Introduction

In July of 2024, Marine Discovery Center completed construction of our new living shoreline. With an opportunity to reverse decades of paving over paradise, MDC and partners removed a large area of impervious pavement, reshaped the shoreline, and converted the shoreline into productive coastal habitat. This project removed 13,000 square feet of parking lot and hardened shorelines to restore them into a living shoreline and interpretive trail. The project was made possible with funds from Disney Conservation Fund and partnerships with Florida Fish and Wildlife Conservation Commission, St. Johns River Water Management District, and the City of New Smyrna Beach.

The living shoreline project included the use of 3 different types of biodegradable breakwaters: Oyster Reef Breaks (ORB), Cement/jute volcanoes, and Pervious Oyster Shell Habitat (POSH). In addition to the breakwaters, native intertidal vegetation, Spartina alterniflora and Spartina patens, were planted along the shoreline behind these breakwaters. Two of these breakwaters, ORB and POSH, are relatively new in our area, and their performance overtime is unknown. To understand their success and performance overtime, MDC has begun a new community science program, Living Shoreline Monitoring, where volunteers assist in conducting research on these breakwaters and overall habitat health. Volunteers conduct transect surveys along each variable, to assess percent cover, density and height of organisms present, and changes in slope of the shoreline. The results of this monitoring can be used to determine the success of breakwaters in buffering wake energy, protecting the shoreline/planted vegetation, allowing for sediment accretion (increasing slope) and providing suitable substrate to promote growth of intertidal organisms. This will in turn provide restoration partners in our area with the necessary information to determine if these breakwaters are suitable for restoration projects in similar environments.

Methods

*****_Methods for this study were adapted from Dr. Melinda Donnelly with University of Central Florida._

The living shoreline is monitoring 1-month post stabilization, 3-month post stabilization, and quarterly after 3 months. Three replicate line transects are run perpendicular to the shoreline per breakwater variable (ORB, control, volcano, and POSH). The transect lines run from subtidal shoreline (2m beyond the breakwater at low tide), through the intertidal zone, and up to the terrestrial zone (up to a maximum of a 10m long transect). At each transect, habitat type (seagrass, oysters, intertidal vegetation), presence and density of invertebrates, water depth, and slope of the shoreline are accounted for. A 0.25m^2 quadrat is used to measure the percent cover of each habitat type at 1m intervals and documenting the substrate type present at 25 points per quadrat (point intercept method). Any vegetation present within quadrats were identified to the species and a shoot count was recorded. Heights were taken for all vegetation within the quadrats including planted or naturally recruited species. The number of fiddler crab burrows, live oysters, and other mobile/sessile invertebrates were recorded when present in the quadrat. Additionally, live oysters were measured to evaluate class sizes. The slope of the shoreline was measured using the width of intertidal habitat and change in height between the lower and upper boundary.

Breakwaters were also analyzed for displacement, damage, and recruitment of oysters or other organisms.

Slope

Quarter 3 monitoring of the living shoreline showed an increase in slope from quarter 1 monitoring across all breakwaters. The rip rap shoreline had the largest slope value of 0.317. The section of shoreline with cement-jute volcanoes had the next largest slope value of 0.185. ORB and POSH slopes followed with a slope value of 0.17 and the control area presented the lowest slope value of 0.167.

The slopes of the rip rap and POSH areas had the greatest percent increase from quarter 1 monitoring to quarter 2 monitoring. The POSH slope showed the greatest percent increase across all variables, with a slope increase of 16.17%. The rip rap area experienced a 14.22% increase in slope, and the control area had a slope increase of 9.09%. The ORB and volcanoes showed the lowest percent increase between the two monitoring periods, with the ORB at 3.29% increase and the volcanoes at 2.05% increase.

A greater decimal indicates a steeper slope while a lesser decimal indicates a more gradual slope. The rip rap was utilized during the initial construction to stabilize an already steep shoreline. The control area had the most gradual slope across all variables, but also experienced a much higher percent increase in slope. This is likely due to the success of the planted vegetation when the shoreline was constructed. The marsh grasses planted, *Spartina alterniflora* and *Spartina patens*, have significantly increased in both density and height from initial planting, likely securing and accreting sediment over time. Further monitoring is necessary to determine if sediment accretion is occurring. The control area contains a kayak launch that has not yet been open to the public, minimizing the amount of foot traffic in this section of the shoreline. The POSH materials were not deployed until 1 week prior to quarter 2 monitoring, thus unlikely having an impact on the significant slope increase. This section of shoreline has many well-established mangroves which were left untouched during shoreline construction and may likely have contributed to the increase in slope.

Hurricane Milton came through the area between quarter 1 and 2 monitoring which made alterations to this shoreline. Much of the shoreline washed down the slope, adding sediment and partially burying some materials such as the volcanoes. This could have contributed to the increased slope across all variables and may explain why volcanoes experienced the lowest percent increase between monitoring periods.

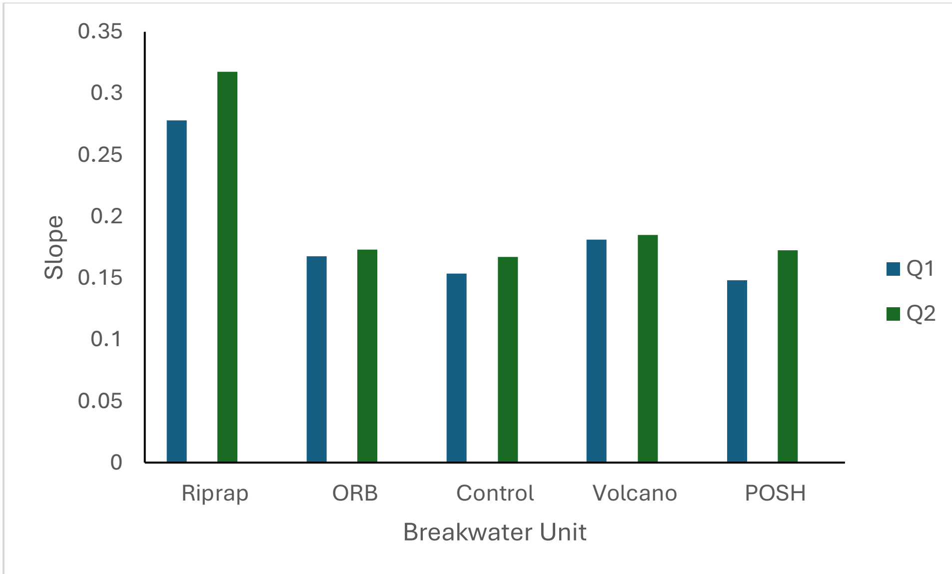

Figure 1. Change in slope between quarter 1 and 2 monitoring periods.

Percent Cover

The percent cover of live oysters across all variables was present between 0 and 3 meters along the transect. The control area had the greatest percent cover of oysters at 0m with 13.33% and decreased in coverage through 2m. POSH had the highest percent cover of oysters at 1m of 13.33%, with oysters present from 0-3m. The volcanoes only had a precent cover of oysters present at 0m and 1m with similar percentages of 6.66% at 0m and 5.33% at 1m. There was 0% coverage of oysters observed at the ORB covered shoreline. An overall negative percent change in oyster coverage was observed from Q1 to Q2 across all breakwaters. The control and POSH shorelines had the smallest negative change in percent cover of oysters, both averaging -80% change between monitoring periods.

The accessibility to oysters was significantly limited during the Q2 monitoring. Monitoring was conducted just a couple of weeks following hurricane Milton which brought heavy rains. Water levels were significantly higher than normal at the low tide, which created a limitation for volunteers. Visibility was poor and volunteers heavily relied on sense of touch to measure percent cover. This may provide a reasonable explanation for the significant decrease in oyster coverage recorded between monitoring periods.

The percent cover of planted vegetation was observed between 5m and 7m along the transect across all variables. POSH and volcanoes had vegetation present in every meter along the transect, with the highest vegetation percentage of 70.66% recorded at POSH-3m. POSH and volcanoes had the highest amount of vegetation coverage across all breakwaters. ORB, control, and volcano shorelines had at least one quadrat which displayed a percent cover of planted vegetation greater than 30% between 5m and 7m, whereas POSH displayed less than 30% among these transect distances.

A minimal negative percent change in the percent cover of vegetation was observed across ORB, control, and volcano areas between Q1 and Q2. A negative percent change of the percent cover of vegetation was observed between 5m and 7m of the POSH area. The greatest change observed here was a -75.71% change of vegetated area at POSH-5m. The greatest increase in percent cover of vegetation was observed in the control shoreline at 5m with an increase of 550%. The volcanoes also resulted in a 466.66% increase in percent cover of vegetation at 4m. The greatest percentage increase of percent cover of vegetation observed in ORB and POSH was 100% at ORB-9m and 70.66% at POSH-3m.

During construction of the living shoreline, any established mangroves present within the construction area were left alone. This left the POSH and volcano shorelines with a significantly greater density of mature black and red mangroves than the control and ORB shorelines. This difference is likely to explain why POSH and volcanoes had a percentage of vegetation observed at every distance along the transect. This is also likely to explain the greatest recorded vegetation percentage of 70.66% at POSH-3m as black mangrove pneumatophores and red mangrove roots are dense among mature mangrove trees. Having the presence of mature mangroves along these shorelines is likely to increase the number of dead branches, leaf material, and fallen trunks present along the transect area. Dead vegetative material is included as vegetation in this data set because it can still provide habitat.

The less than 30% cover of vegetation between POSH 5-7m is likely due to competition between the planted salt marsh grasses and mature adult mangroves. The dense, well established, black and red mangroves in the POSH shoreline minimize the amount of space for the marsh grasses to proliferate. This may have also contributed to the -75.71% change of vegetated area at POSH-5m. Hurricane Milton also may have contributed to the negative percent change in vegetation through sediment and mulch washout. During Q2 monitoring, transect distance decreased from 10m to an average of 7m due to the washout of the pine straw mulch used in the upland landscaping. During monitoring, many plants, including planted *Spartina patens*, were found smothered and recovered following monitoring.

Unlike the variables, the control shoreline lacks mangrove canopy and the presence of mature adult mangroves. The significant light availability and lack of competition between planted *Spartina alterniflora* with other vegetative species may explain the 550% increase in the percent cover of vegetation at 5m. This area of shoreline has not seen significant foot traffic yet around where the kayak launch was placed. It is possible that future open use of this launch and increased foot traffic in the area may impact this growth in future monitoring periods.

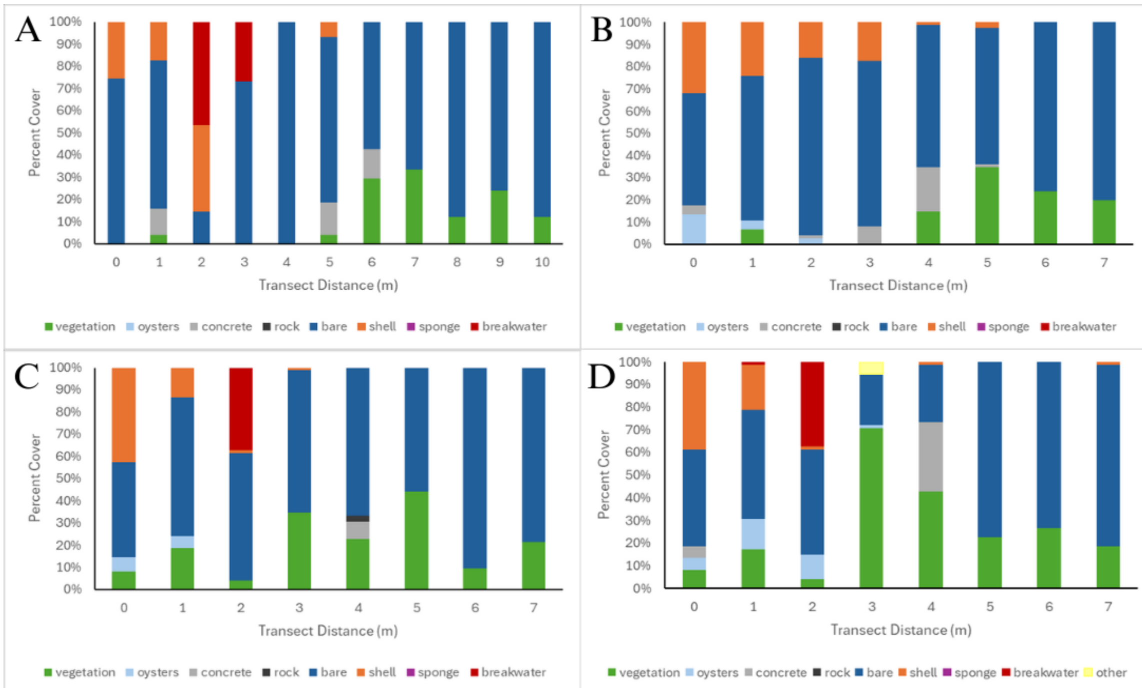

Figure 2. Percent coverage recorded along the transects at ORB (A), Control (B), Volcano (C), and POSH (D) shorelines.

	Vegetation				Oysters			
Transect Distance	ORB	Control	Volcano	POSH	ORB	Control	Volcano	POSH
0	0	0	8	8	-100	2	-78.2609	-77.7778
1	4	6.666667	18.66667	62.5	-100	-80	-76.4706	-33.3333
2	0	0	4	-40	0	-87.5	-100	-76.4706
3	0	0	34.66667	70.66667	-100	-100	-100	-97.7273
4	0	37.5	466.6667	42.66667	-100	-100	-100	-100
5	50	550	3.125	-75.7143	-100	-100	0	-100
6	-33.3333	20	-53.3333	-62.2642	0	0	0	0
7	66.66667	-25	-11.1111	-48.1481	0	0	0	0
8	0				0			
9	100				0			
10	28.57143				0			

Figure 3. Percent change (%) in the percent cover of vegetation and oysters between quarter 1 and 2 monitoring periods.

Planted Vegetation

Spartina alterniflora and *Spartina patens* densities were recorded between 5-7m along the transect for Control, Volcano, and POSH shorelines while the ORB had densities recorded between 5-10m. Overall, *Spartina alterniflora* had the highest densities at 5m and 6m across all variables. The highest density recorded across all variables was 45.66 shoots/0.25m^2 at volcano-5m, but the density significantly decreased at 6m with a density of 5.33 shoots/0.25m^2. POSH had the next highest *Spartina alterniflora* density of 30.33 shoots/0.25m^2 at 6m. The control shoreline had a maximum density of 26.66 shoots/0.25m^2 at 5m, and steadily decreased until 7m. The ORB shoreline had a maximum density of 18.33 shoots/0.25m^2 at 6m. No *Spartina alterniflora* was recorded from 8-10m at the ORB shoreline.

No *Spartina patens* shoots were observed at 5m across all variables. *Spartina patens* shoots were observed from 6-7m for the control and volcano shorelines, at 7m only at the POSH shoreline, and from 6-10m at the ORB shoreline. The highest *Spartina patens* density recorded across all variables was 22.33 shoots/0.25m^2 at control-7m. All variables showed highest densities at 7m along the transect.

Between Q1 and Q2 monitoring periods, a positive percent increase in *Spartina alterniflora* and *Spartina patens* densities were observed across all variables and most transect distances. All positive increases were greater than 100%. The highest percent increases in *Spartina alterniflora* density from Q1 to Q2 were observed at ORB and POSH shorelines. ORB had a density increase of 3,500% at 7m and POSH had a density increase of 3,033.33% at 6m. The control shoreline has significant percent increases of density between 5 and 7 meters with the highest recorded at 2,566.66% at 5m. The volcano shoreline experienced a maximum percent increase of 1,270% at 5m. Negative percent changes were observed at POSH and Volcano shorelines at 7m, and ORB shoreline at 5m and 8m.

Spartina patens density experienced almost all positive percent changes of greater than 100% between Q1 and Q2 monitoring periods. Positive percent changes began at 6m for control and volcano shorelines, where the control shoreline recorded the highest percent increase in density of 1,300%. The POSH shoreline experienced the next highest percent increase in density with 533.33% at 7m. Only one negative percent change was observed at ORB-9m of -36.84%.

The density data suggests the *Spartina alterniflora* has its healthiest range between 5m and 7m along the transect. A lower, water ward boundary is shown at 5m where *Spartina alterniflora* is not detected in quadrats less than 5m along the transect across all variables. This is likely because of physiological limits such as salt tolerance with the presence of a high tide. Competition in some areas of the shoreline can also explain this lower boundary. Established adult mangroves are going to have an advantage over the grasses as they are much older and more well established. An upper boundary becomes evident at 7m as no more *Spartina alterniflora* is observed in quadrats greater than 7m along the transect. With the *Spartina alterniflora* that is observed at this distance, densities are significantly lower. The upper boundary is more likely related to competition than to physiological limits.

The more upland species, *Spartina patens*, typically occupies the area just behind the *Spartina alterniflora*, and the data shows that here. The *Spartina patens* is first seen at Control-6m and Volcano-6m. Greater densities are seen at 7m across all variables. 7m is where our *Spartina alterniflora* densities experience a decline in density. In the same way, *Spartina patens* are limited in their lower boundary by physiological limits such as salt tolerance and explains why we see no *Spartina patens* at 5m and only 2 sites recorded densities at 6m. *Spartina patens* densities were observed from 7-10m at the ORB shoreline, however the washout from hurricane Milton prevented a longer transect at the other variables. Had washout not occurred, *Spartina patens* densities would likely have been observed up to 10m.

In just 2 months, the planted *Spartina spp*. have experienced significant increases in density. The overwhelming positive percent increases in density across all variables is evidence that the *Spartina spp*. are successfully establishing themselves in this new area. This establishment has shown increases in the slope of the shoreline, thus protecting the area from erosion by high energy boat wake. The significant percent increase in density from Q1 to Q2 could be a combination of successful buffering of energy by the installed wave breaks, space for *Spartina spp.* rhizomes to spread and root, and the flowering and seed production of *Spartina spp.* The negative percent change of *Spartina alterniflora* between monitoring periods experienced at ORB, Volcano, and POSH shorelines are likely due to competition and canopy cover of mangroves at the lower boundary and smothering by hurricane washout at the upper boundaries.

Spartina alterniflora height was highest at the ORB shoreline at 1.17m. Control and POSH shorelines had the next tallest with heights of 0.93m at Control shoreline and 0.83m at POSH shoreline. The lowest recorded height for Spartina alterniflora was 0.72m at the volcano shoreline. *Spartina patens* height was highest at both ORB and control shorelines, with a height of 0.78m for both. POSH shoreline has a Spartina patens height of 0.7m and the volcano shoreline had the lowest recorded height of 0.5m.

All variables experienced a positive percent increase in Spartina alterniflora height between Q1 and Q2 monitoring. Two variables saw a percent increase in Spartina alterniflora height greater than 100%. The control shoreline had the greatest percent increase in height of 138.02% and the ORB shoreline saw a 105.22% increase in height. The least percent increase in Spartina alterniflora height was the POSH shoreline with an increase of 8.46% between monitoring periods.

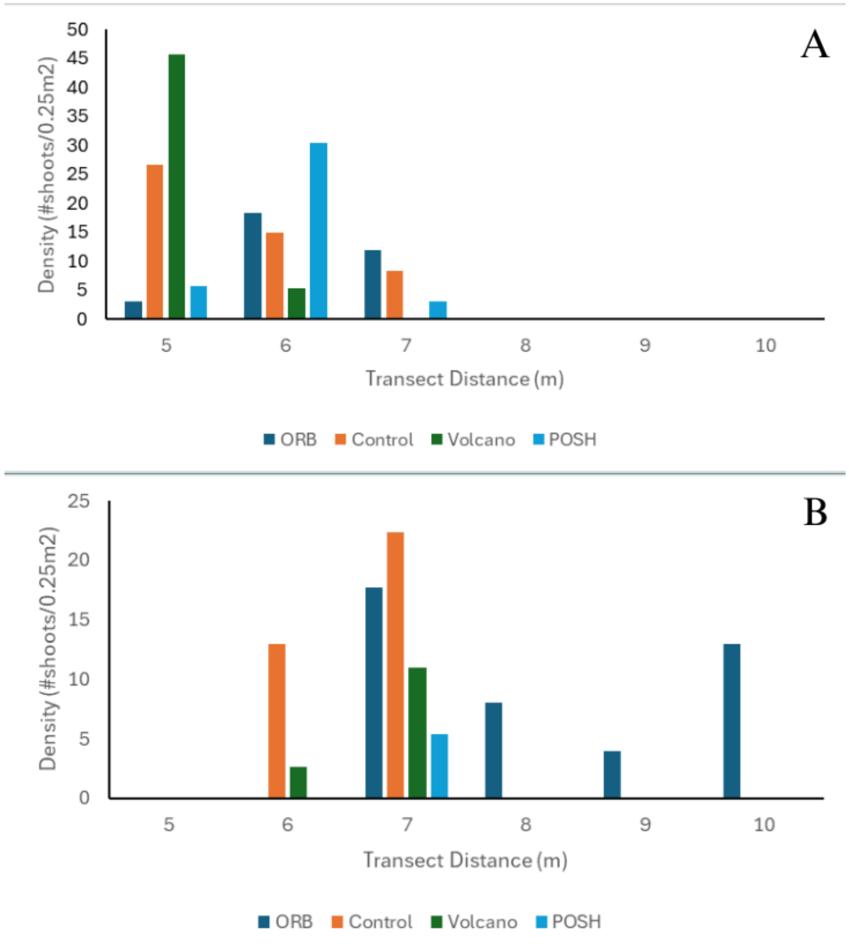

Figure 4. Density of planted vegetation, *Spartina alterniflora* (A) and *Spartina patens* (B), along a transect at ORB, Control, Volcano, and POSH shorelines.

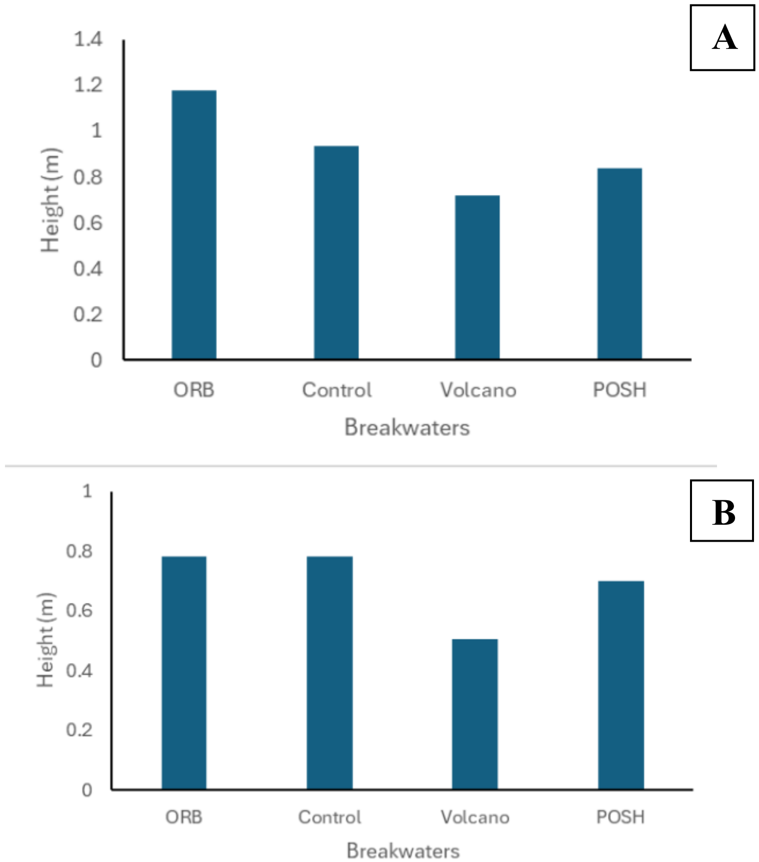

Figure 5. Height (meters) of the tallest *Spartina alterniflora* (A) and *Spartina patens* (B) shoots at ORB, Control, Volcano, and POSH shorelines.

	Spartina alterniflora				*Spartina patens*			
Transect Distance (m)	ORB	Control	Volcano	POSH	ORB	Control	Volcano	POSH
5	-10	2566.667	1270	566.6667	0	0	0	0
6	243.75	1025	128.5714	3033.333	0	1300	266.6667	0
7	3500	177.7778	-100	-10	152.381	131.0345	230	533.3333
8	-100				100			
9	0				-36.8421			
10	0				11.42857			

Figure 6. Percent change of Spartina alterniflora and Spartina patens densities along ORB, Control, Volcano, and POSH shorelines between quarter 1 and 2 monitoring periods.

Breakwater	*Spartina alterniflora*	*Spartina patens*
ORB	105.22876	6.393862
Control	138.02243	13.98747
Volcano	68.717047	-36.0847
POSH	8.4625323	-4.19708

Figure 7. Percent change in *Spartina alterniflora* and *Spartina patens* height along ORB, Control, Volcano, and POSH shorelines between quarter 1 and 2 monitoring periods.

Oyster Density

Oyster densities were observed between 0m and 5m along the transect for all breakwaters. The greatest density of oysters was observed at Volcano-1m with 12 individuals per $0.25m^2$. The volcano shoreline presented the greatest overall oyster density along the transect. POSH shoreline presented the next greatest oyster density for the overall transect. The greatest recorded density for POSH shoreline was 8.33 individuals/$0.25m^2$ at 1m. Control and ORB shorelines recorded the lowest oyster densities for the overall transect. The greatest oyster density observed at the Control shoreline was 6 individuals/$0.25m^2$ at 1m and the ORB shoreline was 3.33 individuals/$0.25m^2$ at 5m.

Very few spat or adult oysters were observed across all breakwaters. The POSH shoreline had the greatest number of spat observed with 6 individuals and Control shoreline had the least with 3 individuals. The control shoreline had the greatest number of adult oysters observed with 13 individuals and ORB shoreline has the least with 0 individuals observed. Juveniles were the most observed oyster class size across all breakwaters. POSH observed the most with 53 juvenile oysters. The volcano and control shorelines observed 41 juveniles, and the ORB shoreline observed the least with 11 juveniles. Oyster class size and density was not measured during the quarter 1 monitoring, therefore there is no percent change between monitoring periods to report on.

The oyster density data suggests the intertidal level ranges between 0 and 5 meters along our transect. The POSH and volcano shorelines likely observed the greatest oyster densities due to their position on the shoreline. Both sections of the shoreline are located on the southern end where it is slightly more protected from boat wakes. These sections of shoreline are on the border of a small cove and see less boat wake than the ORB and control shorelines. This would prevent the displacement of oysters in the water. In the same manner, ORB and control shorelines take the brunt of boat wake as boats pass through. It is likely their low oyster densities are caused by displacement. For all shorelines, the water was significantly higher than the normal low tides, due to hurricane Milton. Higher water levels make it much more difficult for volunteers to access the oysters along the 0-2m transect distances. It is possible oysters simply could not be reached to be included in the data set. The ORB observed the lowest density of oysters, likely due to the design of the breakwater. Oysters have been observed underneath the unit and in between the crevices of each piece. These were inaccessible and not visible within the quadrat and therefore not included in the data set. It is possible after many more generations, we will see greater recruitment on the surface of the ORB breakwater. The breakwaters have not been in the water for long and may also explain the low oyster densities and few numbers of spat observed. The greatest number of adult oysters were observed at the control shoreline, and these oysters have likely been structured here prior to the completion of the shoreline. Some established oyster clusters had to be moved out of the way of the breakwaters when placed in the water to prevent suffocation. This may explain why fewer adults were observed across all breakwaters. Further monitoring is necessary to determine impact of breakwaters on oyster density and oyster class size variation.

	Oyster Density (individuals/0.25m^2)			
Transect Distance	ORB	Control	Volcano	POSH
0	0	4	8.666667	7.666667
1	0	6	12	8.333333
2	0.333333	3.666667	1	3
3	1.666667	1	0	1.666667
4	0	0.333333	0	0
5	3.333333	1	0	0

Figure 8. Oyster densities recorded along ORB, Control, Volcano, and POSH shorelines.

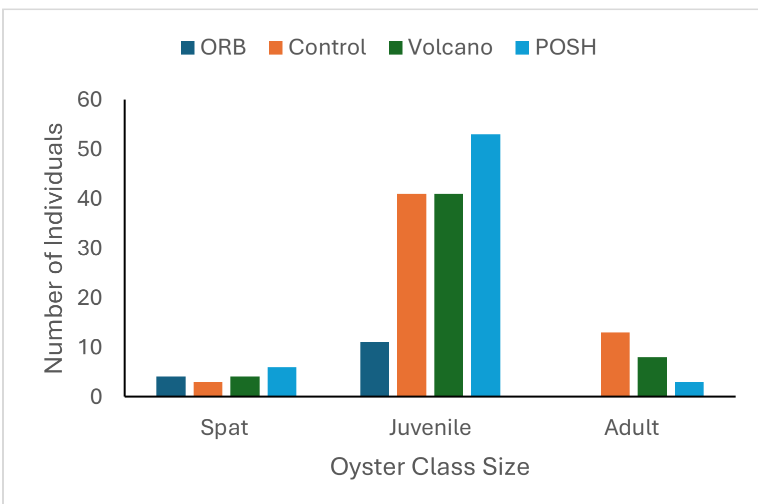

Figure 9. Oyster class sizes observed across ORB, Control, Volcano, and POSH shorelines. Spat are defined as 0-25mm, juveniles as 25-74mm, and adults as >75mm.