Final Report

Pilot quantification of the effects of wave action on eastern oyster reefs in the Matanzas River portion of the Northern Coastal Basin of Florida.

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ABSTRACT

Eastern oyster reefs in the Matanzas River portion of the Northern Coastal Basin of Florida have been declining in recent years. With an increase in recreational activity, anthropogenic forces have been introduced in the form of wave action caused by boat wakes, wind driven and storm waves. The overall objectives from this study were to quantify the health of oyster reefs in the northern coastal basin of Florida that are exposed to chronic wave action as compare to adjacent oyster reefs that are not chronically exposed to wave action. To quantify the health of each reef the shell length of both live and dead oysters was measured, total live and dead oysters were counted, as was mean clusters per meter squared. The t-test statistic was used to evaluation for significance, and correlation coefficient analysis was used to identify the relationship between live oysters, dead oysters, sediments, and oyster clusters. Six pairs of reefs were identified, each pair having one reef exposed to wave action and one reef that was not exposed. It was found that those oyster reefs that were not exposed to wave action were healthier, had more live oysters and larger clusters. The exposed oyster reefs had fewer clusters and more dead oysters. Based on the data, it is apparent that wave action has a detrimental effect on oyster reefs.

INTRODUCTION

Like many oyster reef habitats statewide (Beck et al. 2010; Havens et al. 2013), oyster reefs in the Matanzas River are in decline (Garland and Kimbro 2015). Unfortunately, recovery of these reefs may be significantly impaired for several reasons. Diminished capability for synchronous spawning due to low population numbers (Ergmassen et al. 2012), increased predation pressure (Petes et al. 2012), and the gradual loss of optimal surfaces for spat colonization due to erosion and landward migration of oyster cultch from boat wakes (Meade 1969; Waldbusser et al. 2013). The ecosystem services associated with oyster reefs are numerous and well documented (Lai et al. 2020; Bayraktarov et al. 2016). These services include habitat for numerous benthic species, water filtration, and nutrient storage, as well as providing a valuable fishery, shoreline stabilization and erosion control for which significant economic value is attributed by coastal communities (Barbier et al. 2010; Grabowski et al. 2012).

Loss of oyster reefs exacerbates the problem of shoreline erosion from all sources, boat wake exposure, wind-driven waves, and storm events (Scyphers et al. 2011). This erosion issue is further compounded by sea level rise and coastal development pressure leading to further degradation of critical habitat and ecosystem services (Gittman et al. 2015). Shoreline features that are particularly vulnerable to erosion include unvegetated shorelines, soft sand or marsh sediment shorelines, and areas where oyster reefs were formerly established but have been degraded due to erosion processes (Ridge et al. 2017). Due to concerns for future impacts of sea level rise, shoreline erosion and loss of unarmored shoreline habitat are paramount (Andersen et al. 2014). Further, increased human activities, such as recreational and commercial boating in estuaries is altering the natural hydrodynamics of these areas.

Recent research has shown that oyster reefs have a wave exposure threshold of approximately 500 J/m (Theuerkauf et al. 2017), a threshold that can be reached with high energy boat wakes (Wall et al. 2005; Herbert et al. 2018). As recreational boating activity continues to increase the potential for impacts to oyster reef persistence and proliferation likewise increases (Manis et al. 2015). Thus understanding the effects of chronic boat wake exposure is necessary to inform management of these resources.

This project addresses a fundamental question about oyster reef stability and thus shoreline resiliency by comparing wave exposed reef health to that of immediately adjacent reefs in more quiescent waters to determine characteristics of wave impacts on reef health. It cannot be overstated that oyster habitat and populations are of critical significance to the health and functioning of estuarine ecosystems (Day et al. 2013) and thus determining effects of anthropogenic physical stresses will benefit management in the development of strategies to protect this resource. The objective of this work is to identify six pairs of oyster reefs that provide the opportunity to compare health indices of reefs exposed to chronic wave action to proximal reefs that do not experience this stress to determine physical and biological effects of wave.

METHODS

Study Site

Six reef pairs (12 total reefs) were identified in southern St. Johns County and northern Flagler County on the Matanzas River (Figure 1, Table 1). At each site (Figures 2A-F), a reef exposed to direct wave energy from boat traffic and wind driven waves was paired with a nearby reef protected from wave energy. In all cases the distance between the exposed reef and the protected reef was less than 100m.

Figure 1. *Study reef pairs (red stars) located in southern St. Johns and northern Flagler counties on the Matanzas River. Each site represents a wave exposed and a wave protected reef.*

Site	*Latitude*	*Longitude*	*Wave Exposure*
Reef 1	29°40’19” N	81°13’2” W	Protected
Reef 1	29°40’19” N	81°13’4” W	Unprotected
Reef 2	29°43’28” N	81°14’43” W	Protected
Reef 2	29°43’29” N	81°14’45” W	Unprotected
Reef 3	29°43’42” N	81°14’50” W	Protected
Reef 3	29°43’42” N	81°14’51” W	Unprotected
Reef 4	29°38’54” N	81°13’2” W	Protected
Reef 4	29°38’53” N	81°13’4” W	Unprotected
Reef 5	29°46’12” N	81°15’41” W	Protected
Reef 5	29°46’12” N	81°15’42” W	Unprotected
Reef 6	29°46’16” N	81°15’51” W	Protected
Reef 6	29°46’17” N	81°15’51” W	Unprotected

Table 1. Latitude and Longitude (D M S) of all sites. Reef pairs are denoted as protected and unprotected referring to wave exposure status. Note: reefs within pairs are within 100m of each other in all cases.

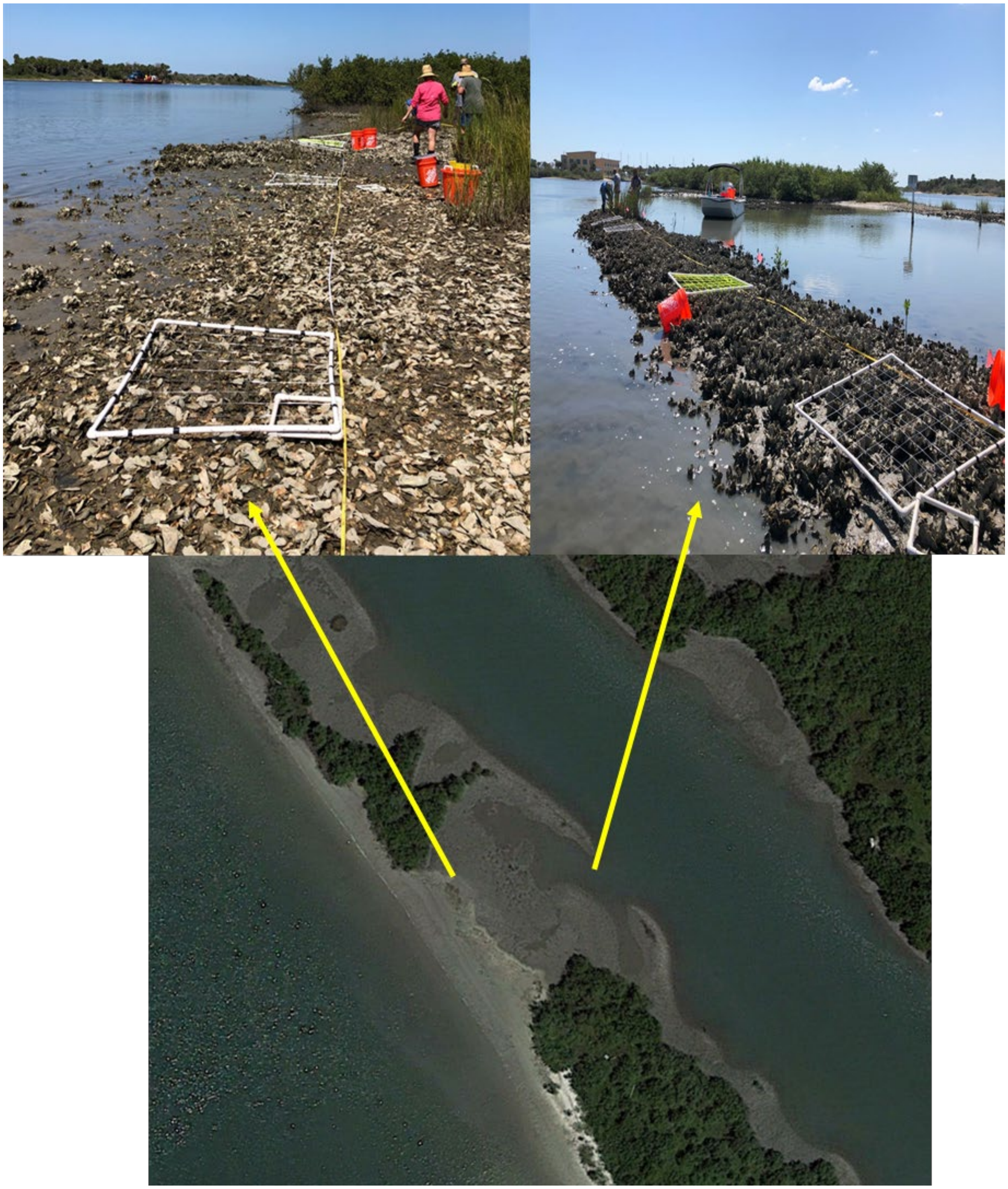

Figure 2A. *Reef pair 1 (Greenburg Key) located just north of the Whitney Laboratory for Marine Biosciences. Wash over induced transport of sediments and shell material by waves is clearly indicated on the wave exposed reef (left).*

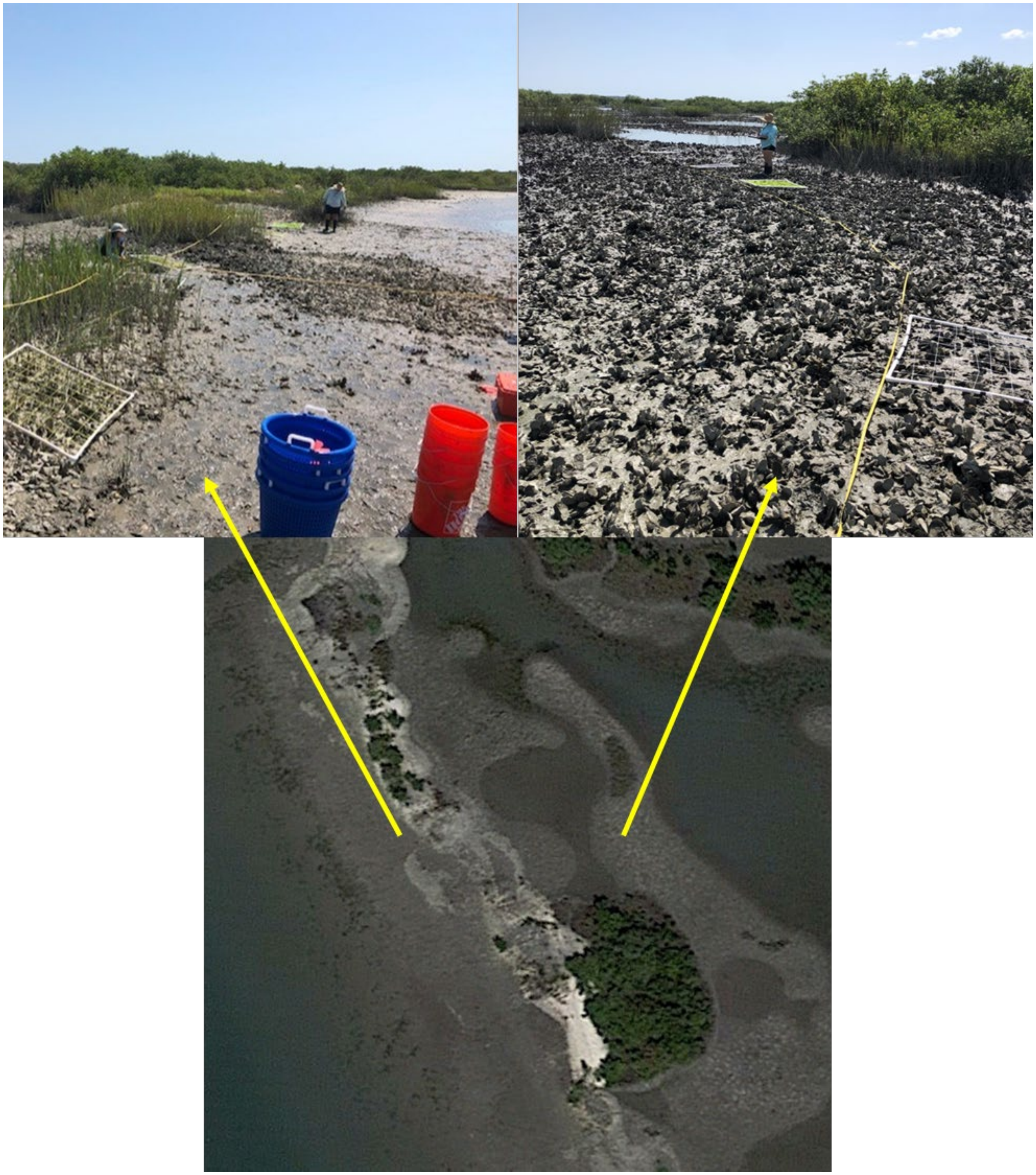

Figure 2B. *Reef pair 2 (Matanzas Inlet East) located just north of the Matanzas Inlet on the east side of the Matanzas River. Wash over induced transport of sediments and scouring of shell material by waves is clearly indicated on the wave exposed reef (left).*

Figure 2C. *Reef pair 3 (Matanzas Inlet East 2) located just north of the Matanzas Inlet on the east side of the Matanzas River. Wash over induced transport of sediments and scouring of shell material by waves is indicated on the wave exposed reef but to a lesser extent than observed previously (left).*

Figure 2D. *Reef pair 4 (Whitney Lab South) located south of Marineland on the west side of the Matanzas River. Wash over induced transport of sediments and scouring of shell material by indirect waves is moderately indicated on the wave exposed reef (right).*

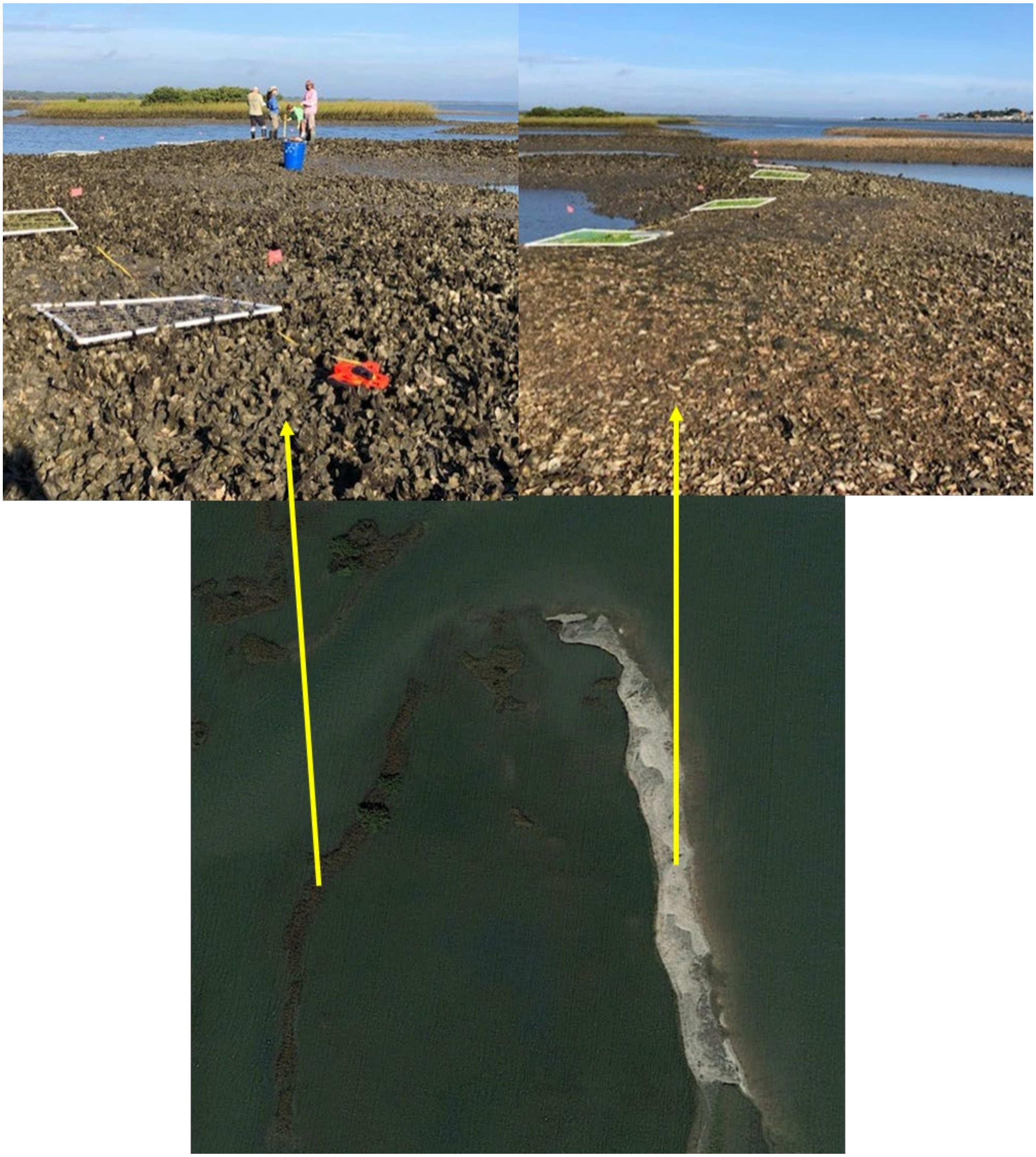

Figure 2E. *Reef pair 5 (Matanzas Inlet West) located just north of the Matanzas Inlet on the west side of the Matanzas River. Wash over induced transport of sediments and scouring of shell material by waves is indicated on the wave exposed reef (right).*

Figure 2F. *Reef pair 6 (State Road 206) located west of Crescent Beach on the west side of the Matanzas River. Significant wash over induced transport of sediments and scouring of shell material by waves is indicated on the wave exposed reef (right).*

Reef Assessments

Surveys of paired reefs were conducted in July and August of 2019 following the Oyster Condition Assessment Protocol (Walters et al. 2015) with minor exceptions. Briefly, previously chosen sites for assessment were visited in associated pairs and each pair was assessed in the same day to avoid potential temporal variation due to weather or storms. At each reef, a 30 meter transect was established across the densest portion of the reef and with a minimal distance of 5m needed for a reef to be acceptable for assessment. Reefs were mapped by hand and photographed with transect tape included and any notable characteristics of the site recorded along with GPS location. Along the transect, five 1m x 1m quadrats were deployed using a random number generator to determine the distance on the transect for quadrat positioning. Percent cover of live and dead oysters was determined in each quadrat by using grid frames (1m x 1m pvc frame with 8 monofilament lines per side giving a 10cm spaced grid with 100 intersections) on which live, dead or sediment was recorded at each intersection. Within each quadrat, the number of oyster clusters consisting of 5 or more live oysters was also recorded. Within each quadrat a 0.25x 0.25m quadrat was deployed in the left corner and reef thickness determined by measurement of distance from highest cluster point to the sediment. Then within the small quadrat, all clusters and shell were excavated to depth of 15 cm and depth of burial recorded. Once rinsed, all live oysters within the shell and clusters were measured. Any additional fauna captured in the small quadrat were identified and recorded. Reef height was determined by laser level from highest point on reef to the point at which oyster density dropped below 10 percent cover. Slope was determined by dividing the reef height by the distance from highest point to nearest edge. Reef complexity (roughness) was determined by laying a 5m chain across the densest portion of the reef and measuring the distance covered by the chain. The distance covered divided by the total length equals the rugosity or roughness coefficient. Lower numbers suggest high levels of topographic variation while numbers approaching one indicate smoothing (lack of clusters) of the reef surface.

RESULTS

Mean shell length (Figure 2) for oysters in protected reefs ranged from 42.80mm to 58.88mm. Mean shell length for oysters in unprotected reefs ranged from 29mm to 55.13MM. Overall, mean oyster shell length on protected reefs was larger than on unprotected reefs.

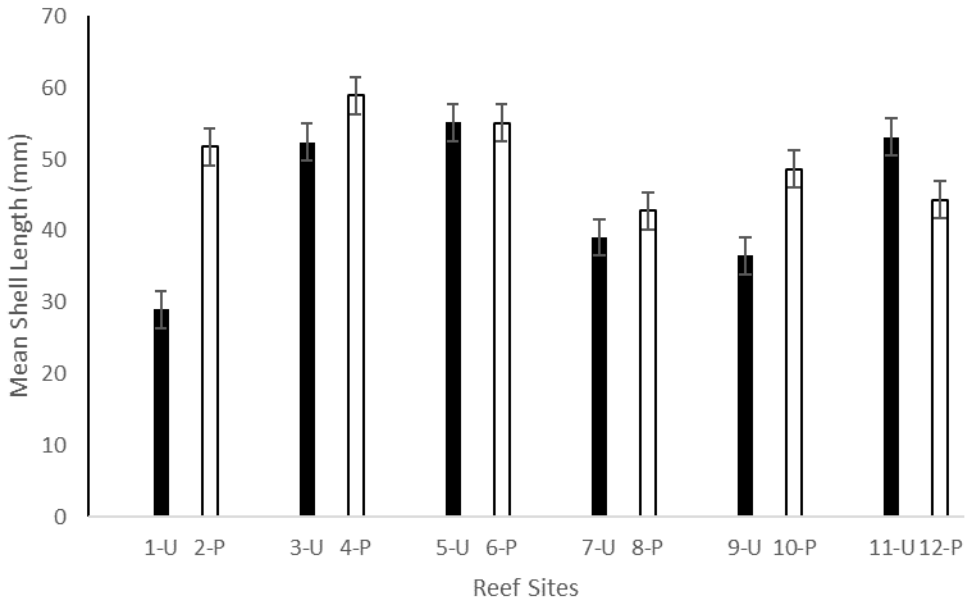

Figure 2. Mean shell length for all reef sites.

Total live oyster count (Figure 3) was much higher for protected reefs as opposed to unprotected reefs. Protected reef oyster count ranged 209 to 250, while unprotected reef oyster count ranged from 59 to 122. The difference observed was significant.

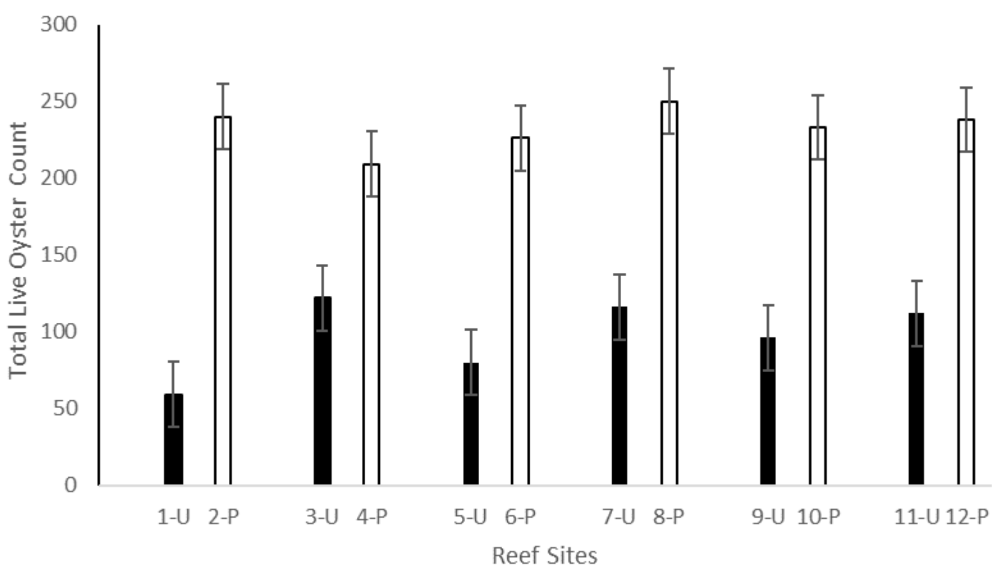

Figure 3. Total live oyster count for all reef sites.

Dead oyster count (Figure 4) was also observed for protected and unprotected oyster reefs. Dead oyster count on protected reefs ranged from 36 to 88, while dead oysters on unprotected reefs ranged from 73 to 92.

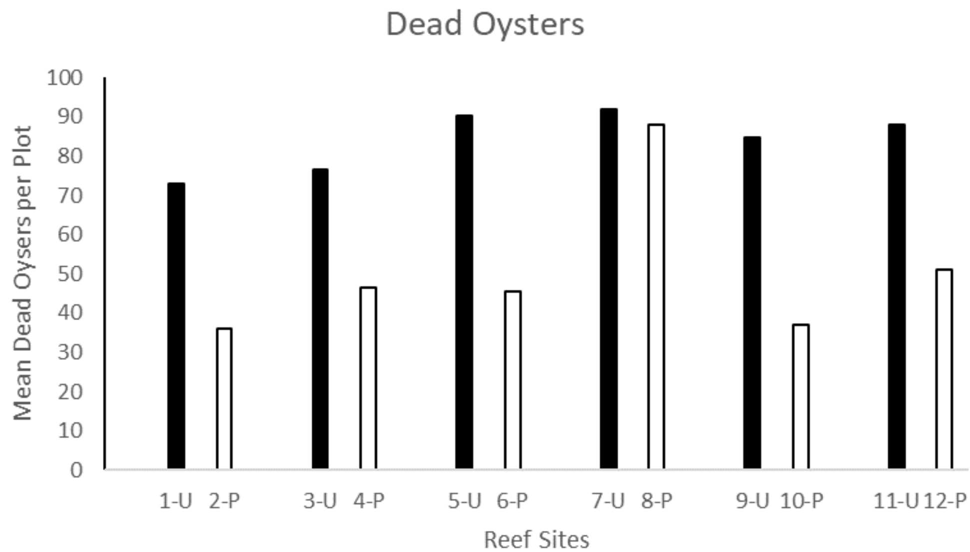

Figure 4. Total dead oysters for each reef site.

Mean oyster clusters (Figure 5) for protected and unprotected oyster reefs were quantified. An oyster cluster is defined as five or more oysters connected in the form of a cluster. For protected oyster reefs the mean oyster clusters ranged from 8 to 35. For unprotected oyster reefs, the range was from 4 to 16.

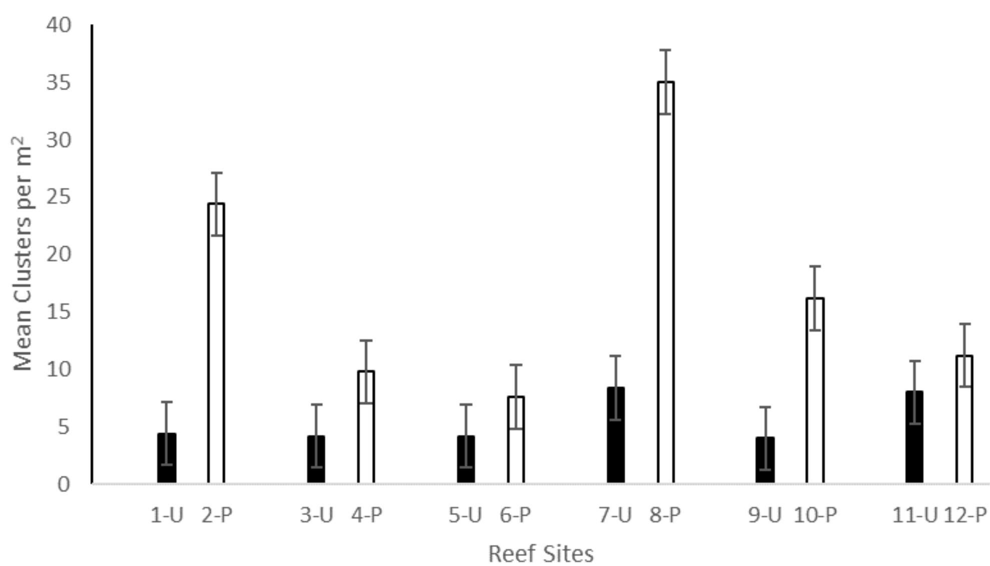

Figure 5. Total mean oysters' clusters for each for each reef site.

Reef dimensions were taken (Table 1). Measurements included reef height, reef slope, roughness coefficient, for protected and unprotected oyster reefs. Overall, reef height for protected oyster reefs were higher than unprotected, but not significantly. In some instances, the unprotected reef was higher. This is explained by the random selection of reefs.

Site	*Latitude*	*Longitude*	*Wave Exposure*
Reef 1	29°40’19” N	81°13’2” W	Protected
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Reef 3	29°43’42” N	81°14’51” W	Unprotected
Reef 4	29°38’54” N	81°13’2” W	Protected
Reef 4	29°38’53” N	81°13’4” W	Unprotected
Reef 5	29°46’12” N	81°15’41” W	Protected
Reef 5	29°46’12” N	81°15’42” W	Unprotected
Reef 6	29°46’16” N	81°15’51” W	Protected
Reef 6	29°46’17” N	81°15’51” W	Unprotected

Table 1. Reef dimensions.

Correlations (Table 2, Table 3) were performed on protected and unprotected reefs. For protected reefs there was a negative correlation of live oysters to dead oysters, and live oysters to sediment. In this instance, as live oysters increased, dead oysters and sediments decreased, as was expected. Neither correlation was very strong. There was a positive correlation between live oysters and oyster clusters as expected, however, it was not a strong correlation. Meaning as live oysters increased, oyster clusters increased. The weak correlation can be explained in that oyster clusters have live oysters, but no limit was placed on the number of oysters in a cluster. A cluster could have two oysters or 20 oysters, and it was still counted as one cluster.

Protected

Live Oyster to Dead Oyster	Live Oyster to Sediment	Live Oyster to Clusters
-0.500115915	-0.705779425	0.309764092

Table 2. Correlation coefficient for protected oyster reefs, live oyster to dead oyster, sediment, and clusters.

Unprotected

Live Oyster to Dead Oyster	Live Oyster to Sediment	Live Oyster to Clusters
-0.842399995	0.406086498	0.70326585

Table 3. Correlation coefficient for unprotected oyster reefs, live oyster to dead oyster, sediment, and clusters.

T-tests (Table 4) were performed on the data for clusters, live oysters, and dead oysters to see determine if the data occurred by chance. A t-test p-value, as shown below, are all less than 5%, which gives us over a 95% confidence that the data is not random.

T-Test, Protected to Unprotected

Clusters	Live Oysters	Dead Oysters
3.94%	2.23%	0.62%

Table 4. T-test, protected to unprotected for clusters, live oysters, and dead oysters.

DISCUSSION

Oyster habitat and resources are being lost in the Northern Coastal Basin due to disturbance events such as episodic storms, chronic boat wake exposure, and wind wave action. The differences between wave exposed and wave protected oyster reef health have not yet been quantified by standard methods of assessment. Thus, the need for protective measures for oyster resources from wave stressors has not been documented. The findings in this study showed larger overall mean oyster shell length from oysters on protected reefs (Figure 2). The number of live oysters on protected reefs as opposed to unprotected reefs (Figure 3). The number of live oysters on protected reefs (Figure 4) as opposed to unprotected reefs was significant. Live oysters ranged from 73 to 92 on protected reefs, and from 32 to 88 on unprotected reefs. Restoration of lost oyster populations is a necessary step in protection of our fragile coastal ecosystems lest there be no resources to manage or protect. Perhaps more impactful to the goal of improving protection and management of coastal resources, is the use of education and hands-on learning to engage the public and foster a sense of ownership and appreciation of these imperiled resources (Conrad and Hichey 2011). Citizen science programs are gaining popularity for good reason, they are very successful in engaging the public and increasing scientific, and in this case environmental, literacy and appreciation for our coastal ecosystems (Beck et al. 2011; Cigliano et al. 2015). Although this work is a standalone contribution to understanding erosion and degradation of oyster resources, the information and knowledge gained from this work will be incorporated to an existing oyster restoration initiative at the Whitney lab that engages citizen scientists and the broader public routinely. We optimize the potential to improve coastal resource stewardship through hands-on volunteer and citizen science projects that provide educational opportunities while solving immediate shoreline erosion problems in the Matanzas River. Further, we leverage our ties to several local groups to both increase our outreach for the program and expand the informative impacts of our activities through integration with these organizations' educational programs. By investigating sedimentary records of storm over wash from coastal ponds, Brandon et al. determined significant increase in storm derived over wash and sedimentation due to loss of oyster reefs to over harvest.   The dimensions of the paired oyster reefs showed the protected reefs were larger, healthier than it is paired unprotected reef (Table 2). Loss of reefs to boat wake exposure increases risks of coastal flooding from extreme events (Brandon et al. 2016)

CONCLUSION

This study focused on overall health of oyster reefs, centering the effect of wave action on oyster reefs, and therefore reef stability. Six pairs of oyster reefs were selected, with one of the pair exposed to wave action, and the other not exposed. The results of the study showed that those reefs that were not exposed to wave action were healthier and more robust. The protected reefs had more live oysters, less dead oysters, overall larger oysters, and more oyster clusters. The protected reefs were, based on reef height, slope, and roughness coefficient, healthier than non-protected oyster reefs. Based on the data collected, the reefs that are protected from wave action are healthier than those oyster reefs that are unprotected.

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