monitoring, oyster biomass production at the end of the demonstration project life, will determine project and construction material effectiveness. See the report provided by Dr. Earl Melancon and T. Baker Smith, LLC (Appendix B) for a complete presentation of results. The following is a summary therein pertinent to the performance of each ring material type.

Oyster settlement was assessed by collecting oyster spat from cylinders positioned along the shore side of the Oysterbreaks; the cylinders were made of the different construction materials and placed behind in pairs behind each Oysterbreak. Oysters did not preferentially settle on the OysterKrete cylinders as oyster spat settled on both construction materials. Interpretation of the Oysterbreak comparisons is confounded by the depth and resultant tidal inundation behind the structures. Oyster spat were more abundant on standard weight cylinders than on OysterKrete cylinders behind the deeper Oysterbreak – West composed of OysterKrete, but there was no apparent difference between concrete types behind the shallower Oysterbreak – East composed of standard weight concrete (Figure 9). From the cylinders recovered for the initial set of spat monitoring, spat from the Standard Weight cylinders had only a single nodal length peak at 5 – 9.9 mm whereas the OysterKrete spat had a primary nodal length peak at 10 – 14.9 mm and a smaller, secondary peak at 35 – 39.9 mm. The larger spat sizes on the OysterKrete cylinders indicate greater growth, and the bimodal distribution indicates survival from an earlier recruitment event (Figure 10A). Based on the second set of oyster spat cylinders, oysters on both cylinder types had a nodal length of 5.9 – 9.9; neither cylinder type had bimodal size distribution which indicates one recruitment event (Figure 10B).

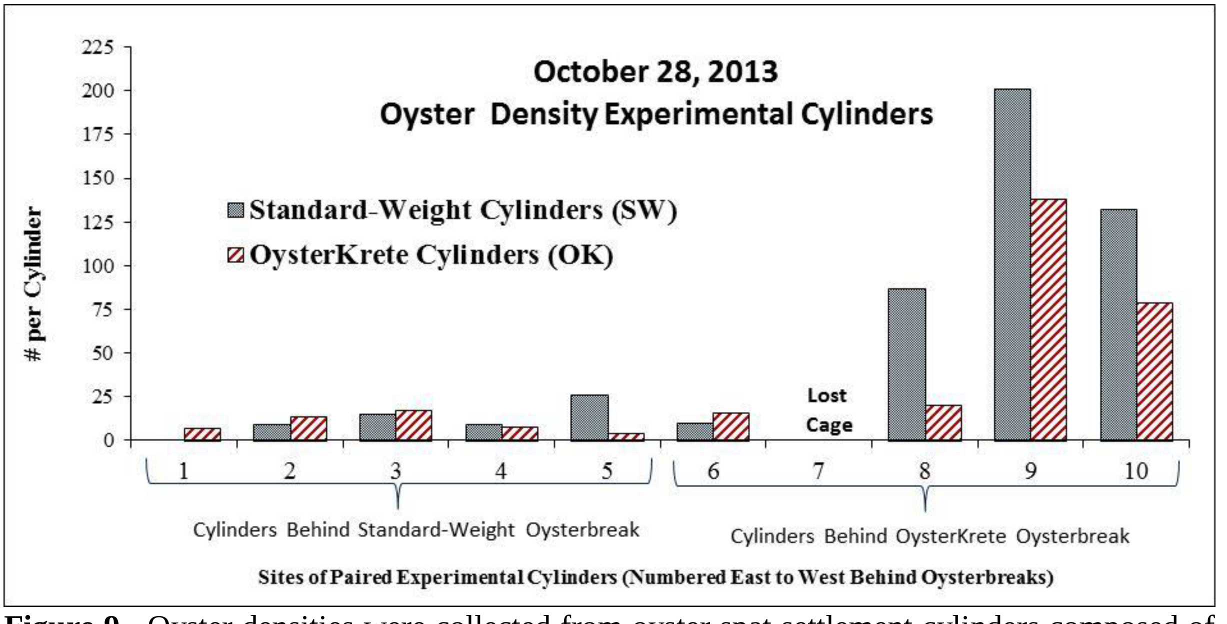

Figure 9. Oyster densities were collected from oyster spat settlement cylinders composed of the different construction cements on October 28, 2013 (graph copied from Appendix B – Figure 8).

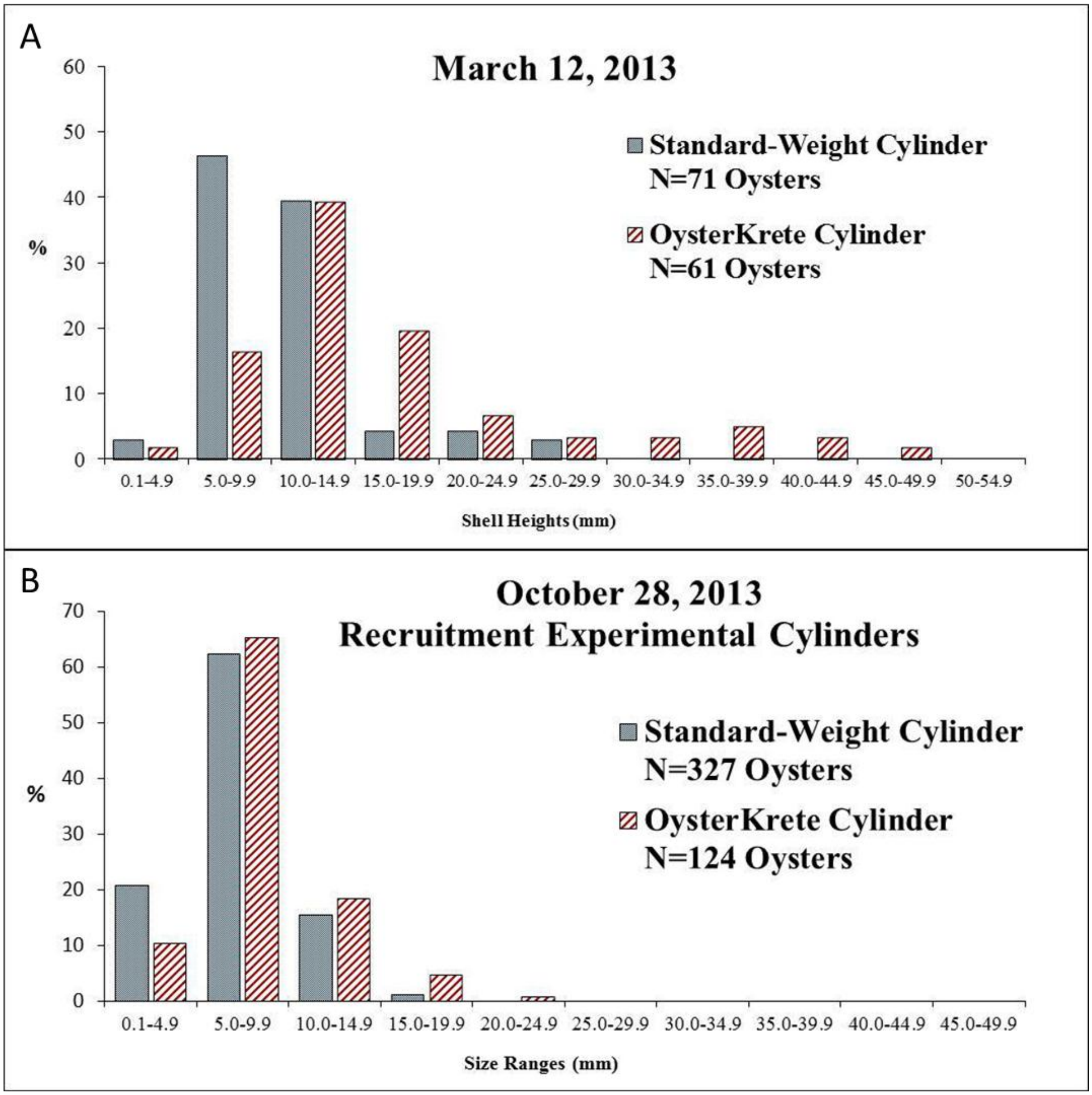

Figure 10. Oyster shell height frequency histogram were collected from oyster spat settlement cylinders composed of the different construction cements on (A) March 12, 2013 and (B) October 28, 2013 (graphs copied from Appendix B – Figures 5 and 7).

Oysters have established and grown on the Oysterbreaks 20 months after construction. Oysters grew at a healthy rate from March to October 2013 on the intertidal portion of both Oysterbeak – East (standard weight, 0.17 mm/y; Figure 11A) and West (OysterKrete, 0.13 mm/y; Figure 11B). The longer shell length on the standard weight rings may be a morphological adaptation of the oyster for clinging to a smoother surface. The oyster biomass did not statistically differ between the between the Oysterbreaks by October 2013.

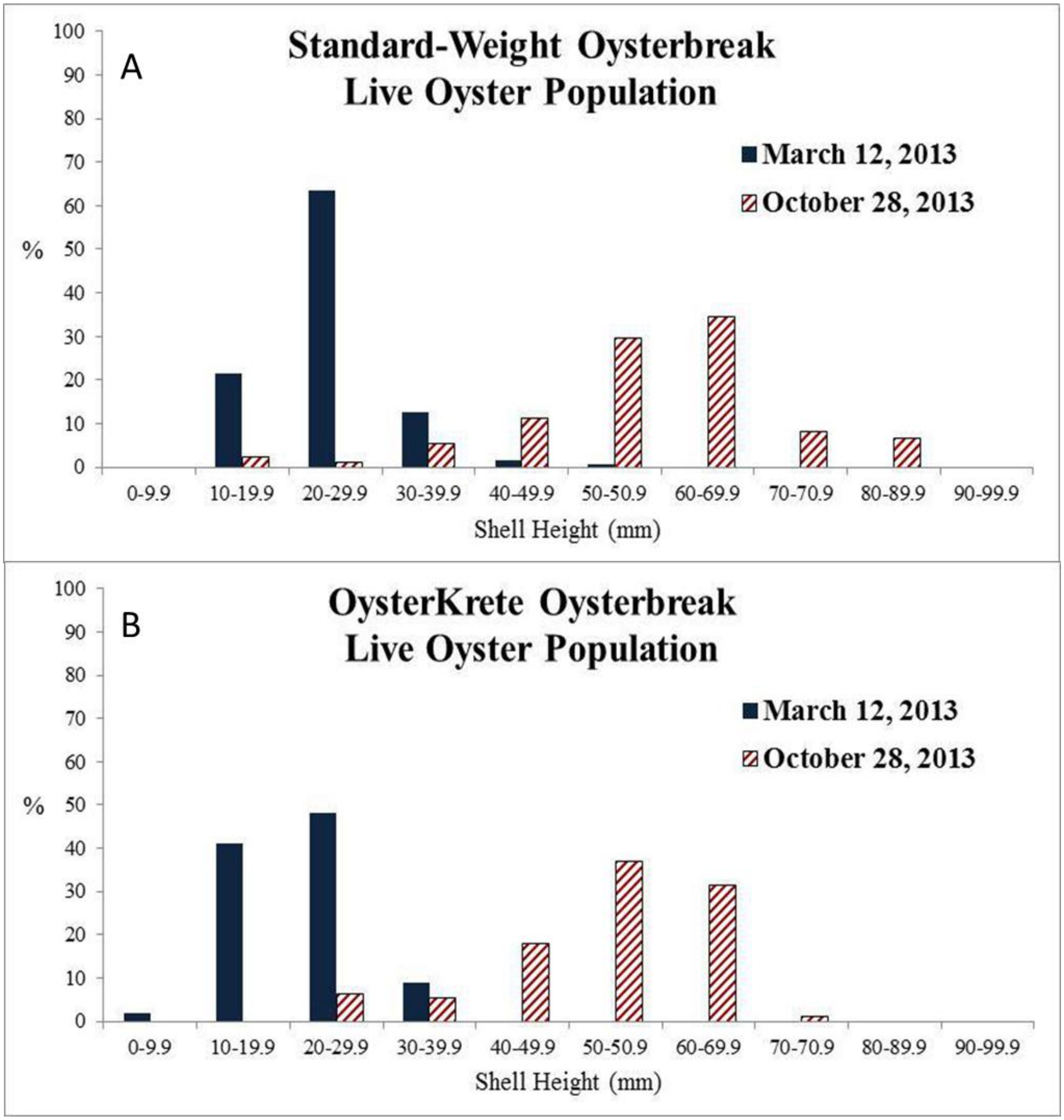

Figure 11. Oyster height frequency distributions collected from (A) Oysterbreak – East composed of standard weight concrete and (B) Oysterbreak – West composed of OysterKrete are compared between two time periods within 20 months of construction.

A limiting factor to the success and productivity of oyster colonies will be oyster drills, predatory snails, which feed on oysters. The oyster drills are common predators in brackish and salt waters that do not receive long durations of low salinity pulses such as the Gulf coast of Rockefeller Refuge. The oyster drills are limited to subtidal waters; consequently, oysters in the intertidal zones of the Oysterbreaks can avoid predation. The top layer of rings should be the most likely area to support viable oyster colonies; the higher, Oysterbreak – East composed of standard weight concrete should have a greater vertical distribution of oysters than the lower Oysterbreak – West composed of OysterKrete.

V. Conclusions

a. Project Effectiveness

Twenty months into the project, LA-08 has been effective at reaching its goal to reduce shoreline erosion behind the Oysterbreaks. The higher, Oysterbreak – East composed of standard weight concrete has reduced shoreline erosion more than the lower, Oysterbreak – West composed of OysterKrete; this is attributed to differences in constructed elevations and water bottom conditions rather than construction materials.

The objective of reducing wave transmission reaching the shoreline by 50% was met by both Oysterbreaks. The higher, Oysterbreak – East composed of standard weight concrete reduced wave transmission more than the lower, Oysterbreak – West composed of OysterKrete; however, this is attributed to differences in constructed elevations rather than construction materials.

Both Oysterbreaks are providing habitat for oyster settlement with no significant difference between construction materials; the OysterKrete material has not provided better habitat for oyster settlement than the Standard Weight concrete at this time. The final phase of oyster monitoring, oyster biomass production, will determine project and construction material effectiveness. Oyster colonization is predicted to be limited to upper tidal areas on the Oysterbreaks because of predation by oyster drills. The top layer of rings should be the most likely to support viable oyster colonies; the higher, Oysterbreak – East composed of standard weight concrete should have a greater vertical distribution of oysters than the lower, Oysterbreak – West composed of OysterKrete.

b. Recommended Improvements

Cement type comparisons for oyster monitoring would not have been confounded with structure elevation if the rings composed of different cement were mixed within the structures rather than having entire structures composed of separate materials.

c. Lessons Learned

Although the shoreline erosion was reduced, and even gained shoreline, immediately behind the Oysterbreaks, the gap between the Oysterbreaks continues to erode at a similar rate as the unprotected areas. Lessening the length of the gap relative to the length of the Oysterbreaks should be considered in future planning.

The difference in crest elevation between the Oysterbreaks resulted in better performance in terms of wave attenuation and shoreline erosion for the higher, Oysterbreak – East composed of standard weight concrete than the lower, Oysterbreak – West composed of OysterKrete.

Settlement of the Oysterbreaks was negligible. If used again for this area, consideration should be given to increase the height of the structure to improve wave breaking potential.

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APPENDIX A

Bioengineered Oyster Reef Demonstration Project
Project No. LA-08
Hydrodynamic Data Collection Report

July – August 2012

T. Baker Smith, LLC

BIOENGINEERED OYSTER REEF DEMONSTRATION PROJECT
PROJECT NO. LA-08
HYDRODYNAMIC DATA COLLECTION REPORT

PREPARED FOR:

COASTAL PROTECTION AND RESTORATION AUTHORITY OF LOUISIANA

DECEMBER 12, 2012

SUBMITTED BY:

TBS T. BAKER SMITH
PROFESSIONAL CONSULTANTS SINCE 1913

BIOENGINEERED OYSTER REEF DEMONSTRATION PROJECT
PROJECT NO. LA-08
HYDRODYNAMIC DATA COLLECTION REPORT

Prepared for: C.P.R.A.
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Lafayette Field Office
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Lafayette, LA 70596-2027

Submitted By: T. Baker Smith, Inc
412 S. Van Ave.
Houma, LA 70363

BIOENGINEERED OYSTER REEF DEMONSTRATION PROJECT
PROJECT NO. LA-08
HYDRODYNAMIC DATA COLLECTION REPORT

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Digital Appendix

- Data Collection Report File (DOC & PDF Format)
- Project Processed Data (.CSV)

HYDRODYNAMIC DATA COLLECTION REPORT
BIOENGINEERED OYSTER REEF DEMONSTRATION PROJECT
PROJECT NO. LA-08

1.0 INTRODUCTION

This report details the first year of the post-construction wave monitoring work, conducted by T. Baker Smith, LLC (TBS), which was performed on the Bioengineered Oyster Reef Demonstration Project (LA-08). A series of gages were deployed in the summer of 2012, by TBS, for a period of one month to monitor the amount of wave attenuation due to the oyster reefs. The data was compiled, analyzed, and will be presented in this report. The data shows that the Bioengineered Oyster Reef Demonstration Project does reduce significant wave heights during high energy wave events.

2.0 PROJECT OVERVIEW

Two engineered oyster reef breakwaters were installed along the coastline of Rockefeller Wildlife Management Area and Game Preserve in Cameroon Parish, LA along the Gulf of Mexico. This is a demonstration project on the 17th Project Priority List of the Coastal Wetland Planning Protection and Restoration Act (CWPPRA). The breakwaters are being monitored to quantify the environmental effects on the surrounding coastline and wetlands. The monitoring will be conducted for a period of four years after installation and will include topographic surveys, bathymetric surveys, oyster monitoring, aerial photography, and spatial analysis. This portion of project monitoring consists of collecting wave data to observe the effects of wave attenuation due to the installed Oysterbreak reefs. A series of staff and pressure gages were installed in the vicinity of the breakwater collecting water levels over time. The water levels were analyzed and water surface elevation, significant wave height, and peak wave period were calculated as a function of time.

3.0 DATA COLLECTION SUMMARY

Wave Staff gages were placed on the landward side of each breakwater structure. Wave Staff gages were selected for the two breakwater sites because water depths between the structure and shoreline are very shallow due to tombolo formation. Installation of a pressure gage at these two locations may have caused complications if the gage became un-submerged during low tide events.

In order to provide comparison of wave heights between the protected (Oysterbreak structures) and unprotected shorelines, a "control" gage was placed on an unaltered section of shoreline approximately 2700' east of the breakwater gages. At the control gage location, both a wave staff gage and a submerged pressure gage were placed at approximately the same distance from the natural shoreline as the two breakwater gages. The water depth at the control gage location was slightly deeper than the breakwater gage locations because of the relatively steep nearshore slope at this site. Because this site was located along an unprotected segment of shoreline, it was decided that the wave staff gage may become damaged during high energy wave events, especially considering that this location was in the nearshore surf zone subject to large breaking waves. It was therefore decided that a redundant pressure gage would also be installed to ensure continuous data was collected at this site. Upon retrieval of the gages, it was found that the wave staff gage at the control site was damaged by high surf. More specifically the gage was leaning and the grounding lug had become disconnected. However the pressure gage was found to be in an unaltered state and collected valid, continuous data throughout the deployment. The pressure gage data for the control location was used for further presentation and analysis in this report.

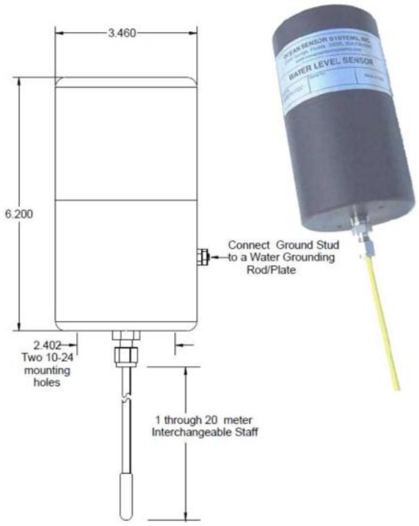
In order to obtain a record of untransformed, incident waves approaching each of the nearshore gages, an offshore (pressure) gage was placed at the -6 ft. contour. More specifically, the gage was placed 1730 ft. eastward of east breakwater gage, between the breakwater gages and the control gage, with the sensor reading at an elevation of -5.9498 ft. (NAVD88).

Each gage used in this deployment was configured to record water levels at a frequency of 10 Hz. for a period of 20 minutes starting every half hour, which provided 288,000 samples per day (48 bursts). The staff gages began collecting data, simultaneously, on July 3, 2012. Due to a period of rough weather, the pressure gages were deployed the following week and deployed during the morning of July 8, 2012. The gages were retrieved on August 6, 2012.

3.1 STAFF GAGES

The wave staff gages consisted of a 1 meter sensor rod attached to the bottom of a data recording and power unit. The recording and power unit was contained within a lockable box with a hole drilled in the bottom to accommodate the sensor rod. The lock box was then u-bolted to a galvanized pipe which was water-jetted securely into the mud. The sensor rod was reinforced with a small bracket connecting the lower portion of the rod to the galvanized pipe to prevent swaying of the sensor rod. Each galvanized pipe was placed shoreward and in roughly the center of each breakwater. The field crew was able to adjust and set the control boxes to approximately the same elevation. When the water elevation fell below -0.5 ft. NAVD88, the sensor did not record any data. However, because of the Oysterbreak structure and the shallow water depths, the incident wave heights approaching the shore during these periods of low water were negligible.

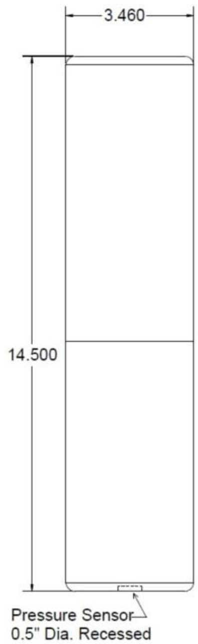
Gage	Northing (ft., NAD83)	Easting (ft., NAD83)	Top of Lock Box (ft., NAVD88)	Bottom of Rod (ft., NAVD88)	Mudline (ft., NAVD88)
East: 679412	420768.486	2813312.116	3.658	-0.538	-1.152
West: 679410	420929.002	2813027.895	3.586	-0.561	-1.374



3.2 PRESSURE GAGES

The pressure gages were deployed by attaching them to a large, metal sled which was anchored into the mud. The pressure gages are tubular shaped with the sensor placed in the center of the circular cap of one side of the gage. The tubular gage was then secured inside a box-shaped housing with the ends and gage caps exposed to the water. The box-shaped housing rested on top of a metal plate which rested on the bottom.

Gage	Northing (ft., NAD83)	Easting (ft., NAD83)	Sensor Elevation (ft., NAVD88)	Mudline (ft., NAVD88)
P01: Control	419696.862	2815845.470	-1.6102	-2.674
P05: Offshore	419969.840	2814849.528	-5.9498	N/A



4.0 DATA PROCESSING METHODOLOGY

The staff gages were deployed on July 2, 2012 at approximately 12:00 PM and 1:00 PM for gages 679412 and 679410, respectively. The Offshore (P05) Gage was deployed on July 8, 2012 at approximately 9:30 AM while the Control (P01) Gage was deployed at 10:00 AM. However, there was a difference between the “gage time” and “real time” on the control pressure gage. The control gage began taking readings in “real time” upon deployment, but the “gage time” indicated readings being taken 5:30 hours after actual deployment. This discrepancy should be noted if the raw data is subsequently processed.

The data was processed using MatLab, a numerical coding and programming environment was used to process the raw data into the requested formats of water surface elevation, significant wave height, and peak wave period. For the two Pressure gages, raw pressure observations were transformed into water heights (above the sensor) using atmospheric pressure readings at the time of deployment. Water densities were obtained from salinity values on a nearby gage in the Calcasieu Ship Channel. To obtain statistical wave heights and periods, a Spectral Density Analysis was performed on the time series data for each burst. A FFT (Fast Fourier Transform) analysis was performed to determine the frequency components of the pressure signal. A Hann window function was also used to smooth the spectral density curves. The pressure response coefficient (Kp) was also applied to the data to correct for depth attenuation of pressure. Once the wave energy spectrum was developed for each burst, the zero moment wave height was computed as

$$H_s = H_{m0} = 4\sqrt{m_0}$$

Where m_0 is the zeroeth moment of a half amplitude squared spectrum and Hs is the average height of the upper 1/3 of all wave heights

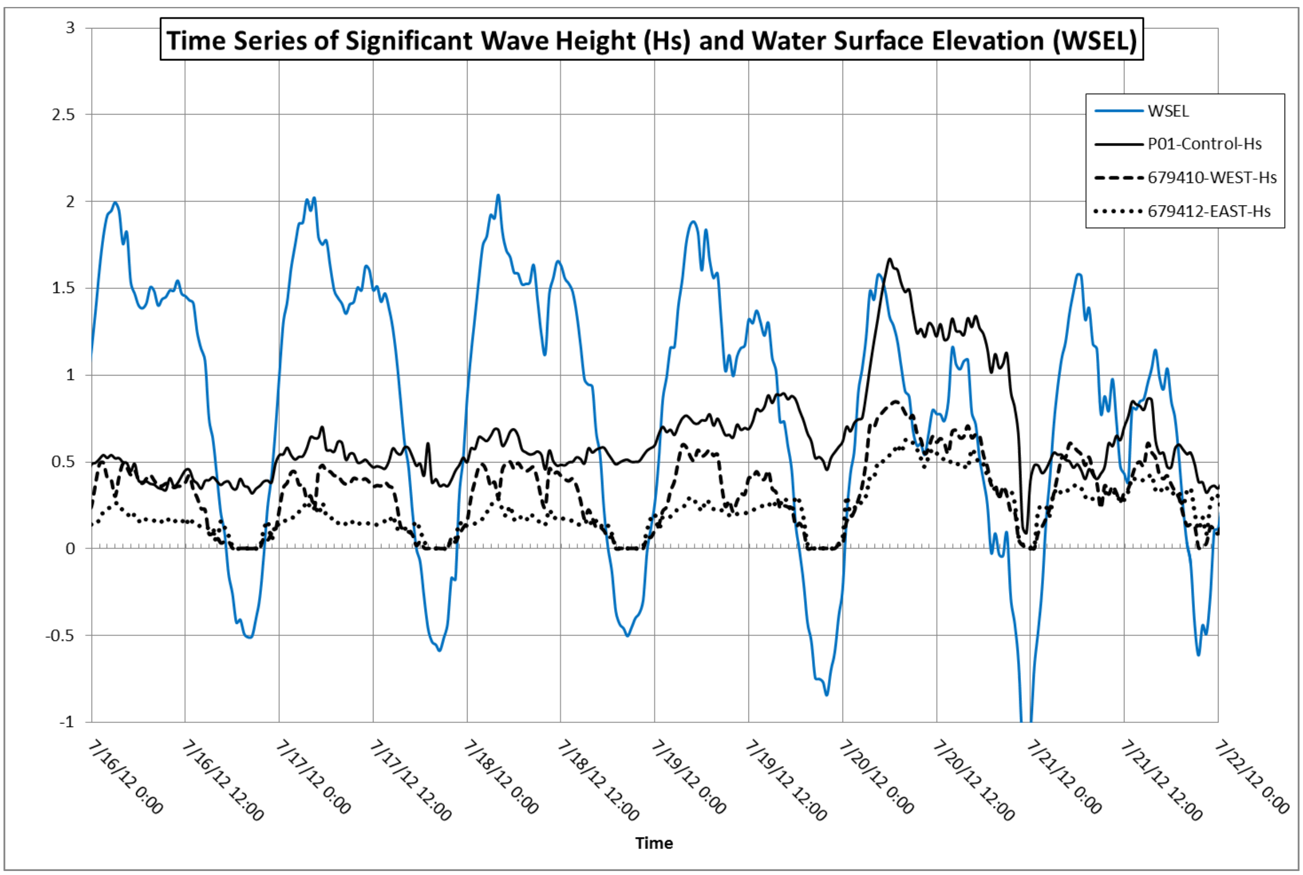
The peak wave period, Tp, was calculated as the inverse frequency of the maximum spectral energy. The peak wave period was limited to 10 seconds to eliminate overestimation during calm, low energy days.

For the wave staff gages, waves were directly recorded on each staff as changes in water surface elevation. In order to obtain wave statistics for each burst, a zero crossing analysis was performed on the data in MatLab. This analysis defines each wave as the portion of the time series record between two successive zero downcrossings. Each wave is ranked and the Significant Wave Height was computed as the average height of the upper 1/3 of all wave heights in the record.

5.0 DISCUSSION

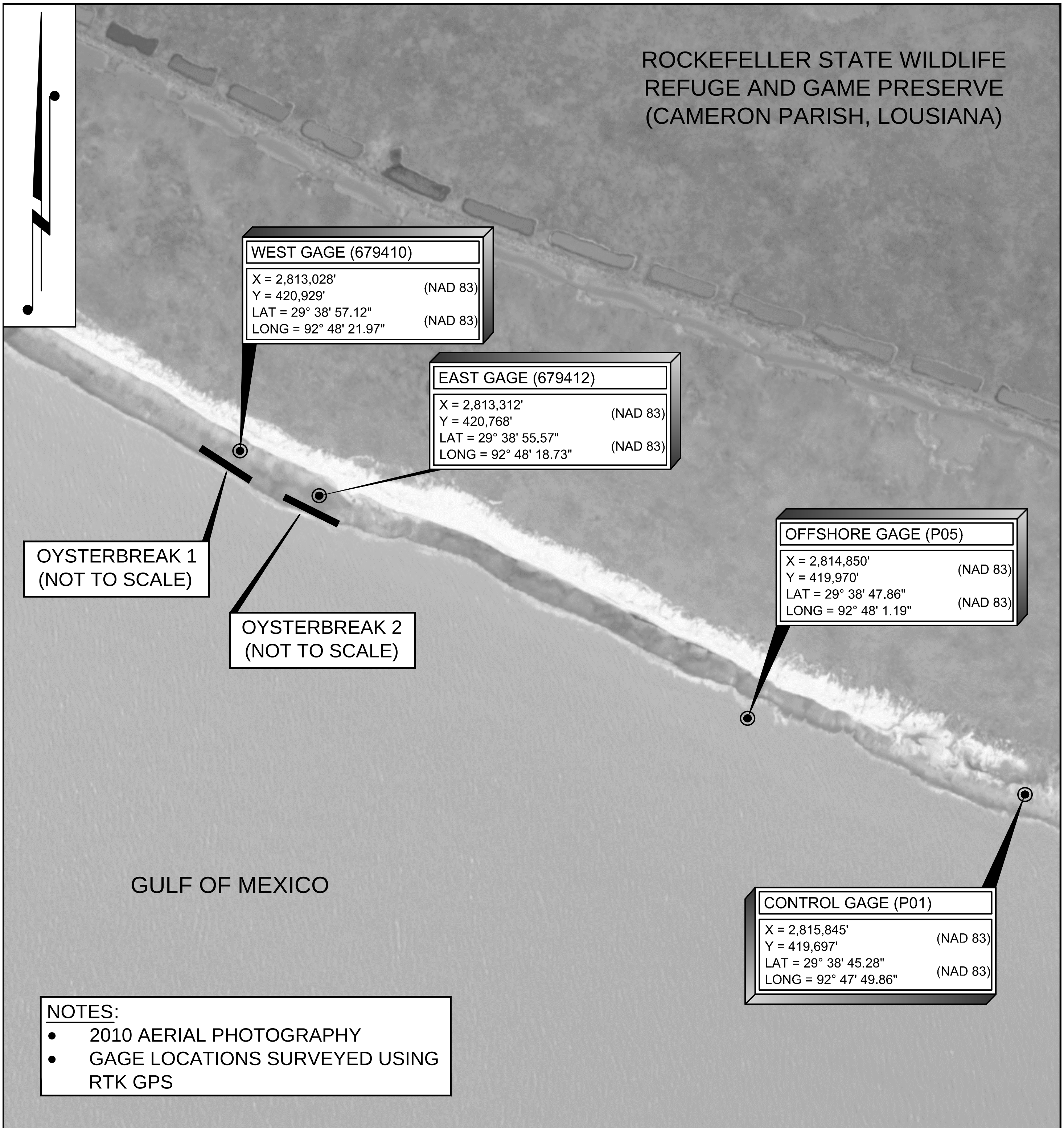
This particular gage deployment occurred during a period of relatively calm wave conditions in the northern Gulf of Mexico. The gages collected continuous, clean data during the period of deployment. Only three (3) high wave energy events occurred during the deployment. The initial analysis conducted by TBS reveals that during high wave energy events, the Bioengineered Oyster Reefs do decrease significant wave heights. It should be noted that wave height reduction between the control gage and the breakwater gages is significantly more pronounced during low-tide conditions. It was also observed that the West Oysterbreak Gage encountered higher significant wave heights compared to the East Oysterbreak Gage during high water levels. This may be attributed to the reef crest elevation of the West Oysterbreak being lower than East Oysterbreak, exposing higher waves heights to the West Oysterbreak compared to the East Oysterbreak. This may be confirmed by conducting field surveys during future monitoring. Another observation of the data is that during lower water levels the Oysterbreak structures are more exposed to the waves, which provides more wave reflection and thereby reduces wave energy propagating across the structure.

For the high wave event on July 20, 2012, the reefs decreased the significant wave heights by approximately 60%. During the event on July 26, 2012, the reefs decreased the significant wave height by 41%, from an average wave height of 0.84 ft. to an average height of 0.50 ft. During the same event, the peak wave periods were decreased from a 5.28 sec. wave to a 4.12 sec. wave, a reduction of 22%. For the July 20, 2012 event, the peak wave periods decreased from a 4.57 sec. average wave to a 3.21 sec. average wave, a reduction of 30%.



APPENDIX 1

Project Map



DRAWN BY: WAC | APPROVED BY: BJK

DATE: 12/10/12 | JOB NO: 2012.0127

DRAWING NAME: GAGE LOCATIONS.DWG

SHEET NO: 1 OF 1

PROJECTION: PROJECTION
GEO. DATUM: NAD83 | VERT. DATUM: NAVD88
US SURVEY FEET

SCALE IN FEET

500' 250' 0' 500'

GAGE LOCATIONS

COASTAL PROTECTION AND RESTORATION AUTHORITY OF LOUISIANA

BIOENGINEERED OYSTER REEF
DEMONSTRATION PROJECT
(LA-08)

TBS T. BAKER SMITH 1913 2013
A CENTURY OF SOLUTIONS
412 South Van Ave, Houma, LA 70363
(985)868-1050 - tbsmith.com

REV. NO: 00 | REV. DATE: --/--/-- | REV. BY: ---

REVISION DESCRIPTION:
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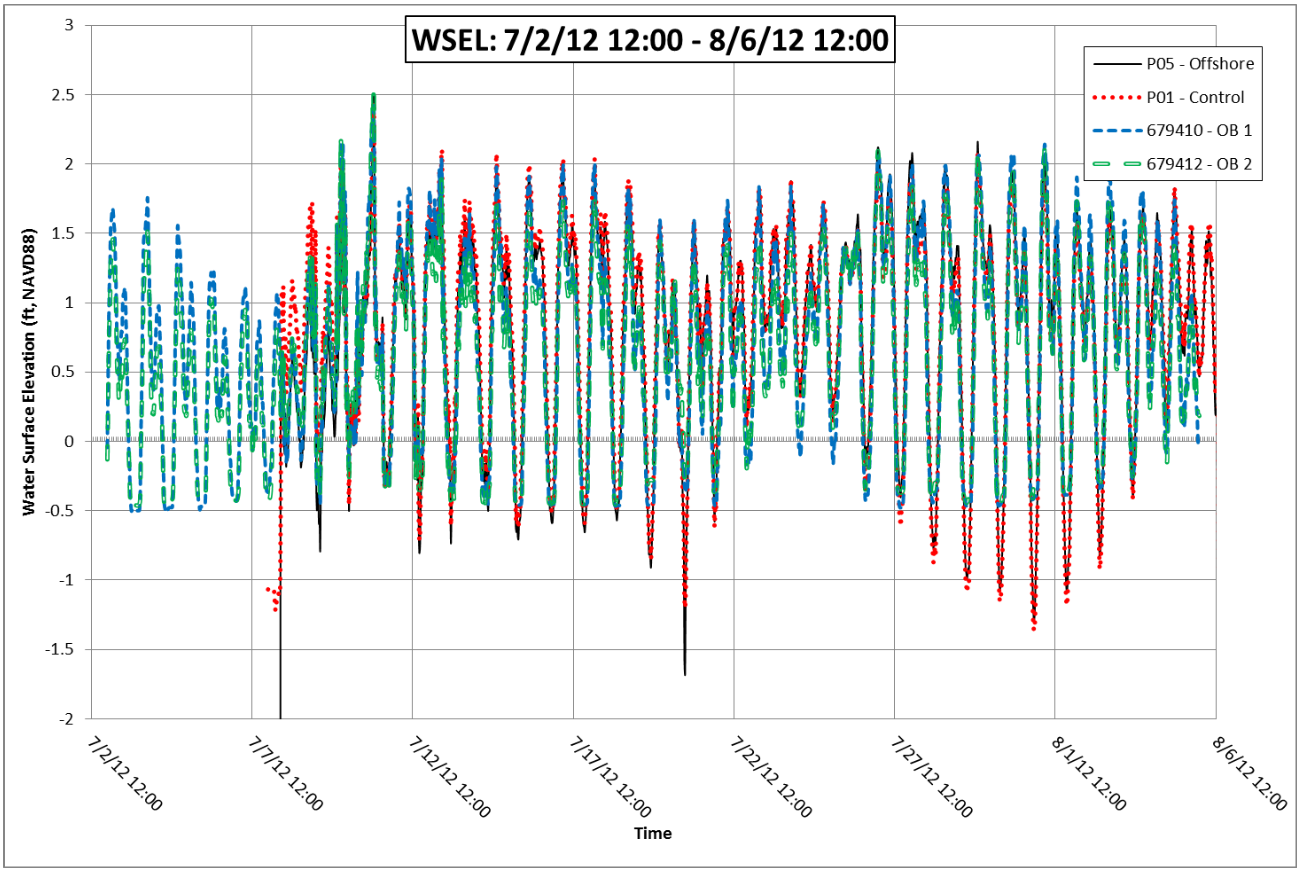
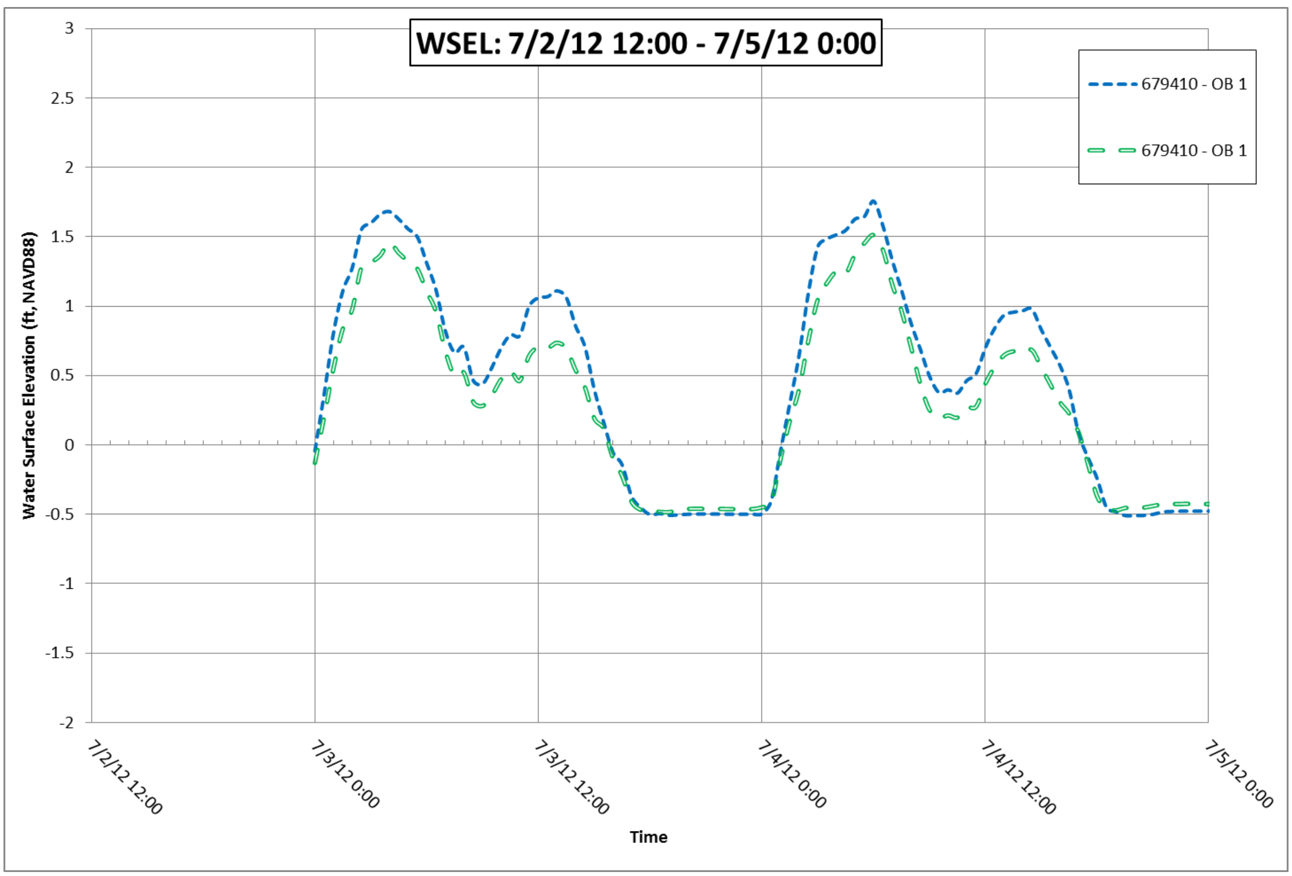
APPENDIX 2

Water Surface Elevation Plots


WSEL: 7/2/12 12:00 - 8/6/12 12:00
P05 - Offshore
P01 - Control
679410 - OB 1
679412 - OB 2
Water Surface Elevation (ft, NAVD88)
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
7/2/12 12:00
7/7/12 12:00
7/12/12 12:00
7/17/12 12:00
7/22/12 12:00
7/27/12 12:00
8/1/12 12:00
8/6/12 12:00
Time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679410 - OB 1
679410 - OB 1
Water Surface Elevation (ft, NAVD88)
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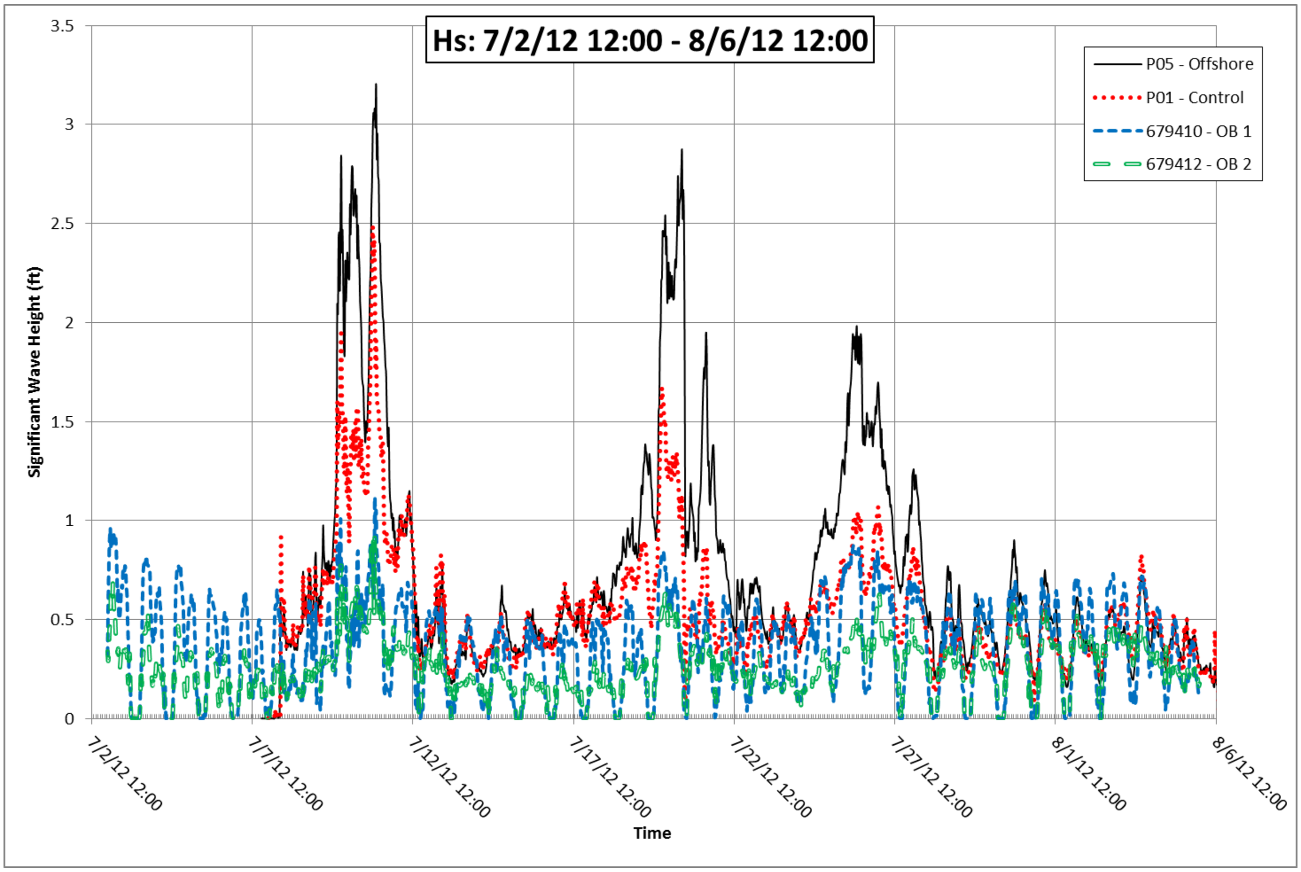
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
7/2/12 12:00
7/3/12 0:00
7/3/12 12:00
7/4/12 0:00
7/4/12 12:00
7/5/12 0:00
Time

APPENDIX 3

Significant Wave Height Plots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Significant Wave Height (ft)
3.5
3
2.5
2
1.5
1
0.5
0
7/2/12 12:00
7/7/12 12:00
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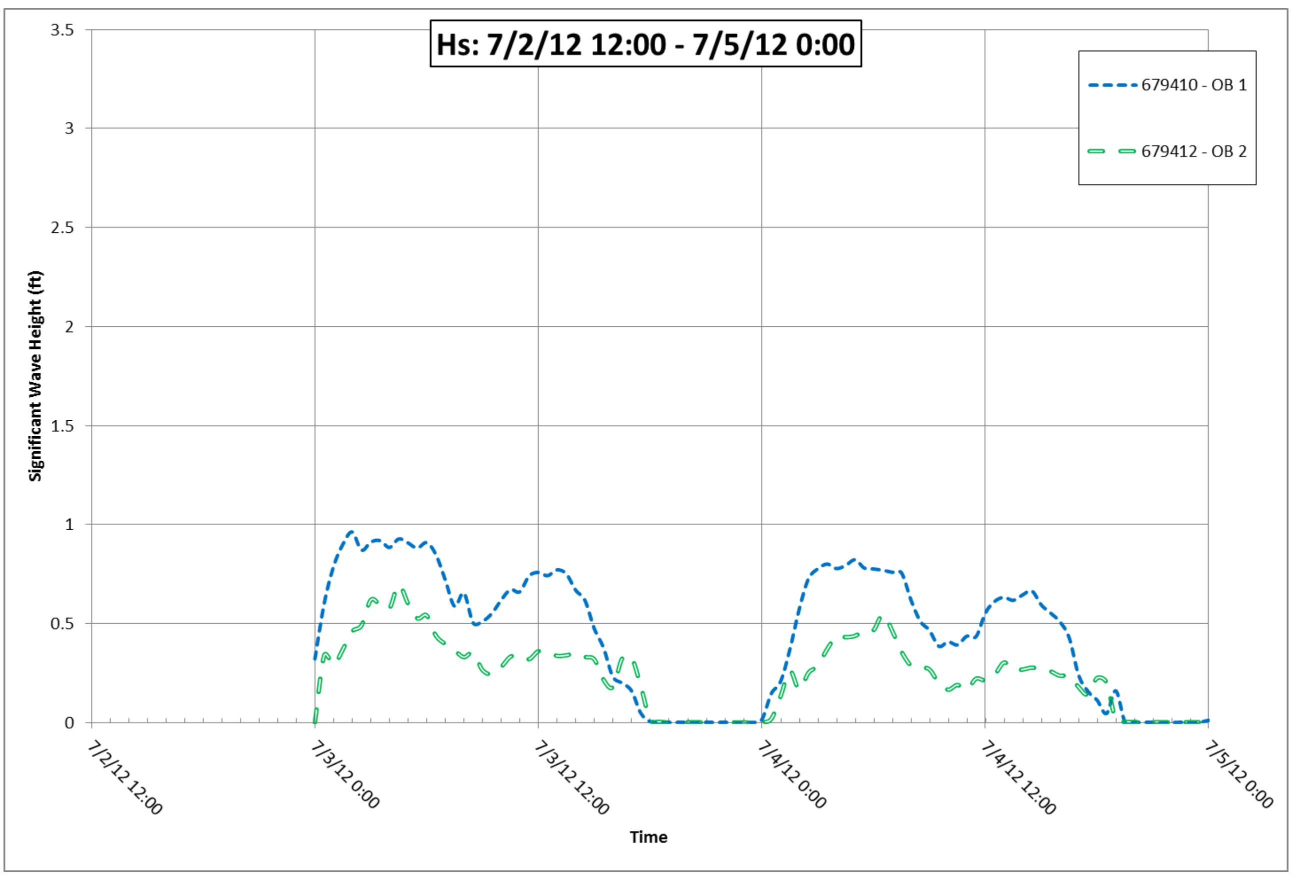
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Significant Wave Height (ft)
3.5
3
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2
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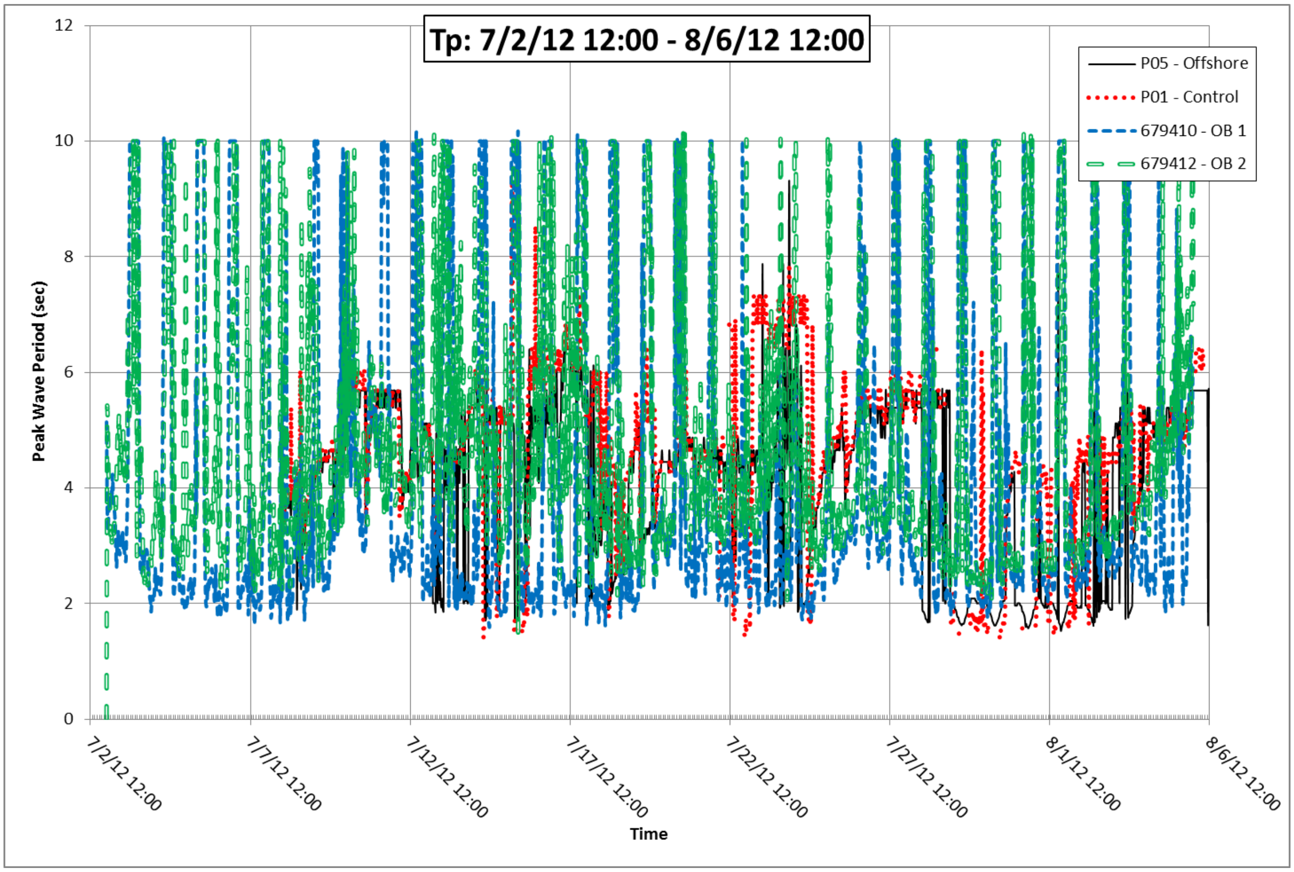
1
0.5
0
7/2/12 12:00
7/3/12 0:00
7/3/12 12:00
7/4/12 0:00
7/4/12 12:00
7/5/12 0:00
Time

APPENDIX 4

Peak Wave Period Plots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2
4
6
8
10
12
7/2/12 12:00
7/7/12 12:00
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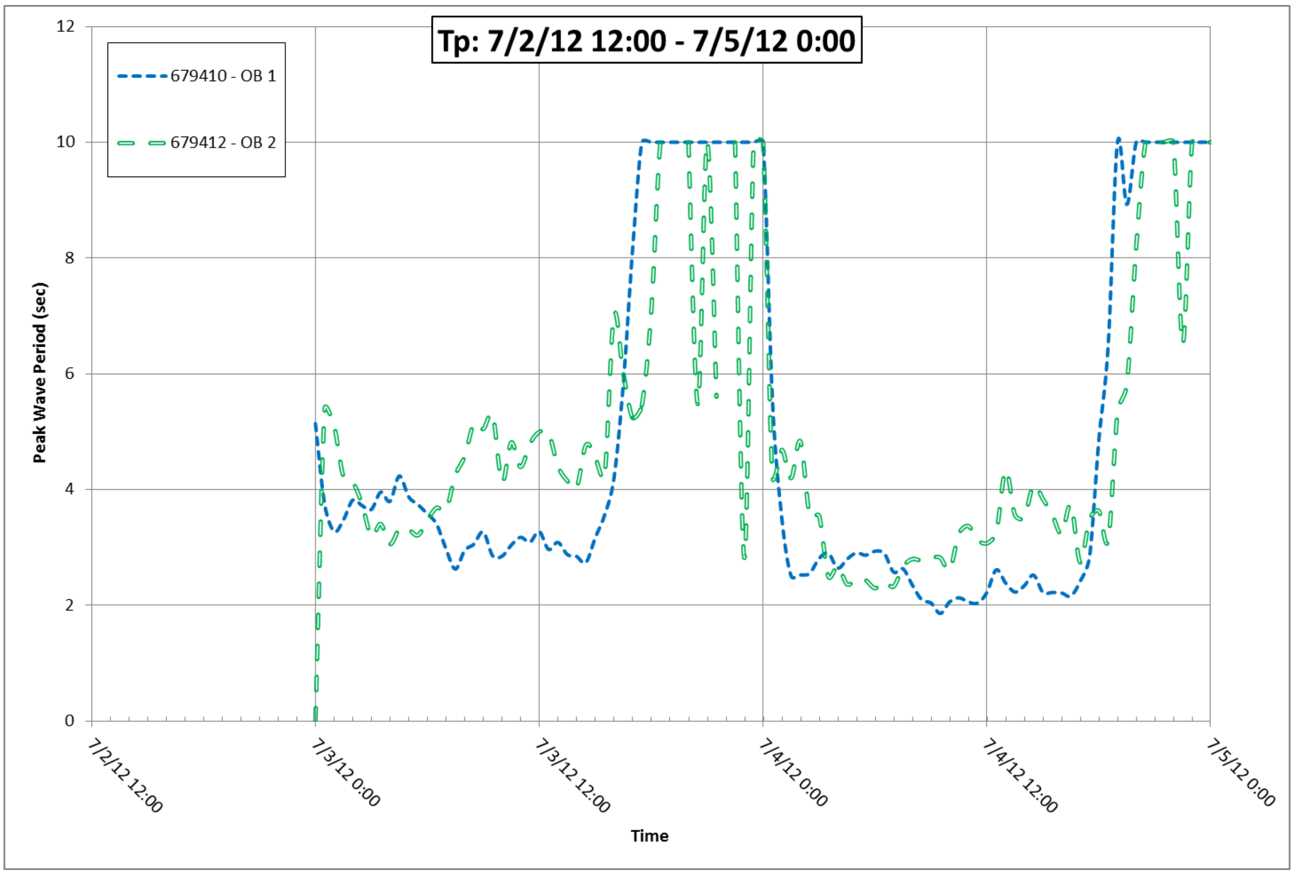
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679410 - OB 1
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Peak Wave Period (sec)
Time
0
2
4
6
8
10
12
7/2/12 12:00
7/3/12 0:00
7/3/12 12:00
7/4/12 0:00
7/4/12 12:00
7/5/12 0:00

APPENDIX 7

Gage Installation Pictures


DANGER
UNDERWATER
OBSTRUCTION

- The Gulf ward edge of each oysterbreak in the March 2013 assessment was covered with the filamentous green alga *Cladophora sp.*, and the folios green alga, *Ulva sp,* besides also have blue-green encrusting algae. Both algae species are relatively common in Louisiana on marine coastal structures in the winter through spring, but disappear by summer until the next winter. This should not interfere with the typically dominant pulses of spring and fall oyster spat recruitment.

APPENDIX B

Bio-Engineered Oyster Reef Demonstration Project (LA-08)
Mid-Term Biological Assessment
February 2012 – October 2013

Bio-Engineered Oyster Reef Demonstration Project (LA-08) Mid-Term Biological Assessment February 2012-October 2013

Prepared by:

Earl J. Melancon, Jr., Ph.D.

Ronnie W. Duke, Jr., M.S.

August 2014

T. BAKER SMITH, LLC
SOLUTIONS START HERE

Houma, LA   Lafayette, LA   Baton Rouge, LA   Thibodaux, LA   Houston, TX
1 (866) 357-1050   www.tbsmith.com

SUMMARY

The analyses from this mid-term data presented in this report, 2-years post construction, gives an opportunity to perform a basic assessment as to success of oyster colonization, survival and potential for reef development, but should not be interpreted as an assessment that one type of oysterbreak is better than the other. A more complete and robust assessment will be conducted in year four (4), the final contractual biological assessment year. The purpose of this interim report is to document the status of oyster reef development and to discuss observed environmental issues that must be addressed in the final assessment of success or failure. The interim assessment based on the 2-year data set and our observations are as follows:

- Mean oyster density per 0.0625m^2 (1/16 m^2) was similar between the Standard-Weight oysterbreak and the OysterKrete™ oysterbreak in October 2014. The mean density assessment is based on quadrat oyster data from top-tier rows #2 and #7 on the Standard-Weight oysterbreak, and rows #4 and #7 on the OysterKrete oysterbreak. This result is based on using top-tier-only rings with comparable-water depths. *Water depth, i.e., tidal depth, is a factor that must be used when comparing the two types of oysterbreaks. Water depth is explained below in other bullets.*

- Based on paired experimental cylinders, one a Standard-Weight (SW) and the other an OysterKrete (OK), there was no statistically significant difference between them in ability to recruit oyster spat, i.e., oyster densities were similar after deployment on March 2, 2013 and retrieval on October 28, 2013. *This experimental cylinder results is a mid-term data set for general interpretation of oyster activity at the sites, but should not be used for direct comparisons to the actual oysterbreaks which have diverse habitats, multiple tidal depths across the structures, and are subjected to harsher wave and other environmental activities.*

- Oyster shell heights on the top-tier rings between the two oysterbreaks are similar. By October 2013, oysters had grown on the OysterKrete oysterbreak to a modal height of 50-59.9 mm from a March 2013 modal height of 20-29.9 mm. Oysters have grown on the Standard-Weight oysterbreak from a modal height of 20-29.9mm in March 2013 to a modal height of 60-69.9mm. (*Oyster shell height* is *the measured distance from the shell hinge to most distal edge of the shell lip; sometimes in the lay community it is referred to as "length of shell"*).

- Based on oyster shell-height frequency analyses, the fall oyster recruitment event and survival appears to be more prevalent than the spring recruitment event.

- Collecting comparable oyster data from the two oysterbreaks is a challenge since there is a definite difference in tidal inundation, both within and between structures. The Gulfward edge of each oysterbreak is deeper, as expected, but the OysterKrete oysterbreak is in deeper water than the Standard-Weight Concrete oysterbreak. This water depth difference may be overcome by assessing specific rows of rings with similar depths on each oysterbreak when it is time to determine success or failure.

- Predation of oysters will be a factor in the success or failure of the oysterbreaks to develop and sustain an oyster reef. Predation in a relatively high salinity environment, such as in the coastal habitat where the oysterbreaks were placed, is tidal influenced. There is an abundance of the oyster predator, *Stramonita haemastoma*. This snail is considered the dominant predator on oysters greater than 10mm in shell height in Louisiana waters. Based on the presence of snails, the most likely habitat for oyster reef development will be the top-tiered rings on the oysterbreak since those rings are more intertidal than the lower-tiered rings beneath.

- Oysters usually remain in the water column for about 2-3 weeks during the late spring through early fall, and during this time are at the mercy of the prevailing currents. The closest known concentration of oysters spawners with a reef-type complex is in a bayou approximately 4.1 Kilometers (2.2 Nautical Miles) to the east. Initial recruitment of larvae may be coming primarily from this area since longshore currents predominantly flow east-to-west along the Louisiana coast. It is possible that as oysters recruit to the structures, they too will spawn and aid in new recruitment to the structures, if currents allow.

- Barnacles, mostly if not all *Balanus sp*., are abundant on the oysterbreaks. In the October 2014 survey barnacles were 35 times denser than oysters. Barnacles compete for space with oyster larvae, especially during early colonization. Over time, as oysters settle on the oysterbreaks, barnacles should become less of a factor and reef development is still possible.

- The Gulf ward edge of each oysterbreak, and therefore the deepest part of each oysterbreak, is encrusted with blue-green algae that will most probably remain year-round, but may not hinder oyster spat recruitment.

INTRODUCTION

The Louisiana Coastal Protection and Restoration Authority (CPRA) authorized a oysterbreak demonstration project in 2007 as part of the state's Priority Project List #17 (PPL17). The PPL17 project is titled, "Bio-Engineered Oyster Reef Demonstration (LA-08)," hereafter referred to as Project LA-08. The primary purpose of this project is "to test a new, bio-engineered product to address rapid shoreline retreat and wetland loss along the Gulf of Mexico Shoreline in areas with soils of low load bearing capacity" (from LA-08 Fact Sheet from CPRA). This bio-engineered product is an oysterbreak reef made of stackable, concrete rings. One oysterbreak is composed of rings made from OysterKrete™ and the other oysterbreak is composed of rings made from Standard-Weight concrete. OysterKrete is a patented concrete mixture "specifically formulated to attract naturally occurring oyster larvae" (from http://wayfarertech.com/).

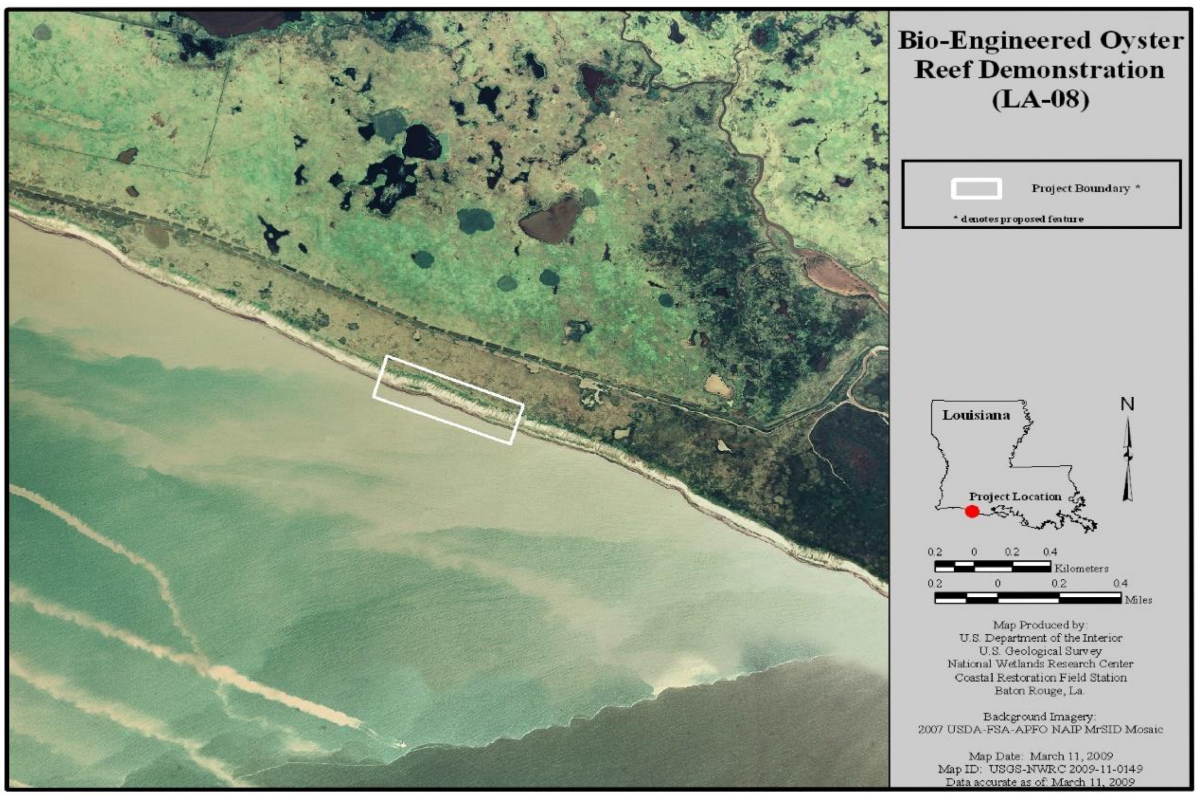

Figure 1. Location of Project LA-08 on Gulf Shoreline of Rockefeller Wildlife Refuge.

Oysterbreak construction was completed on February 18, 2012. "The reef area contains two, 215 ft. reef segments; the western oysterbreak is composed of Oysterkrete©, and the eastern Oysterbreak is composed of Standard-Weight concrete," (from McGinnis and Pontiff, 2012, Operations, Maintenance, and Monitoring Plan); hereafter, referred to as the OysterKrete (OK) and Standard-Weight Concrete (SW) oysterbreaks, respectively (Figure 2).

T-Baker Smith was awarded the biological assessment contract for the CPRA-funded project. The assessment is to document the efficiency of oysterbreaks in establishing an oyster population capable of developing a living reef. This is a mid-term year-two assessment, with another final and more robust assessment in year-four. The assessments are focused on the question if the OysterKrete oysterbreak (OK) is more efficient than the Standard-Weight concrete oysterbreak (SW) in the establishment and retention of an oyster population. The primary objective of this mid-term (second-year) biological report, approximately 21 months post-construction, is to assess the status of oyster recruitment and survival to the two oysterbreaks (Figure 2).

The biomass analyses from the mid-term data sets presented in this report should not be interpreted that one type of oysterbreak is better for oyster colonization and reef-building potential. Two, one-day sampling efforts with tidal fluctuations constrained our time on the oysterbreaks. A more complete and robust biomass assessment will be conducted in year-4, the final biological assessment year.

Figure 2. Aerial View of Completed Project LA-08 Oysterbreaks at near-High Tide along the Gulf of Mexico Shoreline; OysterKrete (OK) is to the West and Standard-Weight Concrete (SW) is to the East.

METHODS

Three one-day trips to project LA-08 were taken to develop this mid-term report. The first trip was on April 19, 2012, two months post-construction, the second on March 12, 2013, and the third on October 28, 2013. During the time between construction completion and the October 2013 biological assessment, two major storm events occurred, Hurricane Isaac in August 2012 (Appendix Figure A-1) and Tropical Storm Karen in October 2013 (Appendix Figure A-2). Because the oysterbreaks were placed in a tidal environment, and because all three trips were one-day events, effort was made to visit on a low or falling tide to allow adequate observations and assessments of the structures.

Personnel from T-Baker Smith on the April 19, 2012 and March 2, 2013 trips included Kiley Cressionie, Thomas Picou, Ronnie Duke and Earl Melancon, and Thomas McGinnis from the CPRA Operations Branch. Personnel from T-Baker Smith on the October 28, 2013 trip included Michael Trahan, Thomas Picou, Ronnie Duke and Earl Melancon, and Thomas McGinnis from the CPRA Operations Branch.

April 2012 Trip

This initial trip was to place equipment necessary to monitor oyster recruitment density, shell growth (height) of oyster spat and survival, and to place a continuous recording Onset HOBO U24-002 conductivity logger™ for water temperature and salinity recordings every hour. The logger was attached subtidally to a 5.1 cm (2 inch) pvc pipe securely driven into the muddy sand bottom between the two oysterbreaks. This technique of securing a logger to pvc pipe has worked successfully in other projects for long-term placement where storms have occurred.

Biological assessments tools to document oyster recruitment were placed in modified commercial crab traps with a coated wire mesh measuring 3.8 cm square (1.5 inch), but with no crab entrances (funnels) or escape rings. Each trap contained an unglazed quarry tile (Appendix Figure A-3) and a single experimental cylinder measuring 15x30cm (5.9x11.8in) of OysterKrete or Standard-Weight concrete. The cages were paired at each site, one with an Oysterkrete cylinder and the other with a Standard-Weight cement cylinder. Each trap was reinforced with iron rebar along the bottom horizontal axis of two sides to add weight, and each vertical corner reinforced with pvc pipe to increase rigidity (Appendix Figure A-3). Additionally, each trap was tethered to a 5.1 cm (2 inch) diameter schedule-40 pvc pipe anchored into the muddy sand bottom. A crab trap could only be accessed through a top-hinged mesh area.

The modified crab trap's mesh size, 3.8 cm (1.5 inch) square, is sufficient to allow water currents to carry oyster larvae through the cage and have them potentially set on the tiles and cylinders, while also keeping many predators out. Two sets of paired of crab traps were placed behind each oysterbreak (leeward side), two sets between the oysterbreaks, and two sets in front of each oysterbreak (windward side) for 10 sets of traps. Thus, cumulative numbers equaled 10 for experimental cylinders of each type and 20 for quarry tiles. In addition to placing the traps and data logger for monitoring purposes, the oysterbreaks were walked and observed to help develop future monitoring strategies.

March 2013 Trip

This trip to the oysterbreaks was approximately 11 months after the initial installation of monitoring cages during trip #1. During the time interval Hurricane Isaac occurred with at least tropical storm force winds experienced along the shoreline where the oysterbreaks are located (Appendix Figure A-1).

The temperature-salinity logger was either stolen or lost during a storm and no hourly data for the site exist. As stated earlier, this technique of strapping a logger to at pvc pipe has been successful for other long-term deployment, including through severe storms and hurricanes, but was unsuccessful here. The loss of the logger may be due to not accounting for the strong rip currents that probably occurred between the oysterbreaks, especially during storm activity. Additionally, all cages except four were lost. All four cages that were retrieved were located behind the oysterbreaks nearest the shore (leeward side of oysterbreaks) and therefore located in the shallowest habitat and truly intertidal. The lost cages in the front may have been lost for the same reason as the logger.

After the April 2012-depolyed cages were retrieved, a new set of cages with experimental cylinders and quarry tiles were deployed. However, this time each trap contained a pair of unglazed quarry tiles (Appendix Figure A-3) and a pair of experimental cylinders, each 15x30cm (5.9x11.8in), and made of the same material as the oysterbreaks; one of Standard-Weight concrete (SW) and the other OysterKrete (OK). In addition, this time all 10 cages were deployed behind the oysterbreaks, and therefore intertidal and leeward of potential Gulf wave and storm activity. Cages #1-5 were placed behind the Standard-Weight concrete oysterbreaks while cages #6-10 were placed behind the OysterKrete oysterbreaks. Another logger was deployed, but this time attached to a schedule-40 pvc pipe with electrical tape and then the pipe then secured to eastern-most permanent metal warning sign post with duct tape (Figure 2).

While the tide was relatively low, 0.0625 m^2 ($1/16^{th}$ m^2) oyster quadrat samples were taken from both oysterbreaks. Quadrat samples were taken from the top tier of rings on the upper rim facing windward by scraping into a plastic ziploc bag all organic material, which included not only the small oysters, but also barnacles and algae (Appendix Figure A-5). The focus of the March 2013 quadrat scrapings was to document colonization of multiple species and to determine if there was a significant difference in biomass based on location relative to tidal inundation. The oyster themselves were too small to focus exclusively on them, but is the primary focus of this project.

Each top-tier row site was labeled from Gulfward and from left to right, e.g., row 2 was more Gulfward (windward) and farther from the shoreline than row 4. Samples were taken from specific rows of top-tier rings in a stratified random design, where a ring row was divided equally into five sections and a random sample taken from within each section. Therefore, each ring row that was sampled had five quadrats collected. Once collected, each oyster sample was bagged and labeled for transport back to the lab for analysis. Each oyster sample was dried to a constant weight in a convection oven at 80°C, then analyzed and graphed as described in the Results and Appendix sections.

October 2013 Trip

This trip was to retrieve sample materials deployed on the March 2013 trip. No new sample materials were placed at the site because the project will not be assessed again until fall 2015 when the final biological assessment occurs; at that time, assessment will be exclusively oysterbreak-based. Similar to the March 2013 trip, the Hobo temperature-conductivity probe was missing and lost. Just prior to the October assessment Tropical Storm Karen passed to the east of the site (Appendix Figure A-2).

Five stratified random quadrat biomass samples, 0.0625 m^2 (1/16th m^2) in area, were also taken on specific oysterbreak ring rows while the tide was relatively low. Samples were collected by prying off all oysters from within the quadrat area. Samples were taken from the top tier of rings on the upper rim facing windward. Oyster samples were transported in labeled plastic bags to the laboratory and meat removed from each shell. Oyster meat was dried in a convection oven at 80°C to a constant weight, then graphed and statistically analyzed as described in the Results and Appendix sections.

Unlike the quadrat samples collected on the March 2013 trip, where all organic material was scraped, which included barnacles and algae, the focus of the October 2013 trip was on oysters. Oysters had colonized and grown to a sufficient shell size to obtain the desired data without the interference of barnacles and algae. Therefore, the March 2013 quadrat samples cannot be compared to the October 2013 quadrat samples because of the different metrics that were used.

RESULTS AND DISCUSSION

Collecting comparable row biomass data from the two oysterbreaks is a challenge since there is a definite difference in tidal inundation between the two, as seen in Figure 2. The OysterKrete oysterbreak was placed in deeper water than the Standard-Weight oysterbreak, and therefore underwater more frequently due to tidal activity. This difference in tidal inundation could potentially skew data results and interpretation if not taken into consideration for final analyses. For example, water tidal height on top-tier ring row #2 on the normal-weight oysterbreak may be equivalent to ring row #4 on the OysterKrete oysterbreak (personal observations).

It must be noted that the pH of the cement used in all of the oysterbreaks is unknown to the authors of this report. The pH can potentially have an influence on initial oyster recruitment, but diminishes over time as the cement ages and cures in the seawater.

March 2013 Assessment

The number of replicate quadrate density samples per top-tier row of an oysterbreak, five, is a minimal number for biomass analysis and is reflected in the large standard deviation per row (Figure 3), but adequate for this mid-term report. Biomass density samples were scrapes of all tissue and shell within a quadrate, including algae, oysters and their shells, and barnacles and their shells. Individual biomass sample photos can be found in Appendix Figure A-7. In the photos, the filamentous green alga is *Cladophora sp.,* and the folios green alga is *Ulva sp.* Both algae species are relatively common on marine coastal structures in the winter through spring and disappear by summer until the next winter.

Water tidal height differences, and therefore daily differences in inundation duration can potentially have great influences on recruitment density of oysters, the density of fouling organisms such as barnacles and algae, predation rate from organisms like the oyster drill snail, as well as feeding rates, physiological stress and shell growth. Such physical differences due to tidal inundation differences could potentially cause misinterpretation of data when comparing the two oysterbreaks for oyster reef development. For example, the presence of blue-green algae (Cyanophyta) encrusted on the structures on the more Gulfward rings (Appendix Figure A-6) due to more frequent inundation and greater opportunity for colonization.

An example of tidal inundation duration influence is the biomass density samples which exhibited significant differences ($P<.05$) for top-tier rings row #2 on the Standard-Weight concrete oysterbreak compared to other row samples (Figure 3). Top-tier row #2 on the Standard-Weight oysterbreak, the more frequently inundated, was six times greater than the next highest biomass density found on the same oysterbreak, top-tier row #4; statistical analyses are found in the Appendix (Table A-1). Correspondingly, top-tier row #4 data for the Standard-Weight concrete oysterbreak was not significantly different from the OysterKrete oysterbreak (labeled as "OK" top-tier rings #6 and #7 in Figure 3). The Oysterkrete oysterbreak is in deeper water and similar in inundation frequency as row #4 on the Standard-Weight oysterbreak.

An oyster shell height (*the measured distance from shell hinge to most distal edge of shell lip*) frequency distribution can be used for generalized oyster recruitment and survival interpretations. Oysters in the northern Gulf of Mexico can spawn through most months of the year but usually have two major spawning events, one in the spring (April-May) when water temperatures are rising above 25°C and again in the fall (September-October) when water temperatures are cooling. This bimodal yearly event can usually be evident in the shell height frequency distributions for oysters a year or less in age, and during which time shell growth is relatively rapid. On average, oysters in a subtidal habitat with relatively good salinities (≥12psu) and sufficient food can attain a shell height of 50-60mm or more within a year, while intertidal oyster growth may be somewhat slower.

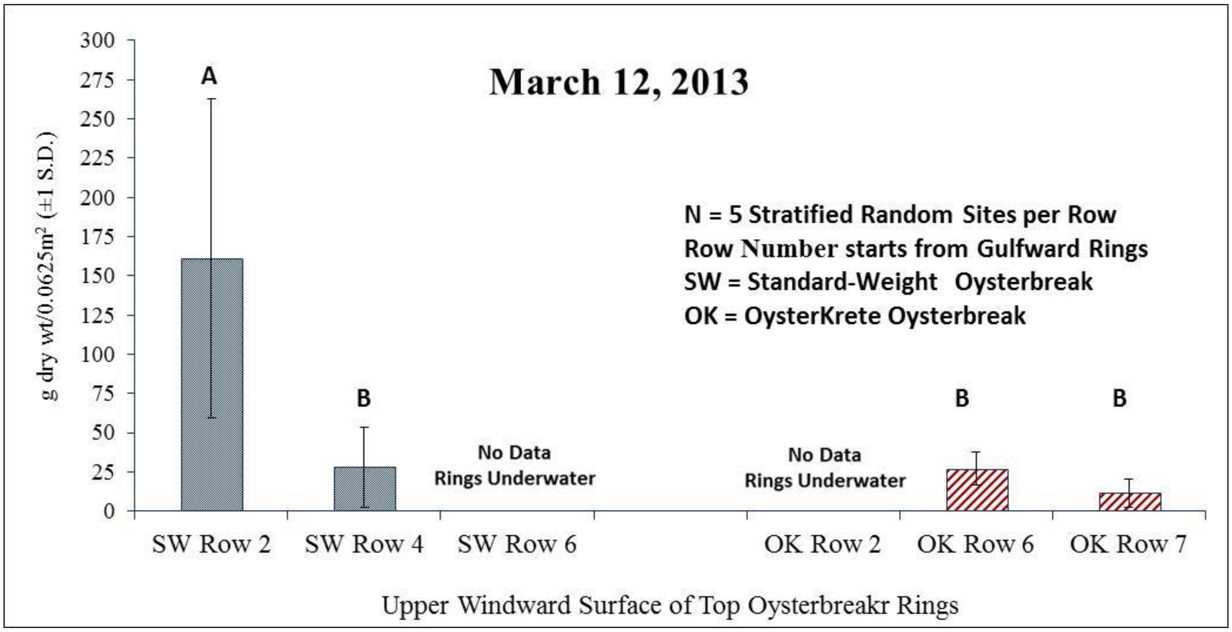

Figure 3. Mean (± 1 S.D.) Dry-Weight Biomass per Oysterbreak Ring Row based on Quadrat Samples Collected on March 13, 2013. If letters above each column are the same then no significant difference (P>.05), but if letters are different then there is significant difference (P≤.05). SW Row #6 and OK Row #2 were attempted for balanced assessment, but tidal height and wave activity prevented. (SW Row 6 was the last to be sampled, and was underwater before assessment could be adequately performed).

There were enough live oysters collected from the biomass quadrat samples in March 2013 to construct frequency distributions for oyster shell height (Figure 4). Live oysters on the two oysterbreaks had similar shell height frequency distributions, with the standard weight oysterbreak having a modal peak in the range 25-29.9mm, and the OysterKrete oysterbreak having a modal peak in the 20-24.9mm range. The majority of live oysters on both oysterbreaks were 25mm or less in shell height and therefore probably due to a fall 2012 or later recruitment. The larger sized oysters are probably due to a spring 2012 recruitment event.

Most of the experimental cages with experimental cylinders and glazed tiles were lost by March 2013, possibly due to the passage of hurricane Isaac (Appendix Figure A-1). Therefore, no density data for cylinders or tiles are presented for the 2013 assessment. However, enough oysters were present on the experimental cylinders to develop a frequency analysis of shell height to give a general interpretation of when the majority of oyster recruitment most likely occurred between April 2012 and March 2013 (Figure 5). The dominance of relative small oysters suggests a fall/winter 2012 set. The larger oysters, most probably survivors from the spring 2012 recruitment event, were all found on the OysterKrete cylinders (Figure 5). The larger oysters on the OysterKrete experimental cylinders could be coincidental or could arguably be due to better survival on the textured surface versus the smooth-surfaced Standard-Weight concrete cylinders. A textured surface with greater rugosity could potential protect oyster spat from predators such as small Portunid and Xanthid crabs, which are known to be voracious predators on recently-set spat; recently-set oyster spat are usually no larger than 400microns (1/64 inch) in shell height. Experimental cylinders that were retrieved can be seen in the photos found in Appendices Figures A-8 and A-9.

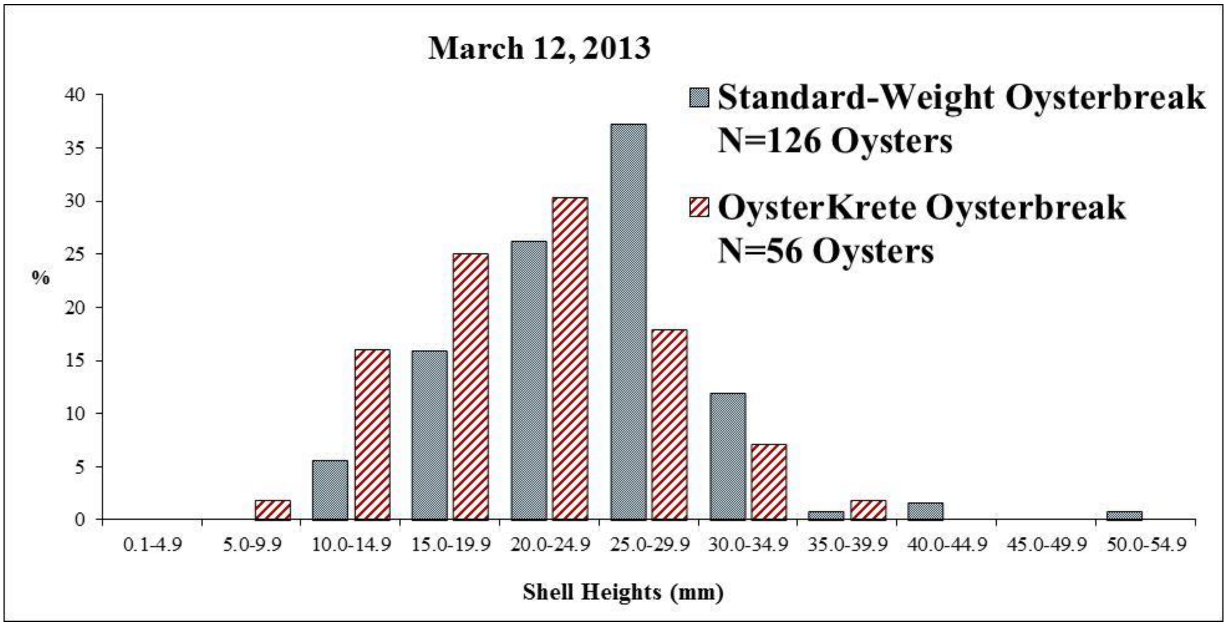

Figure 4. Oyster Shell Height Frequency Histogram for Oysterbreaks sampled March 12, 2013.

The shell height frequency distributions on experimental cylinders in March 2013 (Figure 5) are different from the oysterbreak frequency distributions (Figure 4) that were collected at the same time. The difference is due the fact that oysterbreak data is for a longer period of time for oyster recruitment and growth, and that oysterbreaks span multiple water depths. Such physical differences between experimental cylinder cage sites and oysterbreaks account for the greater shell height frequency distributions seen in Figure 4. This also supports the fact that oysters are recruiting and surviving on the oysterbreaks.

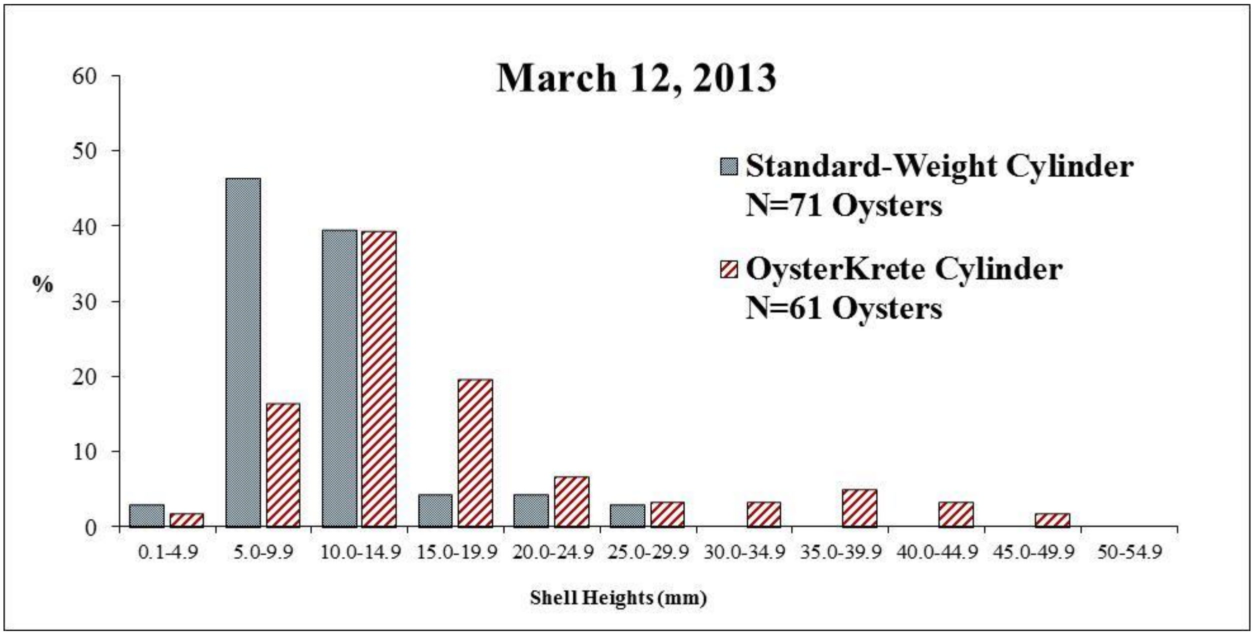

Figure 5. Shell Height Frequency Histogram of Oysters Attached to Experimental Cylinders in Cages Retrieved on March 12, 2013.

October 2013 Assessment

Although tropical storm Karen passed to the east of the LA-08 project just a few weeks prior to the October 2013 assessment (Appendix Figure A-2), there was only one experimental cage lost out of the 10 deployed. Unfortunately, the Hobo probe was lost and there is no documentation of water temperatures and salinities for the site.

Quarry tiles almost exclusively exhibited oyster spat that were less than or equal to 15mm in shell height (Figure 6). This indicates a relatively recent recruitment, probably an early fall 2013 event. Quarry tiles also have a distinction over that of many other substrates used for documenting oyster spat recruitment with the ability to document oyster spat "scars." An oyster scar is the remnant "footprint" of an oyster once it dies (for whatever reason). Recently set spat have a very thin and delicate shell that will easily separate at the hinge when death occurs, and will often leave only the remnant markings of the shell half that adhered to the tile, thus a "footprint." Spat scars were evident mostly in the 5.0-9.9mm range (Figure 6).

Further evidence of a predominantly early fall 2013 spat set, and correspondingly weak spring 2013 set can be seen in the experimental cylinders data (Figure 7). Additionally, unlike the limited data set of March 2013 (Figure 5), the October 2013 data set does not show any distinction in oyster shell height on the OysterKrete cylinders (Figure 7).

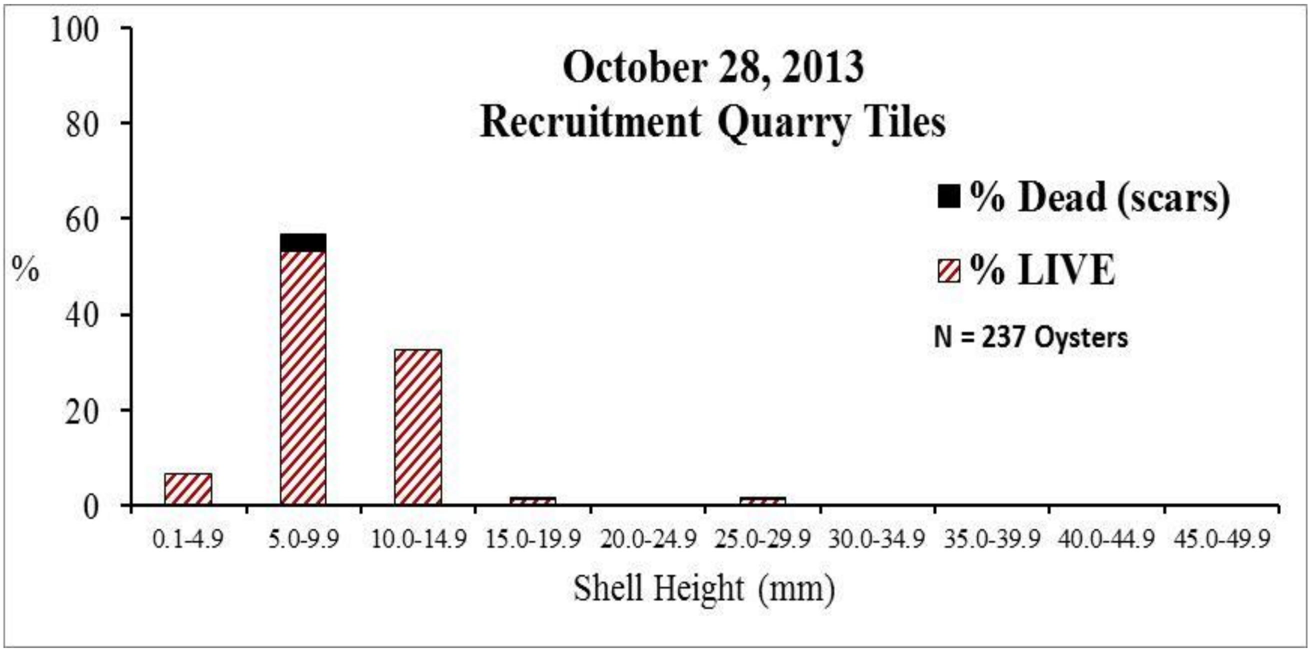

Fig 6. Oyster Shell Height Frequency Histogram of Quarry Tiles collected on October 28, 2013.

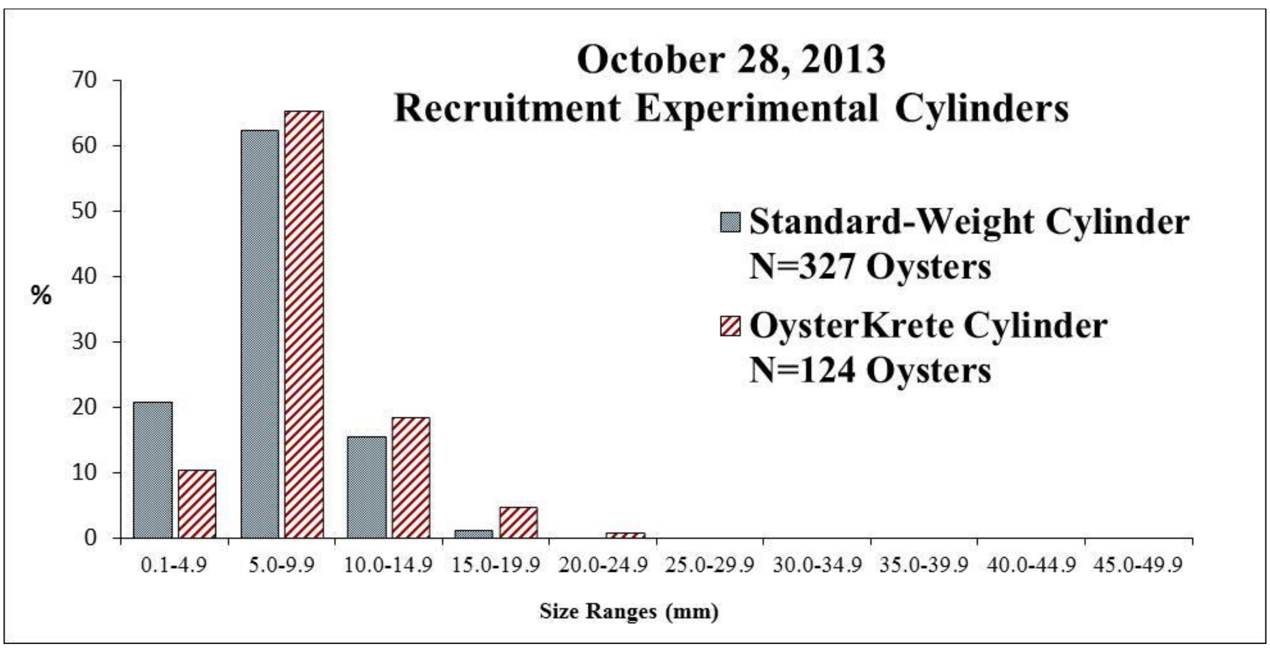

Figure 7. Shell Height Frequency Histogram of Attached Oysters to Experimental Cylinders in Cages Retrieved on October 28, 2013.

An acceptable data set, nine surviving cages out of 10 deployed, allowed for statistical analysis of the paired experimental cylinders (Appendix Table A-2). There was no statistically significant difference (Wilcoxsin-Sign Rank Test, P = 0.359) in paired oyster recruitment density between the Standard-Weight cement and the OysterKrete cylinders (Figure 8); neither one outperformed the other in oyster recruitment, survival and density.

In addition to oyster density comparisons, the experimental cylinders allowed for documentation of barnacle recruitment density, *Balanus sp*., (Appendix Table A-3). Barnacles are competitors for space and some foods, especially during early oyster colonization of a structure such as a oysterbreak. There was no statistically significant difference in paired recruitment barnacle density (t-test, P = 0.571) between the Standard-Weight cement and the OysterKrete experimental cylinders that were deployed in the cages (Figure 8); neither one outperformed the other in barnacle recruitment, survival and density. The density of barnacles on the oysterbreaks in October 2013 was 35 times greater than the density of oysters.

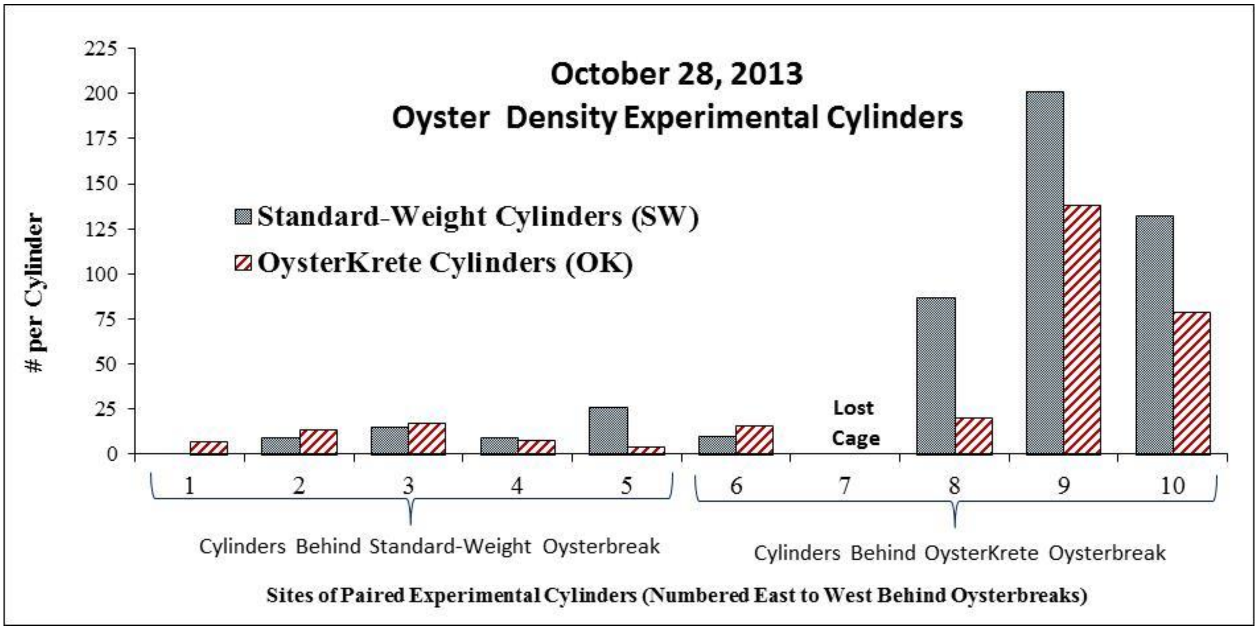

Figure 8. Density of Oysters Attached to Experimental Cylinders in Cages Retrieved on October 28, 2013.

A tombolo, a special kind of sandbar that forms in the shelter of an offshore structure and which may eventually connect to the shore, appears to be developing behind the Standard-Weight concrete oysterbreak in the aerial photo (Figure 2). The water is much shallower behind the Standard-Weight oysterbreak as compared to the OysterKrete oysterbreak. An interesting pattern in oyster and barnacle recruitment is observed on the experimental cylinders within the cages (Figures 8 and 9). The experimental cages were placed behind the oysterbreaks for protection from wave activity, with cages #1-5 behind the Standard-Weight oysterbreak and #6-10 behind the OysterKrete oysterbreak. Oysters clearly show a pattern of greater recruitment density behind the OysterKrete oysterbreak, while barnacles show just the opposite with greater density behind the Standard-Weight oysterbreak. This barnacle and oyster density pattern is probably due to the shallowness of tidal habitat behind the Standard-Weight oyster break as compared to the OysterKrete oysterbreak.

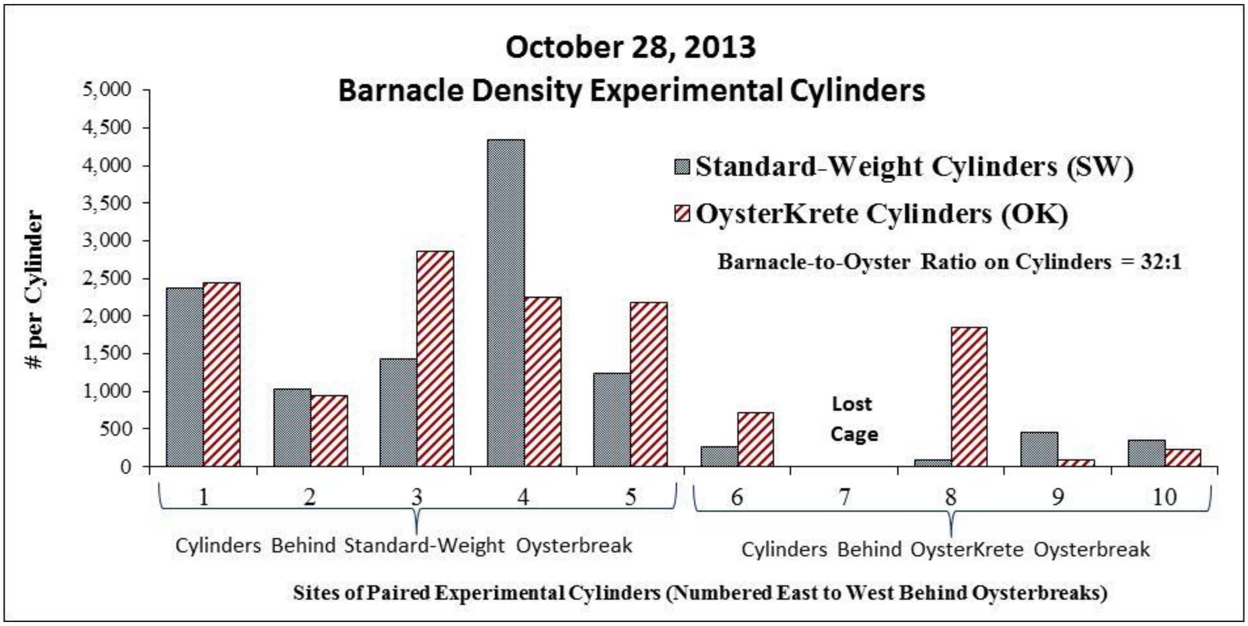

Figure 9. Density of Barnacles Attached to Experimental Cylinders in Cages Retrieved on October 28, 2013.

Oysters often recruit more abundantly in subtidal habitats, while barnacles often recruit more abundantly in intertidal habitats. This pattern of oyster and barnacle recruitment observed on the experimental cylinders in October 2013 (Figure 8 and 9) may be coincidental, but supports the assumption of difficulty that may arise during final assessments of the effectiveness of one type of oysterbreak over the other. Some of this assessment concern could possibly be addressed by not comparing each oysterbreak as a single unit, but instead comparing a ring row by location on a oysterbreak. For example, observations during assessment visits suggest that row #2 on the Standard-Weight concrete oysterbreak may be more similar to the tidal depth of row #4 on the OysterKrete oysterbreak.

Evidence of this potential matchup by row location between oysterbreaks is seen in the mean sizes of oysters on the two oysterbreaks (Figure 10). The Standard-Weight oysterbreak row #2 (SW Row 2) mean oyster shell height is statistically similar to OysterKrete row #4 (OK Row 4) with its similar tidal inundation regimen. Whereas, “SW Row 7” mean oyster shell height is statistically different from that of “OK Row 7” with its difference in tidal inundation periodicity. This pattern of oyster size differences by row location is further supported by evaluating the frequency distribution of live oysters between oysterbreaks (Figure 11). Oyster shell height distributions for “SW Row 2” is clearly similar to the height distributions for “OK Row 4”, whereas “SW Row 7” and “OK Row 7” are clearly different.

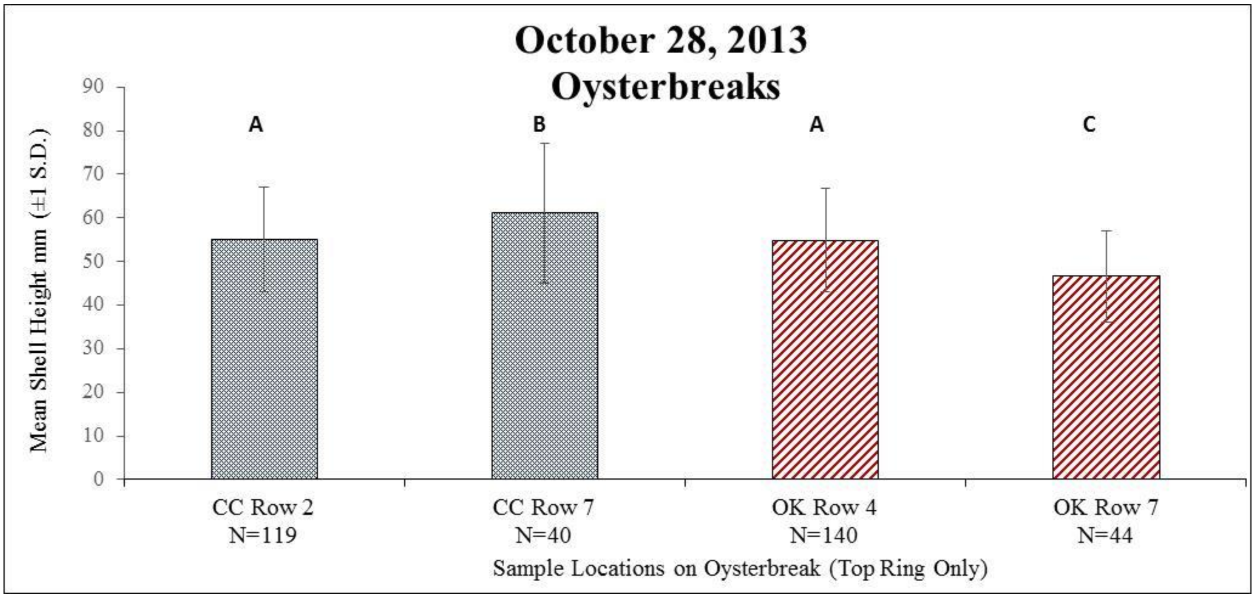

Figure 10. Mean Oyster Shell Height (±1 S.D.) by Oysterbreak Row Location, October 28, 2013. If letters above each column are the same then no significant difference (P>.05), but if letters are different then there is significant difference (P≤.05).

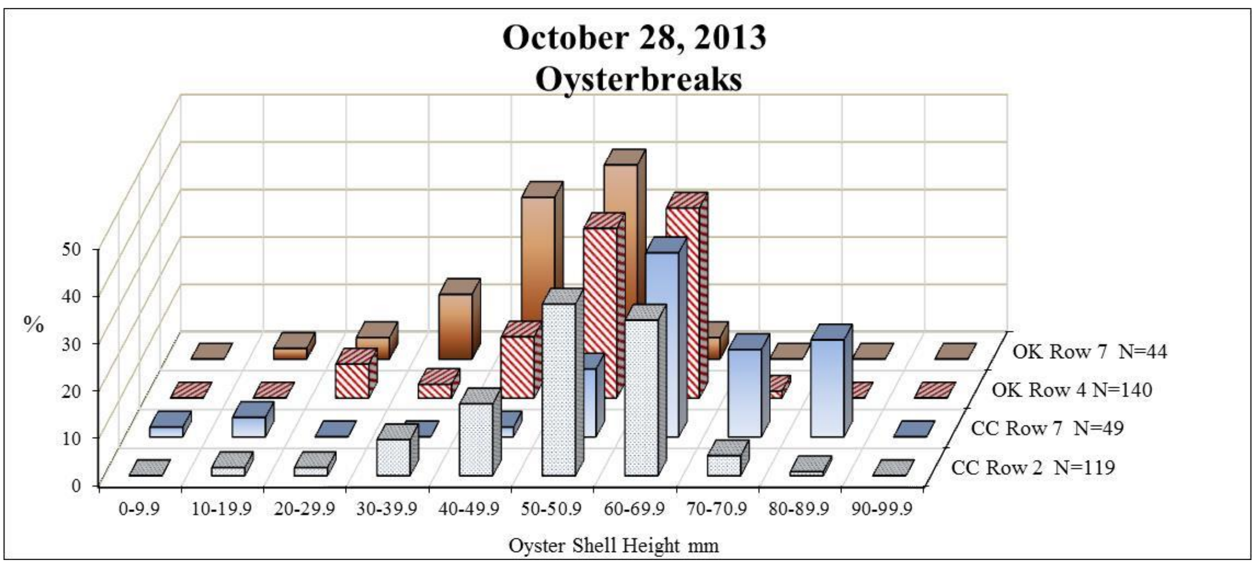

Figure 11. Frequency Distributions of Oyster Shell Heights by Oysterbreak Row Location on Standard-Weight (SW) and OysterKrete (OK), October 28, 2013.

Based on the limited number of quadrats taken (n=10 per oysterbreak) in this preliminary assessment, mean oyster density (Figure 12) per $0.0625m^2$ (1/16 m^2) was similar between the Standard-Weight oysterbreak and the OysterKrete oysterbreak in October 2013(Appendix Table A-4). The mean density assessment is based on quadrat oyster data from top-tier rows #2 and #7 on the Standard-Weight oysterbreak, and rows #4 and #7 on the OysterKrete oysterbreak. This result of no significant difference in density is similar to that found on the paired experimental cylinders (Figure 8).

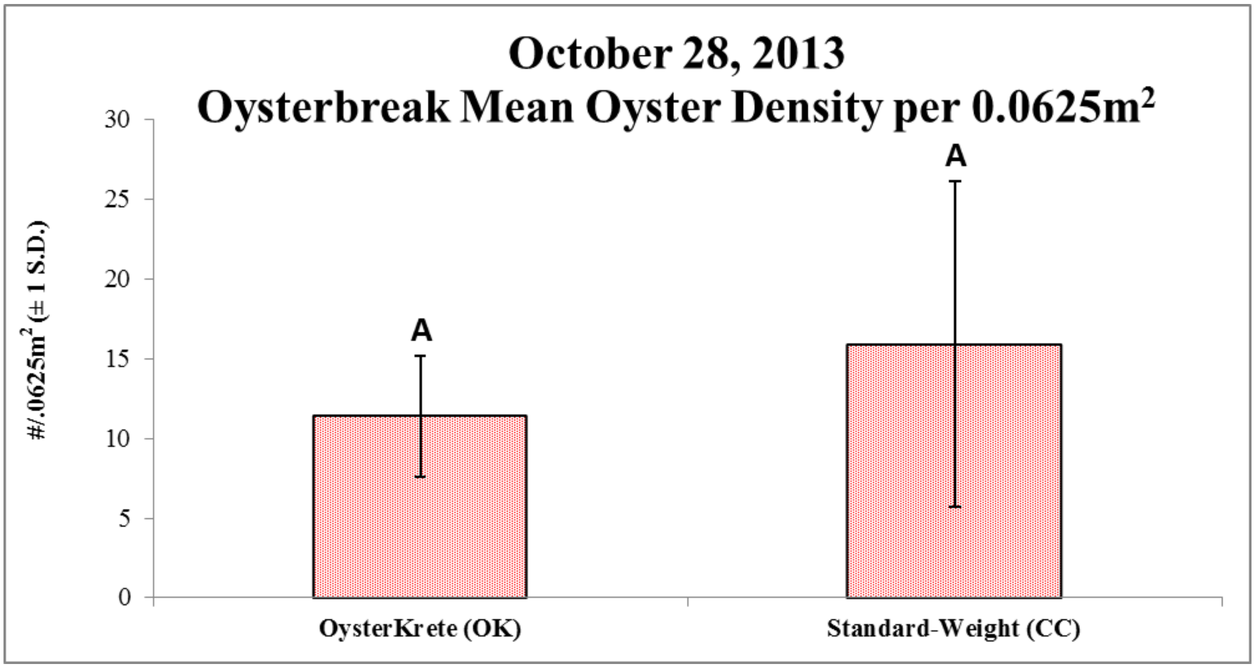

Figure 12. Mean Oyster Density (±1 S.D.) on oysterbreaks, October 2013. If letters above each column are the same then no significant difference (P>.05), but if letters are different then there is significant difference (P≤.05).

Based on the same limited number of quadrats taken (n=10 per oysterbreak) in this preliminary assessment, mean oyster biomass as grams dry weight per $0.0625m^2$ ($1/16\ m^2$) (Figure 13) was, like density, not statistically different between the Standard-Weight oysterbreak and the OysterKrete oysterbreak in October 2013(Appendix Table A-5). The mean biomass, like the density assessment, is based on quadrat oyster data from top-tier rows #2 and #7 on the Standard-Weight oysterbreak, and rows #4 and #7 on the OysterKrete oysterbreak.

Salinity and Predation

Predation on oysters is intricately tied to the synergism of water temperature and salinity. As water temperatures increase in early spring 20°C (68°F) and salinities increase above 15 psu (practical salinity units) predators become more metabolically active. Subtidal oysters are the most vulnerable when water temperature and salinity rises together. Although hourly salinity measurements are not available due to the loss of the data loggers, the coastal habitat where the oysterbreaks are located is known to have salinity averages that run through the year from the mid-teens to higher (from NOAA's National Oceanographic Data Center, http://www.nodc.noaa.gov/). For example, on October 23, 2013 during a site visit the salinity was 22.4 psu with a water temperature of 24.2°C (75.6°F).

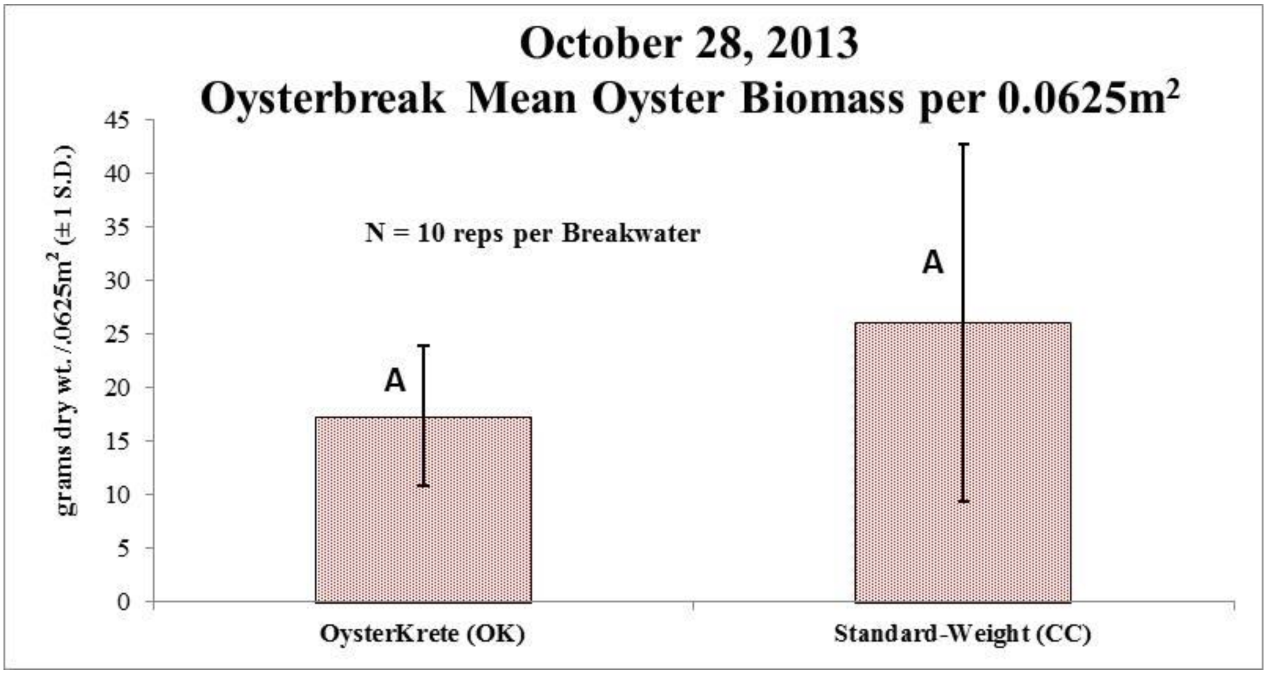

Figure 13. Mean Oyster Biomass grams dry weight (±1 S.D.) on oysterbreaks, October 2013. If letters above each column are the same then no significant difference (P>.05), but if letters are different then there is significant difference (P≤.05).

A significant oyster predator in coastal habitat that consistently has salinities greater than 15 psu is the southern oyster drill, *Stramonita haemastoma*. This snail can potentially destroy a subtidal reef by feeding on oysters. The only protection from this predator in high salinity habitat is to be located in the intertidal zone. The oyster drill was very prevalent in the October 2013 assessment of the oysterbreaks. A random collection of the oyster drills indicated that there was no difference in size of the snails (Figure 14), suggesting equal predation effects on the two oysterbreaks (Appendix Table A-6). This may negate bottom rows of oysterbreaks for oyster survival and reef development.

Potential for Reef Development

The relative growth in population size classes since construction suggest that the potential for oyster survival and reef development, at least on the top-tier of oysterbreak rings, is feasible as long as adequate recruitment occurs. Irrespective of the presence of predatory snails and the tidal inundation differences between oysterbreaks, the top rows of rings are being colonized by oysters and surviving and growing. Oysters have grown on the Standard-Weight oysterbreak from a modal height of 20-29.9mm in March 2013 to a modal height of 60-69.9mm by October 2013 (Figure 15). Oysters have grown on the OysterKrete oysterbreak from a modal height of 20-29.9mm in March 2013 to a modal height of 50-59.9mm by October 2013 (Figure 16).

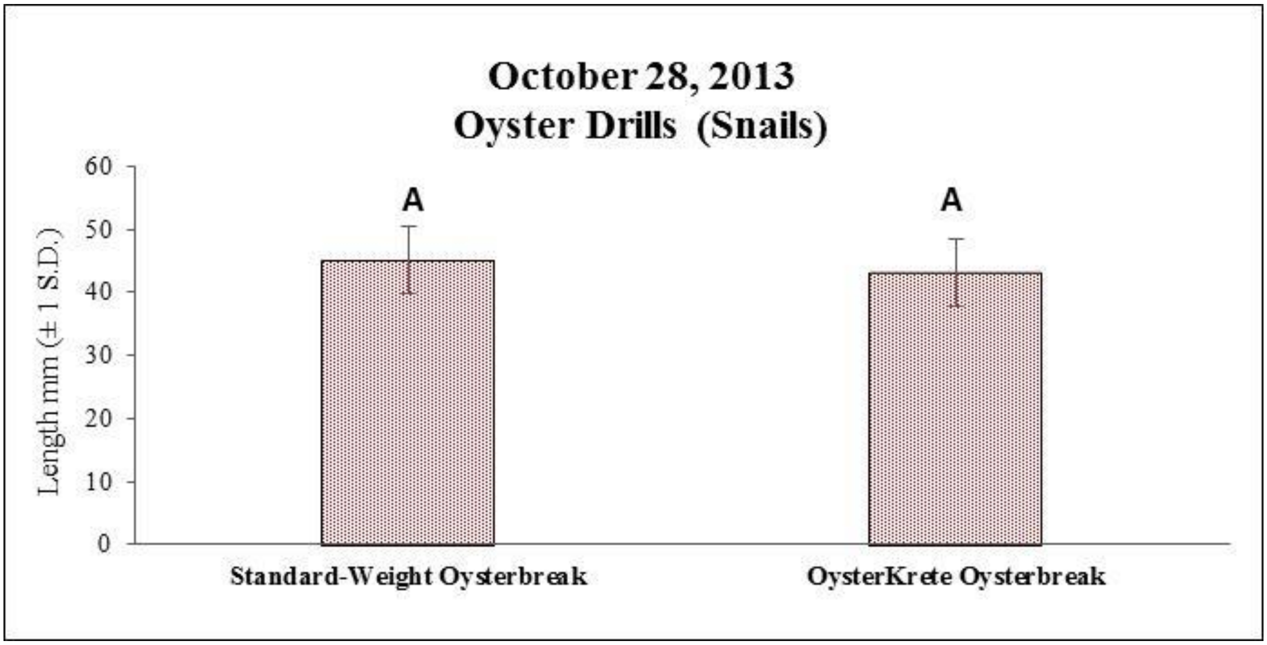

Figure 14. Mean Length (±1 S.D.) of Oyster Drill Snails by Oysterbreak, October 28, 2013. If letters above each column are the same then no significant difference (P>.05), but if letters are different then there is significant difference (P≤.05).

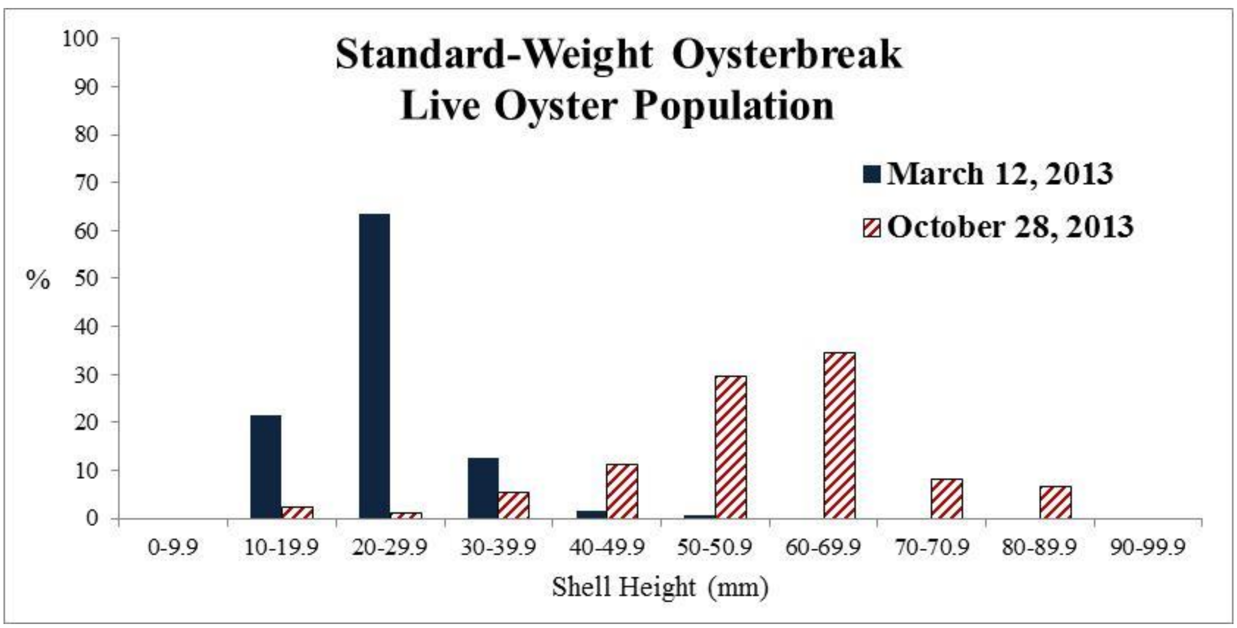

Figure 15. Comparison of Oyster Height Frequency Distributions between March 13, 2013 and October 28, 2013 on the Standard-Weight Concrete Oysterbreak.

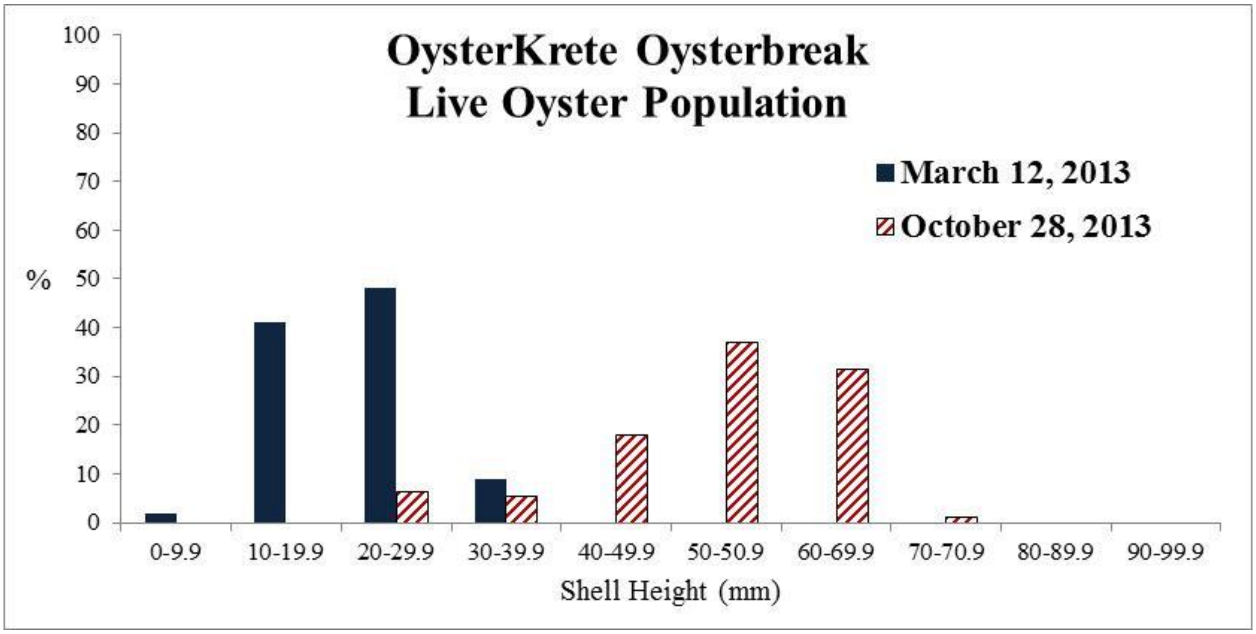

Figure 16. Comparisons of Oyster Height Frequency Distributions between March 13, 2013 and October 28, 2013 on the OysterKrete Oysterbreak.

APPENDIX

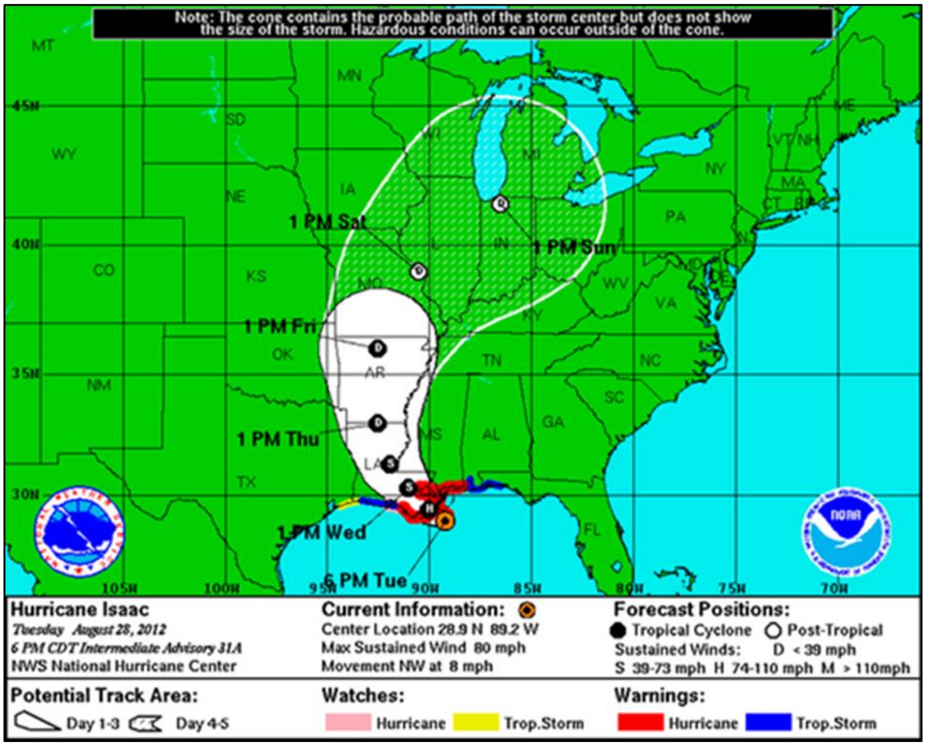

Figure A-1. Path of Hurricane Isaac.

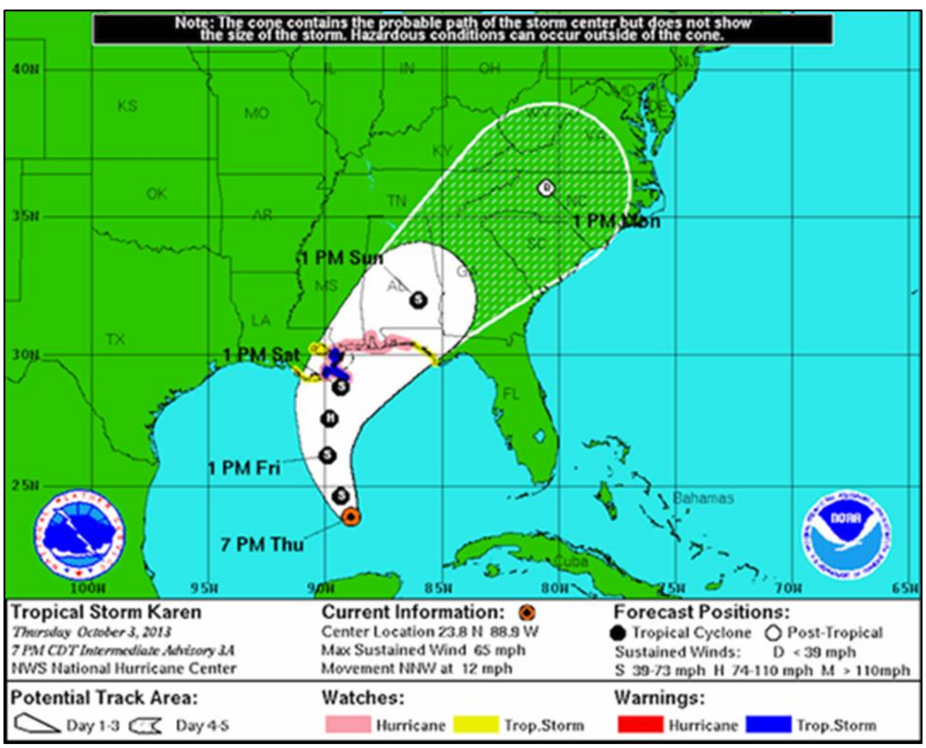

Figure A-2. Path of Tropical Storm Karen.

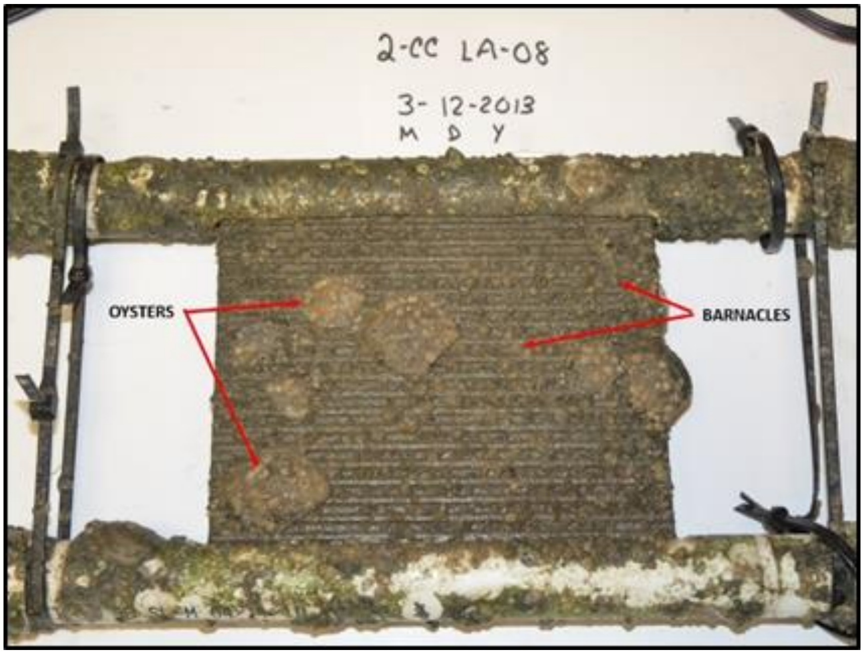

Figure A-3. Photo Example of a Quarry Tile Plate used for Oyster Spat Recruitment.

Figure A-4. Photo of Experimental Cage with two Quarry Tiles and two Experimental Cylinders, one OysterKrete (OK) and the other Standard-Weight Concrete (SW).

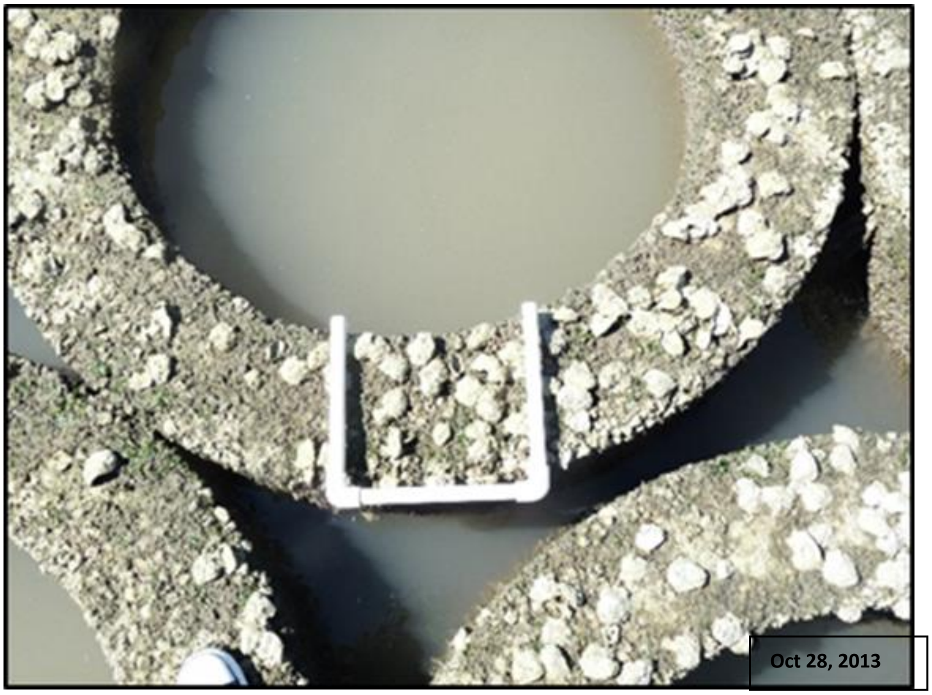

Figure A-5. Photo on Left the 0.0625 m^2 Quadrat Frame placed on Standard-Weight Concrete Ring.

Figure A-6. Standard-Weight Concrete (SW) Oysterbreak showing Algae-Encrusted Gulfward Rings.

Figure A-7. Scrapings within 0.0625 m^2 Quadrats, March 12, 2013.

Figure A-7 (continued)

Figure A-7 (continued)

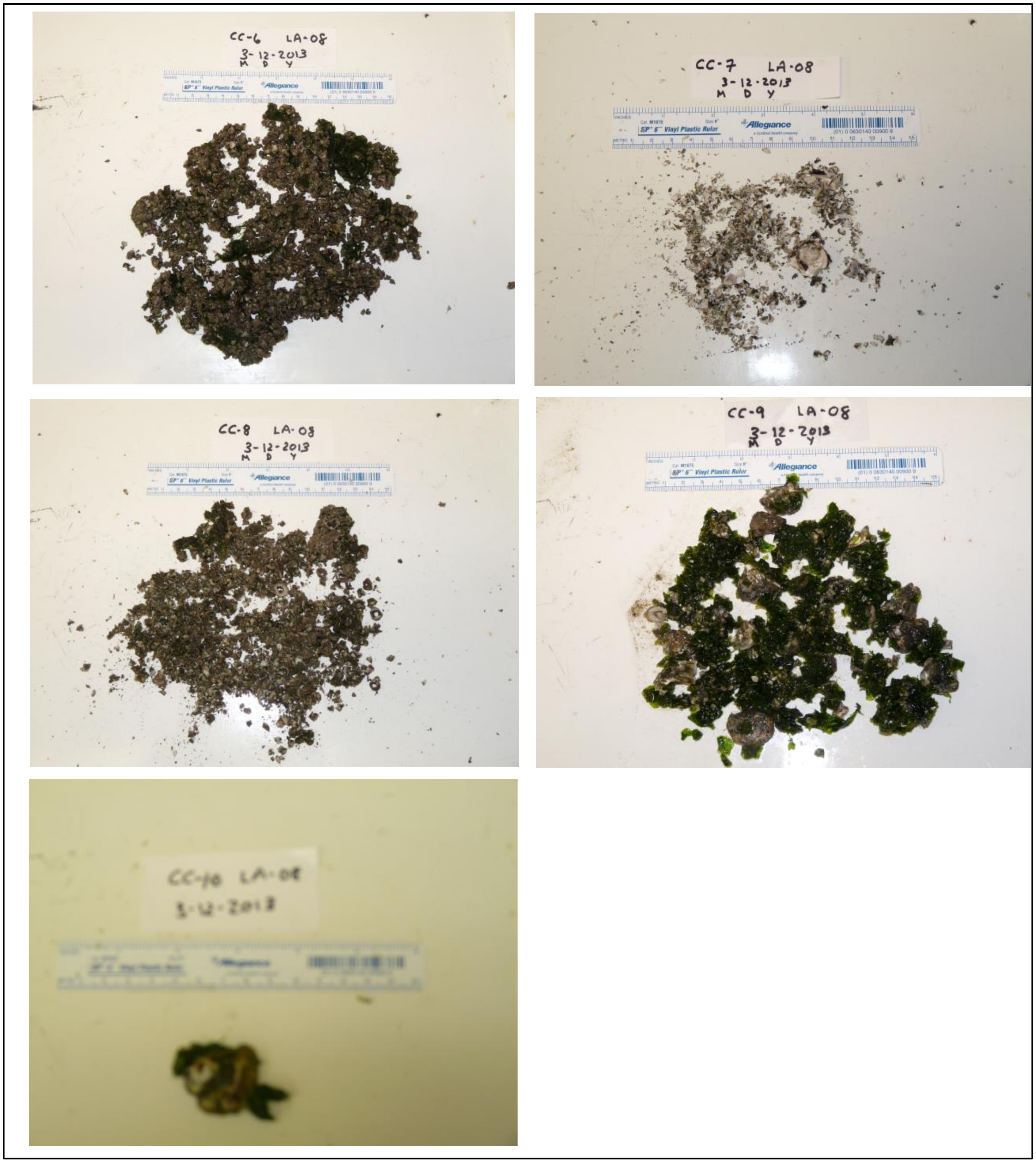

Figure A-7 (continued)

Figure A-8. Experimental Standard-Weight Concrete Cylinders in Cages Deployed on April 19, 2012 and Retrieved on March 12, 2013.

Figure A-9. Experimental OysterKrete Cylinders in Cages Deployed on April 19, 2012 and Retrieved on March 12, 2013.

Figure A-10. Paired Experimental OysterKrete and Standard-Weight Cylinders in Cages Deployed on March 12, 2013 and Retrieved on October 28, 2013.

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Figure A-10 (Continued)

Figure A-11. View Looking West at OysterKrete Oysterbreak at Near-Low Tide (left photo) and again at Near-High Tide (right photo) on March, 12, 2013. Photo by Tommy McGinnis.

Figure A-12. Standard-Weight Oysterbreak in Foreground and OysterKrete Oysterbreak in Background between the two poles on March 12, 2013 as Tide rises; notice that all of OysterKrete Oysterbreak is already under water. Small pvc poles behind Oysterbreaks are Locations for Experimental Cages with Cylinders and Tiles. Photo by Tommy McGinnis.

Figure A-13. Colonization of Oysters on a Top-Tier Ring of the OysterKrete Oysterbreak, October 28, 2013.

Figure A-14. Standard-Weight Oysterbreak Top-Tier Ring on West end of Structure showing Stress Fracture on October 28, 2013.

Figure A-15. Colonization of Oysters on a Top-Tier Ring of the Standard-Weight Oysterbreak on October 28, 2013.

Table A-1. Statistical Analysis of Biomass (g. dry wt.) Data from March 2013 Quadrats; CC=Standard-Weight Oysterbreak, OK=OysterKrete Oysterbreak.

One Way Analysis of Variance

Data source: Data 1 in LA-08_Fall2013Data

March 2013 Biomass Density Data (0.0625m^2)

Data Log-Transformed to attain normality

Dependent Variable: log10(col(17))

Normality Test (Shapiro-Wilk) Passed (P = 0.104)

Equal Variance Test: Passed (P = 0.476)

Group Name	N	Missing	Mean	Std Dev	SEM
CC-2	5	0	2.073	0.455	0.203
CC-4	5	0	1.23	0.544	0.243
OK-6	5	0	1.401	0.177	0.0792
OK-7	5	0	0.888	0.485	0.217

Source of Variation	DF	SS	MS	F	P
Between Groups	3	3.72	1.24	6.445	0.005
Residual	16	3.078	0.192		
Total	19	6.797			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.005).

Power of performed test with alpha = 0.050: 0.870

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor: Breakwater Row

Comparison	Diff of Means	p	q	P	P<0.050
CC-2 vs. OK-7	1.185	4	6.041	0.003	**Yes**
CC-2 vs. CC-4	0.843	4	4.298	0.035	**Yes**
CC-2 vs. OK-6	0.672	4	3.425	0.113	**No**
OK-6 vs. OK-7	0.513	4	2.616	0.288	**No**
OK-6 vs. CC-4	0.171	4	0.874	0.925	**Do Not Test**
CC-4 vs. OK-7	0.342	4	1.742	0.617	**Do Not Test**

A result of "Do Not Test" occurs for a comparison when no significant difference is found between two means that enclose that comparison. For example, if you had four means sorted in order, and found no difference between means 4 vs. 2, then you would not test 4 vs. 3 and 3 vs. 2, but still test 4 vs. 1 and 3 vs. 1 (4 vs. 3 and 3 vs. 2 are enclosed by 4 vs. 2: 4 3 2 1). Note that not testing the enclosed means is a procedural rule, and a result of Do Not Test should be treated as if there is no significant difference between the means, even though one may appear to exist.

Table A-2. Statistical Analysis of Oyster Density Data from October 2013 Experimental Cylinders Placed in Modified Crab Cages; CC=Standard-Weight Oysterbreak, OK=OysterKrete Oysterbreak.

Paired t-test:

Data source: Data 1 in LA-08_Fall2013Data.JNB

Normality Test (Shapiro-Wilk) Failed ($P < 0.050$)

Test execution ended by user request, Signed Rank Test begun

Wilcoxon Signed Rank Test

Data source: Data 1 in LA-08_Fall2013Data.JNB

Group	N	Missing	Median	25%	75%
CC Oys Den/Cyl	9	0	15	9	109.5
OK Oys Den/Cyl	9	0	16	7.5	49.5

W= -17.000 T+ = 14.000 T-= -31.000
Z-Statistic (based on positive ranks) = -1.007
P(est.)= 0.343 P(exact)= 0.359

The change that occurred with the treatment is not great enough to exclude the possibility that it is due to chance (P = 0.359).

Table A-3. Statistical Analysis of Barnacle Density Data from October 2013 Experimental Cylinders Placed in Modified Crab Cages; CC=Standard-Weight Oysterbreak, OK=OysterKrete Oysterbreak.

Paired t-test:

Data source: Data 1 in LA-08_Fall2013Data.JNB

Normality Test (Shapiro-Wilk) Passed (P = 0.539)

Treatment Name	N	Missing	Mean	Std Dev	SEM
CC Barn Den/Cyl	9	0	1275.111	1352.759	450.92
OK Barn Den/Cyl	9	0	1498.111	1023.805	341.268
Difference	9	0	-223	1133.576	377.859

t = -0.590 with 8 degrees of freedom.

95 percent two-tailed confidence interval for difference of means: -1094.344 to 648.344

Two-tailed P-value = 0.571

The change that occurred with the treatment is not great enough to exclude the possibility that the difference is due to chance (P = 0.571)
One-tailed P-value = 0.286

The sample mean of treatment OK Barn Den/Cyl does not exceed the sample mean of the treatment CC Barn Den/Cyl by an amount great enough to exclude the possibility that the difference is due to random sampling variability. The hypothesis that the population mean of treatment CC Barn Den/Cyl is greater than or equal to the population mean of treatment OK Barn Den/Cyl cannot be rejected. (P = 0.571)
Power of performed two-tailed test with alpha = 0.050: 0.082

The power of the performed test (0.082) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.
Power of performed one-tailed test with alpha = 0.050: 0.135

The power of the performed test (0.135) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.

Table A-4. Statistical Analysis of Oyster Density per $0.0625m^2$ from October 2013 Oysterbreaks.

One Way Analysis of Variance

Data source: Data 1 in Oct 2013 Oyster Density

Dependent Variable: #/.0625m^2 Oysters

Normality Test (Sha Failed (P < 0.050)

Equal Variance Test Failed (P < 0.050)

Group Name	N	Missing	Mean	Std Dev	SEM
OysterKrete	10	0	11.4	3.806	1.204
Standard-Weight	10	0	15.9	10.225	3.233

Source of Variation	DF	SS	MS	F	P
Between Groups	1	101.25	101.25	1.701	0.209
Residual	18	1071.3	59.517		
Total	19	1172.55			

The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.209).
Power of performed test with alpha = 0.050: 0.117

The power of the performed test (0.117) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.

Dependent Variable: #/.065m^2 Oysters

Normality Test (Sha Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks

Data source: Data 1 in Oct 2013 Oyster Biomass.JNB

Group	N	Missing	Median	25%	75%
Standard-Weight	10	0	14.5	7.5	21.25
OysterKrete	10	0	11	8.75	13.75

H = 0.469 with 1 degrees of freedom. (P = 0.494)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.494)

Table A-5. Statistical Analysis of Oyster Biomass (g. dry wt.) per $0.0625m^2$ from October 2013 Oysterbreaks.

One Way Analysis of Variance

Data source: Data 1 in Oct 2013 Oyster Biomass.JNB

Dependent Variable: grams dry wt./.065m^2 Oysters

Normality Test (Shapiro-Wilk) Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks

Data source: Data 1 in Oct 2013 Oyster Biomass.JNB

Group	N	Missing	Median	25%	75%
OysterKrete	10	0	15.475	12.785	23.261
Standard-Weight	10	0	23.902	12.665	33.159

H = 1.651 with 1 degrees of freedom. (P = 0.199)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.199)

Table A-6. Statistical Analysis of Snail Length from October 2013 Oysterbreaks; SW=Standard-Weight Oysterbreak, OK=OysterKrete Oysterbreak.

t-test

Data source: Data 1 in Notebook1

Dependent Variable: Snail Length (mm)

Normality Test (Passed (P = 0.519)

Equal Variance 1 Passed (P = 0.852)

Group Name	N	Missing	Mean	Std Dev	SEM
OK	36	0	43.083	5.272	0.879
CC	28	0	45.036	5.337	1.009

Difference -1.952

t = -1.462 with 62 degrees of freedom.

95 percent two-tailed confidence interval for difference of means: -4.622 to 0.717

Two-tailed P-value = 0.149

The difference in the mean values of the two groups is not great enough to reject the possibility that the difference is due to random sampling variability. There is not a statistically significant difference between the input groups (P = 0.149).
One-tailed P-value = 0.0744

The sample mean of group CC does not exceed the sample mean of the group OK by an amount great enough to exclude the possibility that the difference is due to random sampling variability. The hypothesis that the population mean of group OK is greater than or equal to the population mean of group CC cannot be rejected. (P = 0.074).
Power of performed two-tailed test with alpha = 0.050: 0.302

The power of the performed test (0.302) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.
Power of performed one-tailed test with alpha = 0.050: 0.421

The power of the performed test (0.421) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.