2018 Oyster Reef Monitoring Report

Analysis of Data from Large-Scale Sanctuary Oyster Restoration Projects in Maryland Collected from Fall 2018 through Spring 2019

March 2020

Produced in partnership with the Maryland Oyster Restoration Interagency Workgroup under the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team

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Definitions

2012 cohort: Reefs that received restoration treatment in 2011 and 2012, and—per Oyster Metrics and tributary plans—were monitored in 2015, three years post restoration, and again in 2018, six years post restoration.

2015 cohort: Reefs that received restoration treatment in 2015, and—per Oyster Metrics and tributary plans—were monitored in 2018, three years post restoration.

Average planned reef height: The amount of reef-building material placed onto a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.

Fossil shell: Consolidated fossil oyster shell material from Florida used as a base to construct reefs. This is oyster shell cemented into a fossilized limestone, and is a true fossil, mined from 30 to 40 feet under dry land, as opposed to the Chesapeake Bay dredged shell. See Figure 21.

Mixed shell: A mixture of scallop, conch, and clam shell from processing plants.

Oyster Metrics: Success criteria for restored oyster reefs targeted for restoration under the 2014 Chesapeake Bay Watershed Agreement. These are defined in the report "Restoration Goals, Quantitative Metrics and Assessment Protocols for Evaluating Success on Restored Oyster Reef Sanctuaries,"[1] http://www.chesapeakebay.net/channel_files/17932/oyster_restoration_success_metrics_final.pdf. See Table 3 for description of the six reef-level criteria.

Premet reef: Reefs that were assumed to have met the Oyster Metrics density target criteria (50+ oysters per m^2) when surveyed prior to commencement of large-scale restoration efforts. However, the prerestoration data on some reefs was at an insufficient resolution to determine definitively whether or not the reefs met the density target. Thus, it is an assumption that the reefs in fact met the density success metric at that time, but it is not certain. Because these reefs were assumed to have met the oyster density success criterion, they received no initial restoration treatment. These reefs are monitored every three years, as are other reefs, to determine appropriate adaptive management needs.

Reference reefs: Reefs left unrestored (untreated) to serve as comparisons to restored (treated) reefs. Typically, these would be called 'control' reefs, but they are not true controls, as it is not possible to ensure that restoring nearby reefs would not influence these reference reefs. That is, these reefs might receive larvae from nearby restored reefs, so the term 'reference reefs' is used. Per oyster population data collected prior to commencing large-scale restoration work in Harris Creek, the reference reefs did not meet the 50 oysters per m^2 Oyster Metrics target success criterion.

Second-year-class seeding: A second planting of spat-on-shell some reefs receive approximately four years after initial restoration. This is intended to ensure that each reef has at least two year classes, which is a reef-level success criterion per Oyster Metrics. It can also help ensure that reefs meet the oyster density and biomass Oyster Metrics success criteria. Second-year-class seedings are called for in each river's oyster restoration tributary plan. If a reef shows higher-than-expected oyster density when monitored three years post restoration, and a second year class is present, a second-year-class seeding may not be required.

Seed-only reefs: Reefs treated only with hatchery-produced oyster seed (spat-on-shell). No base reef-building substrate was added prior to seeding. This treatment was generally used on reefs where the prerestoration population was five oysters per m^2 or greater, but fewer than 50 oysters per m^2 (see Harris Creek Tributary Plan[2], Little Choptank Tributary Plan[3], and Tred Avon Tributary Plan[4] for detailed description of how the Workgroup determined treatment type for each reef).

Sentinel reefs: A subset of the restored reefs that are monitored annually (rather than only three years and six years after restoration, which is the standard for other restored reefs).

Spat-on-shell: Hatchery-produced juvenile oysters attached to the shells of dead oysters. Shell typically comes from shucking houses.

Stone substrate reefs: Reefs constructed using a type of stone that is geologically classified as amphibolite. The stone was graded to fit through a six-inch mesh screen. See Figure 21. These reefs were then seeded with spat-on-shell.

Stone reefs topped with mixed shell: Reefs constructed from a stone base, then capped with mixed shell and seeded with spat-on-shell.

Stone reefs topped with fossil shell: Reefs constructed from a stone base, then capped with fossil shell and seeded with spat-on-shell.

Substrate + seed reefs: Reefs treated with reef-building substrate, generally to a height of six inches to one foot above the surrounding soft bottom. Substrate used for the 2015 cohort was either Florida fossil shell or stone capped with mixed shell. Substrate placement was followed by planting with hatchery-produced spat-on-shell. Substrate-and-seed treatment type was generally used where prerestoration oyster populations were below five oysters per m^2, or where sonar surveys found no evidence of shell.

Table 1: Description of restoration treatment types for reefs monitored in 2018

Treatment Name	Reef-building Substrate Added?	Substrate Material	Cap Material	Reef seeded?
Seed only	No	None	None	Yes (spat-on-shell)
Mixed shell	Yes	Mixed shell (clam, conch, and whelk)	None	Yes (spat-on-shell)
Stone	Yes	Amphibolite (stone)	None	Yes (spat-on-shell)
Stone topped with mixed shell	Yes	Amphibolite (stone)	Mixed shell (clam, conch, and	Yes (spat-on-shell)
Stone topped with fossil shell	Yes	Amphibolite (stone)	Fossil shell	Yes (spat-on-shell)
Fossil shell	Yes	Fossil shell	None	Yes (spat-on-shell)
Reference*	No	None	None	No
Premet**	No	None	None	No

*Did not meet oyster density success criteria prior to restoration; would typically require restoration, but none was undertaken so reefs could serve as reference sites.

**Assumed to have met the oyster density success criteria prior to restoration, so no restoration activities undertaken.

Executive Summary

Background and Context

The 2014 Chesapeake Bay Watershed Agreement[5] includes a goal to restore oyster populations in ten Chesapeake Bay tributaries by 2025. This has generally been interpreted as five tributaries in Maryland and five in Virginia. In Maryland, partners including the National Oceanic and Atmospheric Administration (NOAA), U.S. Army Corps of Engineers' Baltimore District (USACE), Oyster Recovery Partnership (ORP), and the Maryland Department of Natural Resources (DNR) are working to achieve this goal through the Maryland Interagency Oyster Restoration Workgroup (hereafter, the Workgroup). The Workgroup is convened under the Sustainable Fisheries Goal Implementation Team of the Chesapeake Bay Program.

In Maryland, Harris Creek was the first tributary selected for large-scale oyster restoration, followed by the Little Choptank and Tred Avon rivers. A set of oyster restoration success criteria, commonly known as the Chesapeake Bay Oyster Metrics[1], was developed by scientists and resource managers prior to implementing restoration work. There are six Oyster Metrics success criteria. This report describes the success of each reef relative to these criteria: oyster density, oyster biomass, multiple year classes, shell budget, reef height, and reef footprint (Table 3).

For each of the first three rivers selected in Maryland, partners developed tributary plans[2,3,4] to guide restoration. These plans describe tributary-specific oyster restoration goals, including the locations within a given tributary where restoration was to take place.

Consistent with the tributary plans and the Oyster Metrics success criteria, partners collaboratively monitor each restored reef three years, and again six years, after restoration treatment. This report describes the results of 2018 monitoring of:

- 2012 cohort reefs (reefs restored in 2011 and 2012, and monitored in 2018, six years post restoration);
- 2015 cohort reefs (reefs restored in 2015, and monitored in 2018, three years post restoration);
- Reference reefs; and
- Sentinel reefs (monitored annually).

Data and analyses in this report may be used by restoration partners to help inform what adaptive management measures, if any, should be taken on each of the monitored reefs. It will also be used to guide restoration in other tributaries.

Key Results from 2018 Monitoring

This section describes some of the key results from 2018 monitoring. Full results are in tables throughout the document and appendices.

Table 2 shows key results from Harris Creek and Little Choptank River. Tred Avon River only had sentinel reef monitoring in 2018; the oldest reefs there will receive three-year postrestoration monitoring in 2019. Information on Tred Avon sentinel reefs is in Appendix D.

Table 2: Key results from 2018 Harris Creek and Little Choptank River monitoring.

Tributary	Reef type	# reefs monitored	Met minimum threshold success criteria for oyster density	Met target success criteria for oyster density	Met minimum threshold success criteria for oyster biomass	Met target success criteria for oyster biomass	Met success criteria for multiple year classes of oysters	Met success criteria for shell budget	Met success criteria for reef footprint	Met success criteria for reef height
Harris Creek	2012 cohort (6-year-old reefs)	12	100%	33%	100%	42%	100%	67%	100%	100%
	2015 cohort (3 year-old reefs)	33	97%	87%	97%	97%	100%	TBD	29 reefs monitored; of those, 100% met metric.	30 reefs monitored; of those, 100% met metric.
	Reference Reefs (untreated)	4	75%	0%	75%	0%	100%	100%	TBD	TBD
Little Choptank	2015 cohort (3 year-old reefs)	6	100%	100%	100%	100%	100%	TBD	100%	100%
	Reference Reefs (untreated)	3	100%	67%	100%	67%	100%	TBD	TBD	TBD

Patterns in the 2018 monitoring data include:

- In Harris Creek, the highest oyster densities among three-year-old reefs were found on stone-base reefs, stone-base with mixed shell reefs, and stone-base with fossil shell reefs. The lowest densities (besides reference reefs) were found on seed-only reefs. (See Table 12 in Appendix C.) However, it is unclear if these differences are due to reef treatment type, differences in sampling gear method, or a combination (see Box 1).
- In Little Choptank River, three-year-old reefs consisted of stone-base reefs (1 of 5 reefs), fossil-shell-base reefs (3 of 5 reefs), and stone-base reefs with fossil shell (1 of 5 reefs). All oyster densities found on these reefs were higher than 107 oysters per m^2. (See Table 14 in Appendix C.) There was no clear relationship between oyster density and the reef base materials monitored in 2018 in Little Choptank River (stone, fossil shell, or a combination). All of these reefs were monitored with divers.
- In both tributaries and across all reef age classes, oyster density tracked closely with oyster biomass.
- In both Harris Creek and Little Choptank River, large numbers of oysters were found attached to stone substrate material. (See Appendix C, Tables 12 and 15, columns 'Average live density on stone' and 'Average live density on shell', and associated standard error columns.) In many cases (ex: reefs H67, H78, and H92, among others), substantially more oysters were found on stone material than on shell. This suggests that stone is a suitable settlement substrate for juvenile oysters and that oysters are setting on these reefs in sizable quantities. Oysters found on oyster shell could be either the result of natural recruitment or hatchery production; oysters found on stone are solely the result of natural recruitment.

Key Results from 2015-2018 Monitoring

In 2018, the oldest reefs (restored in 2011 and 2012) turned six years old. Per Oyster Metrics, this is the year at which each reef can be considered successfully restored if it meets each of the six success criteria. Of the 12 reefs that turned six years old in 2018 (all in Harris Creek):

- 100% met the minimum threshold criteria for oyster density
- 100% met the minimum threshold success criteria for oyster biomass
- 100% met the success criteria for multiple year classes
- 67% met the success criteria for shell budget
- 100% met the success criteria for reef footprint
- 100% met the success criteria for reef height

All 12 of the reefs that turned six years old in 2018 received a second-year-class seeding four years post-restoration, as was planned in the Harris Creek Oyster Restoration Tributary Plan[2]. See Table 10 in Appendix C for information on second-year-class seedings on each reef.

Section 3: Results Summary has additional results, including information about how all three-year-old reefs monitored between 2015 and 2018 fare relative to the Oyster Metrics success criteria. Section 4: Discussion shows graphed results.

Note on Sampling Gear Used on Different Types of Reefs

For structural metrics (reef height; reef footprint): Data collection and analysis methods were identical for all reef restoration treatment types (ex.: reference reef, seed-only reefs, mixed-shell-base reefs, stone-base reefs, etc.).

For biological metrics (oyster density, oyster biomass, multiple year classes, and shell volume): Methods used to select sampling sites, analyze samples, and assess success relative to each metric were identical for all reefs. However, two types of gear were used to collect samples, depending on reef substrate type. Divers were used to collect saples from reefs with substrate materials that were not amenable to patent tong sampling (stone and fossil shell substrate reefs). Patent tongs were used to collect samples from all other reef types (seed only, mixed-shell base, reference, and premet reefs) because it is more cost efficient than using divers. Previous field comparisons[6] on natural oyster reefs revealed no difference in sampling efficiency between oyster densities estimatd using divers and those estimated using patent tongs. A similar field comparison on restored reefs[7] is nearing completion as of the drafting of this report. Because two different gear types were used, it is not appropriate to directly compare oyster density and biomass on reefs sampled with patent tongs versus divers.

Section I: Introduction and Background

1.1 Policy Drivers, Oyster Metrics Success Criteria, and Oyster Restoration Planning

The 2014 Chesapeake Bay Watershed Agreement[5] oyster outcome calls for restoring oyster populations in 10 Chesapeake Bay tributaries by 2025. The Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (Fisheries GIT) is charged with working to achieve this goal. Driven by Executive Order 13508 (Chesapeake Bay Protection and Restoration) from 2009, some work toward tributary-scale oyster restoration was under way even before the Chesapeake Bay Watershed Agreement was signed. The Fisheries GIT had convened the Chesapeake Bay Oyster Metrics Workgroup, which, in its 2011 report "Restoration Goals, Quantitative Metrics and Assessment Protocols for Evaluating Success on Restored Oyster Reef Sanctuaries"[1] (hereafter, Oyster Metrics), established Bay-wide, science-based, consensus success criteria for oyster restoration to be tracked three years and six years following restoration efforts.

Table 3: The Oyster Metrics reef-level success criteria.

Biological Metrics	Oyster density	Minimum threshold = 15 oysters per m^2 over 30% of the reef area Target = 50 oysters per m^2 over 30% of the reef area
	Oyster biomass	Minimum threshold = 15 grams dry weight per m^2 over 30% of the reef area Target = 50 grams dry weight per m^2 over 30% of the reef area
	Multiple year classes	Presence of multiple year classes on the reef, as defined by oysters in at least two of the following size classes: market (>76 mm); small (40-75 mm); spat (<40 mm)
	Shell budget	Stable or increasing shell budget on the reef
Structural Metrics	Reef footprint	Stable or increasing reef footprint compared to baseline
	Reef height	Stable or increasing reef height compared to baseline

Once these success criteria were adopted, the Fisheries GIT convened interagency workgroups in Maryland and Virginia to plan restoration work in each state, in consultation with appropriate partners. In Maryland, the Maryland Oyster Restoration Interagency Workgroup (hereafter, the Workgroup) is chaired by the National Oceanic and Atmospheric Administration (NOAA) and includes members from the Maryland Department of Natural Resources (DNR), Oyster Recovery Partnership (ORP), and the U.S. Army Corps of Engineers' Baltimore District (USACE).

The first three Maryland tributaries selected for large-scale oyster restoration were Harris Creek, Little Choptank River, and Tred Avon River. These were selected primarily based upon their status as oyster sanctuaries (areas where harvest of oysters is not allowed) as established by DNR in 2010, historic and ongoing presence of oysters, and whether current-day water-quality and benthic habitat conditions are suitable for oysters. The Workgroup developed oyster restoration tributary plans for each river[2,3,4] in consultation with a group of consulting scientists and the public. Restoration work is under way in all three tributaries. The upper St. Mary's and Manokin rivers have been selected as the fourth and fifth tributaries in Maryland.

1.2 Overview of Report Content

Consistent with the tributary plans for each river and the Oyster Metrics success criteria, partners collaboratively monitor each restored oyster reef three years, and again at six years, after restoration treatment. A subset of reefs (cohort) in Harris Creek and Little Choptank River have matured to either three years or six years, and in 2018 these underwent postrestoration monitoring. In Tred Avon River, only sentinel reefs were monitored, as no restored reefs have matured to three years.

Data and analysis for the 2012 cohort (six-year-old reefs), 2015 cohort (three-year-old reefs), and reference reefs are provided in the main body of this report. Information on sentinel reefs is in Appendix D. Table 4 shows which year each cohort was monitored and includes links to past monitoring reports. Table 5 describes which reefs were monitored in 2018 and which monitoring category they fell into. See the Definitions section for monitoring categories.

The 2015 cohort (three-year-old reefs) will be monitored again in fall 2021, per Oyster Metrics recommendations and each river's tributary plan. Additional cohorts will be monitored as they mature to three years old, and again when they are six years old. At six years, a determination will be made whether each reef can be considered successfully restored, per the Oyster Metrics criteria.

Table 4: Restoration cohort monitoring schedule and associated report links.

Monitoring Report Year	Monitoring Years Covered	Link to monitoring report
2015	2012 cohort 3-year monitoring	https://www.chesapeakebay.net/documents/2015_Oyster_Reef_Monitoring_Report.pdf
2016	2013 cohort 3-year monitoring	https://www.chesapeakebay.net/documents/2016_Oyster_Reef_Monitoring_Report_.pdf
2017	2014 cohort 3-year monitoring	https://www.chesapeakebay.net/documents/2017_Oyster_Reef_Monitoring_Report_.pdf
2018	2015 cohort 3-year monitoring; 2012 cohort 6-year monitoring	*This report*

Table 5: Reefs monitored in 2018.

	Harris Creek		Little Choptank River		Tred Avon River	
	# reefs	*acres*	*# reefs*	*acres*	*# reefs*	*acres*
2012 cohort (6-year-old reefs)	12	99.4	0	0	0	0
2015 cohort (3-year-old reefs)	33	91.02	6	34.11	0	0
Reference (untreated to serve as control)	4	10.72	3	7.75	0	0
Sentinel (monitored annually)	2	5.8	3	5.8	4	11.82

1.3 Availability Data Related to this Report

Geographic Information System (GIS) data relevant to this report are in the oyster restoration geodatabases for each tributary, available at https://www.habitat.noaa.gov/chesapeakebay/gis/Oyster_Restoration_Geodatabases/. In some cases, metadata and/or analyses are provided in the GIS geodatabases. These databases can be accessed using a GIS program or by downloading the free and open-source QGIS program, http://www.qgis.org/en/site/.

Site_ID numbers (used in the GIS geodatabases) were replaced with simpler reef numbers in this report for clarity. Site_ID numbers are consistent throughout the GIS geodatabases. Reef numbers can be cross-referenced with Site_ID numbers in the geodatabase using Table 6.

Table 6: Cross-reference list of Reef IDs used in this report and Geodatabase Site_IDs

Report Reef ID	Geodatabase Site_ID	Report Reef ID	Geodatabase Site_ID
H01	AltSub_104	H78	AltSub_53
H02	AltSub_106	H79	AltSub_55B
H03	Seed_02	H80	AltSub_58B
H04	Seed_08	H81	Seed_06
H05	Seed_46	H82	AltSub_63
H06	Seed_56	H83	AltSub_64B
H07	Seed_72	H84	Seed_65
H08	TREATMENT_1	H85	SS_66
H09	TREATMENT_2	H86	AltSub_67
H10	TREATMENT_3	H87	AltSub_68
H11	TREATMENT_4	H88	SS_69
H12	TREATMENT_5	H89	AltSub_77
H13	EXCEDES_GOAL_2012	H90	AltSub_78
H14	CONTROL_1	H91	AltSub_80
H15	CONTROL_3	H92	AltSub_81
H16	CONTROL_4	H93	AltSub_83
H17	CONTROL_2	H94	SS_84
H18	AltSub_20A	L001	SO_17
H61	AltSub_16B	L002	SS_02
H63	AltSub_22B	L005	SS_03
H64	AltSub_31B	L006	SS_11A
H65	AltSub_32	L007	SS_15
H66	AltSub_33	L008	SS_38B
H67	AltSub_35	L009	SS_70
H68	SS_36	L029	SS_18
H69	AltSub_37	L034	SS_25C
H70	AltSub_38	L052	CONT_SO_01
H71	AltSub_40	L053	CONT_SO_03
H72	AltSub_43A	L054	CONT_SO_02
H73	AltSub_43B	T01	SS_44
H74	AltSub_44	T02	SS_56
H75	AltSub_45	T04	SO_13
H76	Seed_50	T09	SS_46
H77	Seed_51		

1.4 Funding and Acknowledgements

Monitoring data for the biological success metrics (oyster density, oyster biomass, multiple year classes, and shell budget) were collected, managed, and analyzed by a combination of Paynter Labs at the University of Maryland, Versar, Inc., and ORP with funds from:

- A $130,000 award from NOAA to ORP, and
- A $148,063 programmatic agreement from USACE to ORP.

Data for the reef structural metrics (reef height and reef footprint) were collected and analyzed by the NOAA Chesapeake Bay Office. This report was drafted by NOAA, with guidance from the Maryland Interagency Oyster Restoration Workgroup. Results of these analyses will be used to document the status of restoration efforts, to guide adaptive management of these reefs, and to inform future oyster restoration efforts. Technical review of this report was provided by the Workgroup members and by additional technical reviewers, per NOAA research communications guidelines.

Section 2: Methods Summary

This section summarizes the data collection and analysis methods used in this report. For a full description of methods, see Appendix A: Methods for Data Collection and Analysis.

2.1 Summary of Biological Metrics Methods (oyster density, oyster biomass, multiple year classes, and shell budget)

Data to determine success relative to the four biological metrics were collected at the same time, using a stratified random survey design. Hydraulic patent tongs were used to sample on seed-only reefs, mixed-shell-base reefs, reference reefs, and premet reefs. Divers were used to sample on fossil-shell-base reefs, stone-base reefs topped with mixed shell, and stone-based reefs topped with fossil shell. Previous field comparisons[6] on natural oyster reefs revealed no difference in sampling efficiency between oyster densities estimated using divers and those estimated using patent tongs. A similar field comparison on restored reefs[7] is nearing completion as of the drafting of this report. Because two different gear types were used, it is not appropriate to directly compare oyster density and biomass on reefs sampled with patent tongs versus divers (see Box 1). Oyster density and oyster biomass information were standardized based on area sampled. See Appendix A for full description of methods.

2.2 Summary of Structural Metrics Methods (reef height, reef footprint)

Staff from the NOAA Chesapeake Bay Office conducted multibeam bathymetric (depth) surveys following the construction of substrate reefs, and again at three years and six years post restoration. Results were compared to determine persistence of reef height and footprint at three years and six years post restoration.

Sonar surveys were not conducted on seed-only reefs immediately following planting with spat-on-shell. Therefore, no comparison of reef height or footprint can be made at three years post-restoration on these reefs. Sonar data will be collected on these reefs when they are six years old, and will be compared with three-year data to determine success relative to the structural metrics. For six-year-old seed-only reefs, three-year postrestoration data was compared to six-year postrestoration data to determine success relative to the structural metrics.

See Appendix A for full description of methods.

2.3 Diagnostic Monitoring

In addition to monitoring to determine if reefs met the Oyster Metrics success criteria, information—primarily water-quality data and oyster disease data—was also collected to aid in diagnosing why reefs may have succeeded or failed. With funding from The Nature Conservancy, DNR monitored three water-quality stations on Harris Creek. NOAA maintains a vertical profiler on the Tred Avon River to collect water-quality data. All data from these stations is available on DNR's Eyes on the Bay website (mddnr.chesapeakebay.net/eyesonthebay). Salinity and dissolved oxygen were suitable for oysters throughout 2018. Disease data is available in DNR's 2018 Fall Survey Report, https://dnr.maryland.gov/fisheries/Documents/18ReptFinal.pdf.

2.4 Location of Monitored Reefs

Figures 1 and 2 show the locations of reefs monitored in 2018, along with reef numbers.

Figure 1: Map showing locations and numbers of reefs monitored in Harris Creek in 2018.

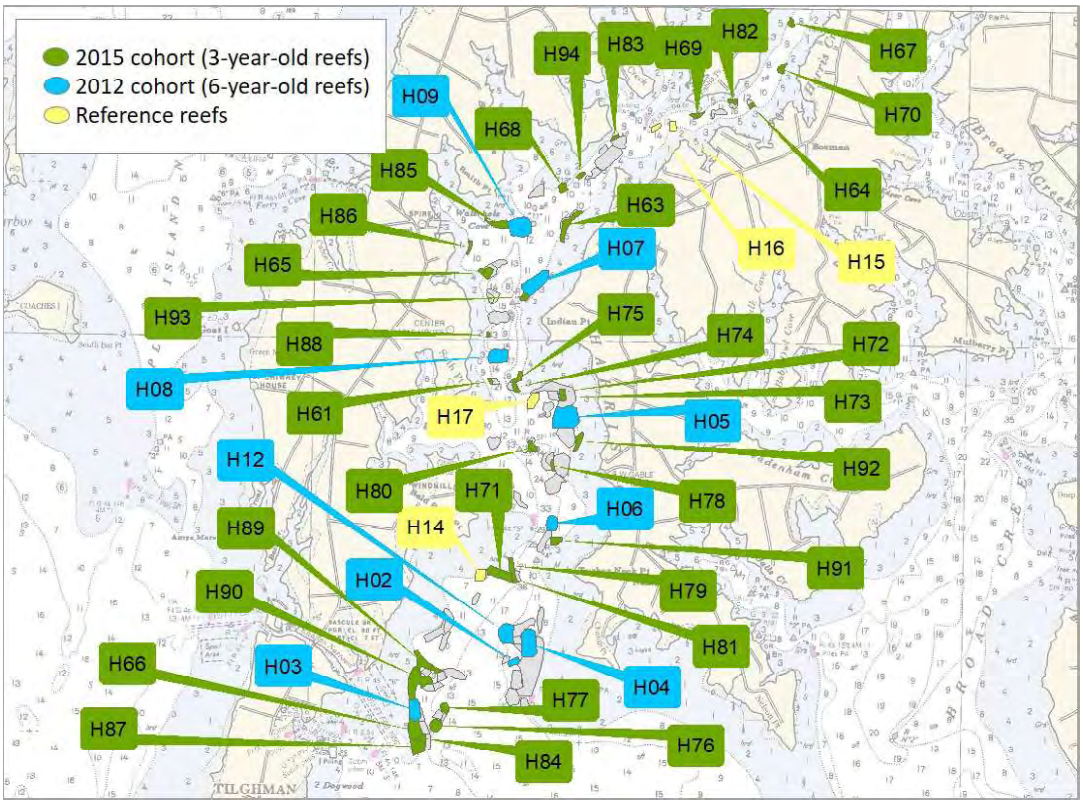
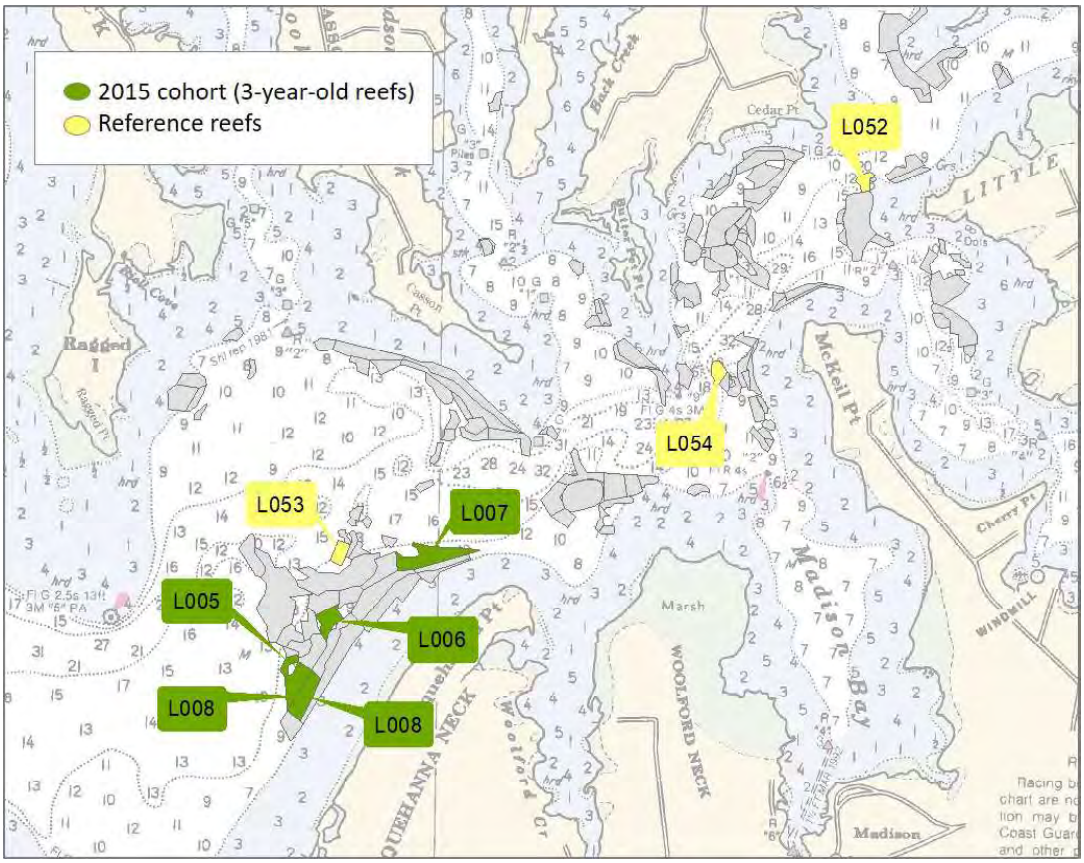


Figure 2: Map showing locations and numbers of reefs monitored in Little Choptank River in 2018.



2.5 Restoration Treatment and Monitoring Information

Tables 10 and 11 in Appendix C show the restoration treatment and sampling information for each reef.

Section 3: Results Summary

Below are summarized results for each tributary, by Oyster Metrics success criterion. More detailed information is provided in Appendix B (individual reports by reef including sonar images and histograms of oyster shell height distributions), Appendix C (Tables 12-17 provide detailed evaluations of each reef in relation to success criteria), and Appendix D (Information on the sentinel reefs).

3.1 Harris Creek Results Summary

Table 7 shows whether each Harris Creek reef monitored in 2018 meets each Oyster Metrics criterion.

Table 7 (at right): Harris Creek 2018 monitoring results, showing how each reef fared relative to each Oyster Metrics success criterion. 'Subs & Seed' is an abbreviation for 'substrate + seed.'

Monitoring Type	Report Reef ID	Restoration treatment	Substrate type added	Average planned reef height[a]	Year planted with spat (initial planting)	Second year class replanting	Fall 2018: Did reef meet minimum threshold density?	Fall 2018: Did reef meet target density?	Fall 2018: Did reef meet minimum threshold oyster biomass?	Fall 2018: Did reef meet target oyster biomass?	Is the shell budget stable/ increasing?	Are multiple year classes present?	Is reef footprint stable/ increasing?	Is reef height stable/ increasing?
Harris 2012 Cohort (6-year-old reefs)	H01	Substrate & Seed	Mixed Shell	12	2012	2017	Yes	No	Yes	No	No	Yes	Yes	Yes
	H02	Substrate & Seed	Mixed Shell	12	2012	2017	Yes	No	Yes	No	Yes	Yes	Yes	Yes
	H03	Seed Only	None	N/A	2012	2017	Yes	No	Yes	No	No	Yes	Yes	Yes
	H04	Seed Only	None	N/A	2012	2017	Yes	No	Yes	No	Yes	Yes	Yes	Yes
	H05	Seed Only	None	N/A	2012	2017	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
	H06	Seed Only	None	N/A	011 & 201	2017	Yes	No	Yes	No	No	Yes	Yes	Yes
	H07	Seed Only	None	N/A	2012	2017	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	H08	Seed Only	None	N/A	2012	2017	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	H09	Seed Only	None	N/A	2012	2017	Yes	No	Yes	No	Yes	Yes	Yes	Yes
	H10	Seed Only	None	N/A	2012	2017	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
	H11	Seed Only	None	N/A	2012	2017	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	H12	Seed Only	None	N/A	2012	2017	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Harris 2015 Cohort (3-year-old reefs)	H61	Substrate & Seed	Stone base with mixed shell	12	2014	2015	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H63	substrate & Seed	Stone base with mixed shell	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H64	Substrate & Seed	Stone base with mixed shell	12	2015	2015	Yes	Yes	Yes	Yes	TBD in 2021	Yes	TBD in 2021	TBD in 2021
	H65	Substrate & Seed	Stone base with mixed shell	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H66	Substrate & Seed	Stone base with fossil shell	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H67	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	TBD in 2021	TBD in 2021
	H68	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H69	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H70	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H71	Substrate & Seed	Stone	6	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H72	Substrate & Seed	Mixed Shell	12	2015	N/A	Yes	Yes	Yes	No	TBD in 2021	Yes	Yes	Yes
	H73	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H74	Substrate & Seed	Stone base with mixed shell	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H75	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H76	Seed Only	None	N/A	2015	2016	No	No	No	No	TBD in 2021	Yes	Yes	Yes
	H77	Seed Only	None	N/A	2015	N/A	Yes	No	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H78	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H79	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H80	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H81	Seed Only	None	N/A	2016	N/A	Yes	No	Yes	No	TBD in 2021	Yes	Yes	Yes
	H82	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H83	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H84	Seed Only	None	N/A	2015	N/A	Yes	No	Yes	No	TBD in 2021	Yes	Yes	Yes
	H85	Substrate & Seed	Stone	6	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H86	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H87	Substrate & Seed	Stone	12	2015	2016	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H88	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	TBD in 2021	TBD in 2021
	H89	Substrate & Seed	Stone base with fossil shell	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H90	Substrate & Seed	Stone	12	2015	2016	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H91	Substrate & Seed	Stone base with fossil shell	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H92	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	TBD in 2021	TBD in 2021
	H93	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	H94	Substrate & Seed	Stone	12	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
Reference	H14	None (control site)	None	N/A	N/A	N/A	Yes	No	Yes	No	Yes	Yes	No data in 2018	No data in 2019
	H15	None (control site)	None	N/A	N/A	N/A	Yes	No	Yes	No	Yes	Yes	No data in 2018	No data in 2019
	H16	None (control site)	None	N/A	N/A	N/A	Yes	No	Yes	No	Yes	Yes	No data in 2018	No data in 2019
	H17	None (control site)	None	N/A	N/A	N/A	No	No	No	No	Yes	Yes	No data in 2018	No data in 2019

3.2 Little Choptank River Results Summary

Table 8 shows how each Little Choptank River reef monitored in 2018 performed relative to each Oyster Metrics criterion.

Table 8: Little Choptank River 2018 monitoring results, showing how each reef fared relative to each Oyster Metrics success criterion. 'Subs & Seed' is an abbreviation for 'substrate + seed.'

Monitoring Type	Report Reef ID	Restoration treatment	Substrate type added	Year planted with spat (initial planting)	Second year class replanting	Fall 2018: Did reef meet minimum threshold density?	Fall 2018: Did reef meet target density?	Fall 2018: Did reef meet minimum threshold oyster biomass?	Fall 2018: Did reef meet target oyster biomass?	Is the shell budget stable/ increasing?	Are multiple year classes present?	Is reef footprint stable/ increasing?	Is reef height stable/ increasing?
Little Choptank 2015 Cohort (3-year-old reefs)	L02	Substrate & Seed	Fossil Shell	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2019	Yes	Yes	Yes
	L05	Substrate & Seed	Stone base with fossil shell	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	L06	Substrate & Seed	Stone	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	L07	Substrate & Seed	Fossil Shell	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	L08	Substrate & Seed	Fossil Shell	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
	L09	Substrate & Seed	Fossil Shell	2015	N/A	Yes	Yes	Yes	Yes	TBD in 2021	Yes	Yes	Yes
Little Choptank Reference Reefs	L52	None (control site)	None	N/A	N/A	Yes	No	Yes	No	TBD in 2020	Yes	No data in 2018	No data in 2018
	L53	None (control site)	None	N/A	N/A	Yes	Yes	Yes	Yes	TBD in 2020	Yes	No data in 2018	No data in 2018
	L54	None (control site)	None	N/A	N/A	Yes	Yes	Yes	Yes	TBD in 2020	Yes	No data in 2018	No data in 2018

3.3 Summary of Cumulative Monitoring Results, 2015-2018

Reefs constructed under the '10 tributaries' outcome were monitored in 2015, 2016, 2017, and 2018. Each reef was monitored at three years, and reefs constructed in 2011/2012 were monitored again at six years, post restoration. Summarized results for Harris Creek and Little Choptank River combined are in Table 9, and in Section 4: Discussion.

Table 9: Success of three-year-old and six-year-old reefs monitored in 2018, relative to each Oyster Metrics criteria (Harris Creek and Little Choptank River combined).

	% met minimum threshold density	% met target density	% met minimum threshold biomass	% met target biomass	% with multiple year classes	% with stable or increasing shell budget	% with stable or increasing reef footprint	% with stable or increasing reef height
6-year-old reefs (12 reefs, all in Harris Creek. All were sampled by patent tongs)	100%	33%	100%	42%	100%	67%	100%	100%
3-year-old reefs (98 reefs; 39 sampled by patent tongs and 59 sampled by divers)	96%	81%	96%	80%	100%	TBD at 6 year	73 reefs monitored; 100% of those successfully meet the metric	73 reefs monitored; 100% of those successfully meet the metric

Section 4: Discussion

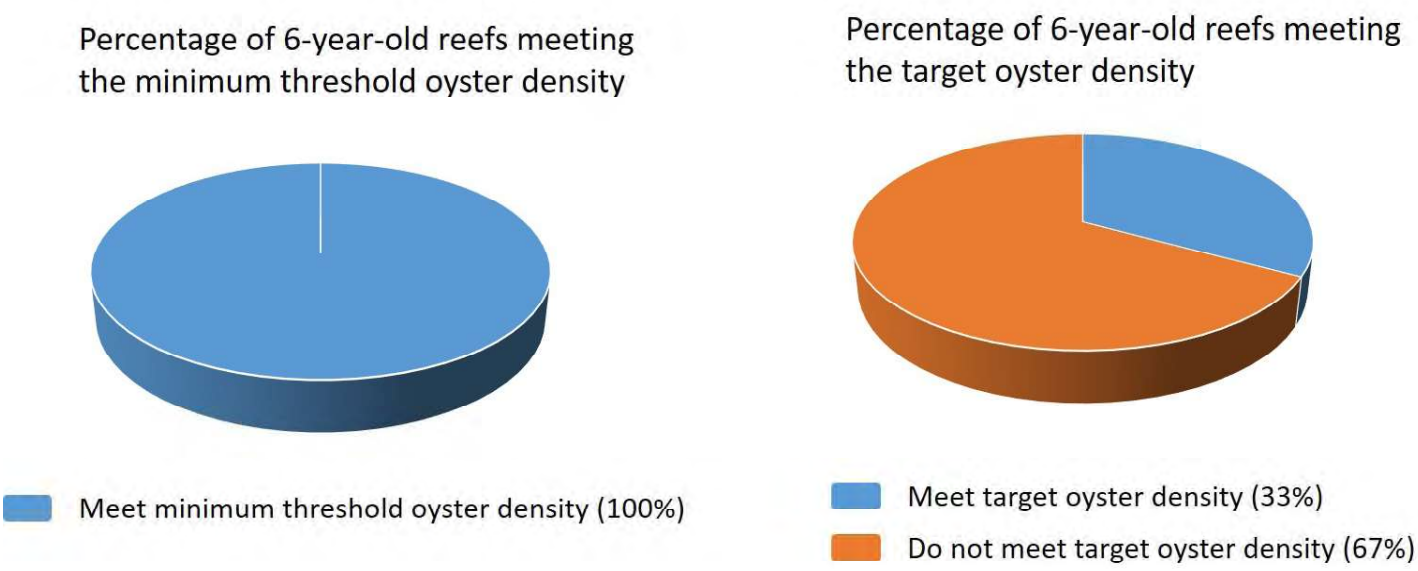
4.1 Six-year-old reefs

The oldest reefs restored under the '10 tributaries' outcome turned six years old in 2018. Per Oyster Metrics, this is the year at which each reef can be considered successfully restored if it meets each of the six success criteria. As shown in Table 9, all 12 six-year-old reefs (99.4 acres) met the success criteria for oyster density (minimum threshold), oyster biomass (minimum threshold), multiple year classes, reef height, and reef footprint. (Target densities for oyster density and biomass are the ideal standards, but per Oyster Metrics reefs must only meet the minimum threshold levels to be considered successfully restored.) It is worth noting that all 12 of the reefs that turned six years old in 2018 received a second-year-class seeding four years post restoration, as was planned in the Harris Creek Oyster Restoration Tributary Plan[2]. See Table 10 in Appendix C for information on second-year-class seedings on each reef.

Only 67% of the six-year-old reefs met the success criteria for shell budget. The other 33% of six-year-old reefs showed a statistically significant reduction in shell volume between age three (when the first shell volume data was collected) and age six (2018).

Oyster density and biomass tend to be of particular interest to the oyster management community. Oyster Metrics lays out both a minimum threshold and target for each of these (Table 3), and these two elements tracked closely in the data (Table 7 and Figure 6). Figure 3 shows the percentage of six-year-old reefs that met the minimum threshold and target criteria for oyster density. Results were similar for oyster biomass (Figure 5).

Figure 3: Six-year-old reefs meeting the oyster density minimum threshold and target success criteria. Results were similar for oyster biomass.



4.2 Three-year-old reefs

Ninety eight three-year-old reefs were monitored from 2015 to 2018. These reefs were in Harris Creek and Little Choptank River. Figure 4 shows the percentage of three-year-old of reefs that met the Oyster Metrics minimum threshold and target densities. Oyster density tracked closely with oyster biomass across all reefs (Figure 6). All 98 reefs (100%) met the success criteria for multiple year classes. Due to lack of a baseline in some cases, many reefs have not been evaluated for the shell budget, reef height, or reef footprint at three years post restoration (see Appendix A: Methods for Data Collection and Analysis for more information). Those that were evaluated met the success criteria (Table 9).

Figure 4: Three-year-old reefs meeting the minimum threshold and target oyster densities.

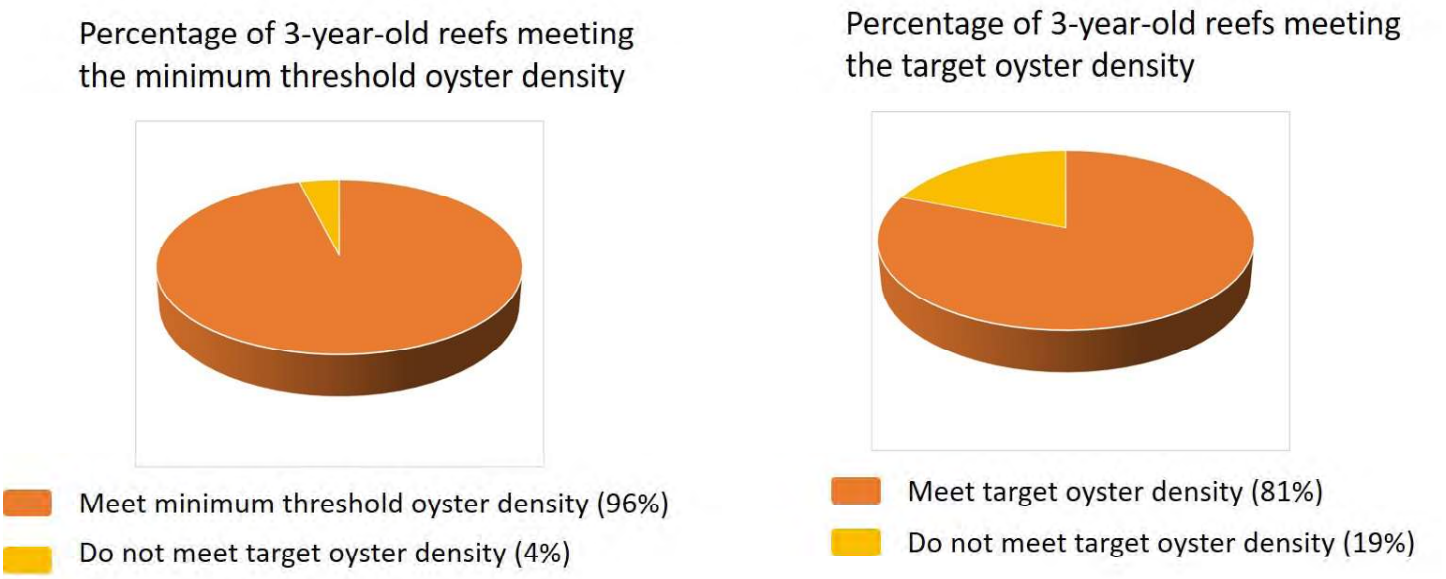
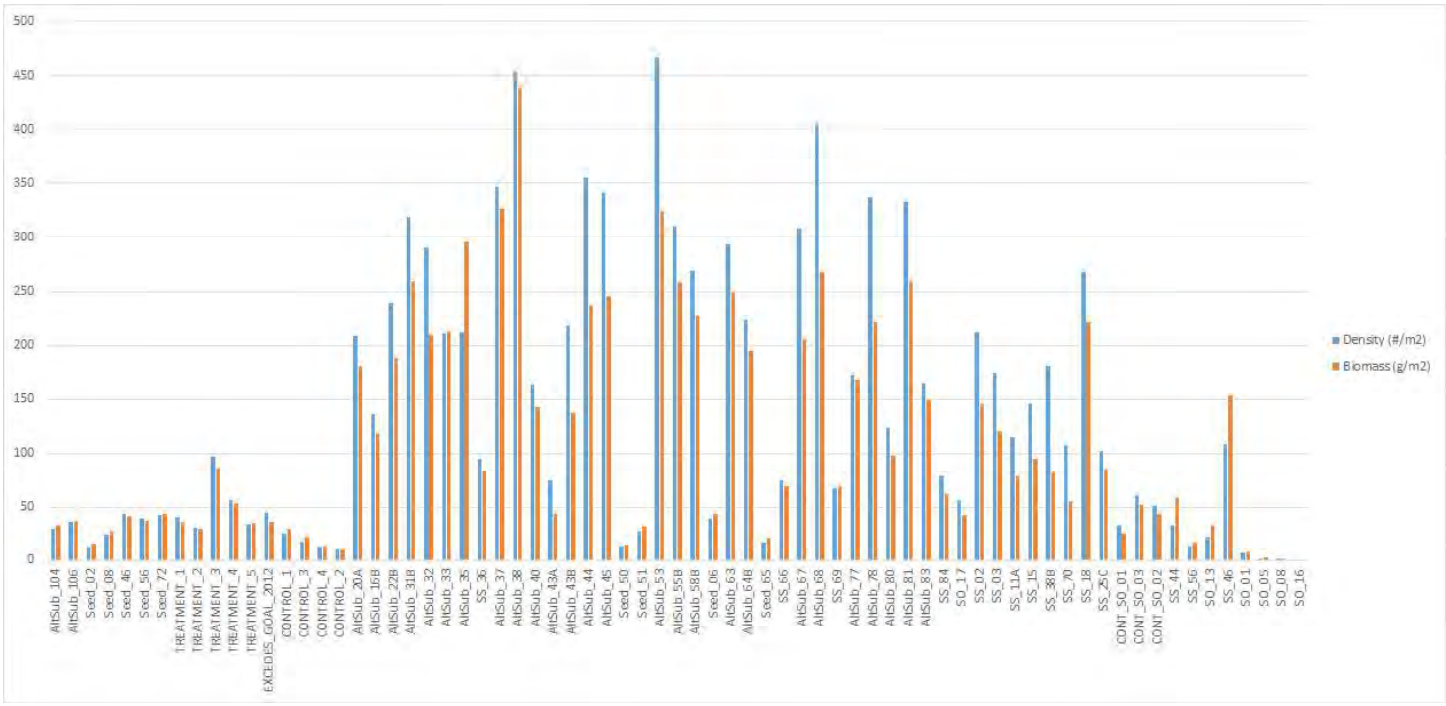


Figure 5: Graph showing oyster density (blue) and biomass (orange) for each reef monitored in fall 2018.



4.3 Future Factors to Consider

Although the information in this report looks promising for success in Harris Creek and Little Choptank River, several factors could affect continued success. These include future water-quality issues, oyster disease, funding, and poaching (illegal oyster harvesting). Results from this report will be used to help inform adaptive management of the oyster reefs that have been monitored.

References

1. Restoration Goals, Quantitative Metrics and Assessment Protocols for Evaluating Success on Restored Oyster Reef Sanctuaries. Report to the Sustainable Fisheries Goal Implementation Team of the Chesapeake Bay Program. Oyster Metrics Workgroup. 2011. http://www.chesapeakebay.net/channel_files/17932/oyster_restoration_success_metrics_final.pdf.
2. Harris Creek Oyster Restoration Tributary Plan: A blueprint to restore the oyster population in Harris Creek, a tributary of the Choptank River on Maryland's Eastern Shore. Maryland Interagency Oyster Restoration Workgroup of the Sustainable Fisheries Goal Implementation Team. 2013. https://www.chesapeakebay.net/documents/Oyster_Restoration_Blueprint_Harris_Creek_1.13_2.pdf.
3. Little Choptank River Oyster Restoration Tributary Plan: A blueprint for sanctuary restoration. Maryland Interagency Oyster Restoration Workgroup of the Sustainable Fisheries Goal Implementation Team. 2015. https://www.chesapeakebay.net/documents/Oyster_Restoration_Blueprint_Tred_Avon_4.15_1.pdf.
4. Tred Avon River Oyster Restoration Tributary Plan: A blueprint for sanctuary restoration. Maryland Interagency Oyster Restoration Workgroup of the Sustainable Fisheries Goal Implementation Team. 2015. https://www.chesapeakebay.net/documents/Oyster_Restoration_Blueprint_Tred_Avon_4.15_1.pdf.
5. Chesapeake Executive Council, 2014. The Chesapeake Bay Watershed Agreement. https://www.chesapeakebay.net/documents/FINAL_Ches_Bay_Watershed_Agreement.withsignatures-HIres.pdf.
6. Chai A, Homer M., Tsai C., Goulletquer P. (1992). Evaluation of oyster sampling efficiency of patent tongs and an oyster dredge. *North American Journal of Fisheries Management*, 12, 825-832.
7. Sustainable Fisheries Goal Implementation Team of the EPA Chesapeake Bay Program, Contract #15794/Development of a Long-Term Oyster Monitoring Plan.

Appendix A: Methods for Data Collection and Analysis

A.1: Methods for determining success relative to biological Oyster Metrics criteria (oyster density, oyster biomass, multiple year classes, shell budget)

Survey Design for Biological Metrics

Prior to 2018, monitoring was conducted using a systematic survey design. A sampling grid was developed in ArcGIS (ESRI, Version 10.5) and superimposed over a GIS layer of constructed oyster reefs. Grid cell sizes were 12.5 x 12.5 m, 25 X 25 m, 50 x 50 m, or 100 X 100 m, depending on reef size. In 2018, the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team funded an assessment to evaluate the survey design and methods used to assess restored oyster reefs.[1] The goal of the assessment was to evaluate the precision and accuracy of the existing survey design and monitoring methods to determine whether additional survey optimization could be performed. As more and more reefs are restored, the need to be cost-effective in monitoring increases. Results from the assessment recommended alterations to the previous survey design. Therefore, for the 2013 and 2015 cohorts, each reef was treated as a stratum and assigned a specific number of samples generated as a result of the programmatic review. Random samples for each reef were created using ArcMap, and the coordinates of each sample were used to navigate to each sampling location during field data collections.

Sampling Methods for Biological Metrics

Patent Tong Surveys

Patent tongs were used to sample reefs of the following treatment types: seed only, mixed shell, and untreated sites (reference reefs and premet reefs). Hydraulic patent tongs are a specialized commercial fishing gear used to harvest oysters in the Chesapeake Bay. They collect oysters and underlying substrate from a known fixed area of the bottom. Scientists from Versar, Inc., and ORP conducted patent tong sampling from on board the commercial fishing vessel *Captain's Lady* between March 11 and April 4, 2019 (Table App A1). Weather concerns and resource limitations pushed the sampling window beyond the fall of 2018. Sampling was conducted during daylight hours. Field crews navigated to sampling locations and recorded coordinates with a differential global positioning system (DGPS) attached to a laptop with ArcView 10.2. The patent tongs were suspended from a boom over one side of the vessel and deployed to the bottom at each sampling location. The number of samples specified by the sampling design were collected from within the boundaries of each individual reef (see Appendix B for number of patent tong or diver samples collected from each reef). The DGPS antenna was positioned adjacent to the location where the patent-tongs were deployed, and the geographic coordinates of each sample location were documented when the patent-tong sample was brought to the surface.

Sampling teams processed each sample by recording the primary, secondary, and tertiary substrates before sorting through the sample to separate live and dead oysters. A subsample of at least 30 live oysters was measured from each sampling location, and all others were enumerated. Oyster clumps, the number of oysters associated with a clump, and the substrate type that oysters were attached to were documented. Sampling teams also recorded the percent of the sample that was anoxic (black shell), percent of shell hash in the sample, and percent fouled with organisms such as mussels, barnacles, and tunicates. Graduated buckets were used to estimate the volume of oysters and substrate collected. Surface and bottom water temperature, dissolved oxygen, pH, and salinity were collected during each sampling event at representative locations over each oyster reef using a 6600 multiparameter water-quality sonde (YSI Corporation, Yellow Springs, Ohio). Other environmental and station specific variables collected at each site included sample number, date and time, depth of water, Yates Bar name, vessel name, and staff present.

Diver Surveys

Divers were used to sample reefs of the following treatment types: stone, stone base topped with mixed shell, and stone base topped with fossil shell. For the 2018 monitoring survey, two separate dive teams were employed. The University of Maryland Paynter Laboratory conducted dive operations between September 27, 2018, and January 8, 2019, from the R/V *Callinectes*. Versar, Inc., conducted dive operations between February 27, 2019, and March 19, 2019, from the private vessel *Dam Boat*. For diver sampling, the vessel navigated to the random sampling points generated for each reef and deployed dive-flag-labeled buoys with anchors to mark each sample location. Divers descended to the bottom at each buoy with a 0.71 m x 0.71 m (0.5041 m^2) quadrat that was placed on the reef surface, oriented upstream with one corner touching the anchor.

There are several known logistical constraints prohibiting divers from physically excavating all material from within each quadrat. For example, stones from constructed reefs can be too heavy to be removed and transported to the surface by a diver. In addition, reduced visibility can make it difficult to determine how deep a diver has excavated a particular substrate. Therefore, the diver quadrat sampling protocols were developed to provide as much consistency as possible when excavating material from any type of constructed reef. In the case of all reef types, all loose oysters and shell, including hatchery oysters and clumps, were removed from within the quadrat and transported in dive bags up to the vessel for processing. For reefs constructed with stone, a representative piece of alternate substrate (stone) was randomly collected from only some of the quadrats samples on each reef. These samples were used to collect measurements from attached oysters, and to document condition (live, box, or gaper).

There were minor differences in the methods employed by each dive team. The Paynter Lab transported samples back to the University of Maryland for processing, while teams managed by Versar, Inc., processed all samples in the field. The following variables were visually assessed for each sample: percent of shell hash present; percent of the sample covered by tunicates or mussels; percent exposed alternate substrate; and primary, secondary, and tertiary substrate type. On stone-based reefs, surface shell (loose shell and shell hash) could be removed in sample bags and measured to the nearest liter. Surface shell on stone reefs with shell veneer and on reefs with fossil shell base was estimated by measuring the depth of shell at each corner and the middle (five locations) of the quadrat until the diver reached stone, fossil shell, or mud. For loose oysters and shell collected in each sample, a minimum of 30 live oysters were measured, and the remainder were enumerated. Oyster clumps, the number of oysters associated with a clump, and the substrate type that oysters were attached to were documented. Surface and bottom water temperature, dissolved oxygen, pH, and salinity were collected at each oyster reef using a 6600 multiparameter water-quality sonde (YSI Corporation, Yellow Springs, Ohio). Other environmental and station specific variables collected at each site included sample number, date and time, weather information, depth of water, vessel name, and staff present.

Date	Tributary	Reefs Sampled	Crew	Gear Type	Gear Area	Vessel
27-Sep-18	Harris Creek	AltSub_31B (H64), AltSub_63 (H82)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
3-Oct-18	Harris Creek	AltSub_33 (H66), AltSub_68 (H87)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
4-Oct-18	Harris Creek	AltSub_44 (H74), AltSub_45 (H75)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
22-Oct-18	Harris Creek	AltSub_37 (H69)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
23-Oct-18	Harris Creek	AltSub_78 (H90)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
30-Oct-18	Harris Creek	AltSub_35 (H67), AltSub_38 (H70)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
14-Nov-18	Harris Creek	AltSub_40(H71), AltSub_55B (H79)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
17-Nov-18	Harris Creek	AltSub_53 (H78), AltSub_58B (H80)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
19-Nov-18	Harris Creek	AltSub_81 (H92)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
30-Nov-18	Harris Creek	AltSub_43B (H73)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
6-Dec-18	Harris Creek	AltSub_64B (H83)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
12-Dec-18	Harris Creek	AltSub_32 (H65), AltSub_20A (H18)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
13-Dec-18	Harris Creek	AltSub_67 (H86)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
19-Dec-18	Harris Creek	AltSub_22B (H63), AltSub_83 (H93)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
8-Jan-19	Harris Creek	AltSub_80 (H91), AltSub_16B (H61)	UMD - Paynter Lab	Diver Quadrat	0.5 sq m	Callinectes
27-Feb-19	Harris Creek	AltSub_77 (H89), AltSub_66 (H85), AltSub_69 (H88)	Versar	Diver Quadrat	0.5 sq m	Dam Boat, Capt. Rick Younger
28-Feb-19	Harris Creek	AltSub_36 (H68), AltSub_84 (H94)	Versar	Diver Quadrat	0.5 sq m	Dam Boat, Capt. Rick Younger
1-Mar-19	Little Choptank	SS_70 (L009), SS_38B (L008)	Versar	Diver Quadrat	0.5 sq m	Dam Boat, Capt. Rick Younger
3-Mar-19	Little Choptank	SS_11A (L006), SS_25C (L034)	Versar	Diver Quadrat	0.5 sq m	Dam Boat, Capt. Rick Younger
5-Mar-19	Little Choptank	SS_15 (L007), SS_18 (L029)	Versar	Diver Quadrat	0.5 sq m	Dam Boat, Capt. Rick Younger
8-Mar-19	Little Choptank	SS_03 (L005), SS_02 (L002)	Versar	Diver Quadrat	0.5 sq m	Dam Boat, Capt. Rick Younger
11-Mar-19	Harris Creek	Seed_02 (H03), Seed_51 (H77)	Versar	Patent Tong	1.61 sq m	Captain's Lady
12-Mar-19	Harris Creek	Seed_72 (H07), TREATMENT_1 (H08), TREATMEANT_4 (H11)	Versar	Patent Tong	1.61 sq m	Captain's Lady
13-Mar-19	Harris Creek	AltSub_104 (H01), AltSub_106 (H02), Seed_08 (H04), Seed_50 (H76), Seed_65 (H84)	Versar	Patent Tong	1.61 sq m	Captain's Lady
14-Mar-19	Harris Creek	CONTROL_3 (H15), CONTROL_4 (H16), TREATMENT_3 (H10)	Versar	Patent Tong	1.61 sq m	Captain's Lady
19-Mar-19	Tred Avon	SO_16 (N/A), SS_56 (T02)	Versar	Patent Tong	1.61 sq m	Captain's Lady
19-Mar-19	Tred Avon	SS_46 (T09)	Versar	Diver Quadrat	0.5 sq m	Dam Boat, Capt. Rick Younger
20-Mar-19	Harris Creek	Alt_Sub43A (H72), CONTROL_1 (H14), Seed_06 (H81), Seed_56 (H06), TREATMENT_5 (H12)	Versar	Patent Tong	1.61 sq m	Captain's Lady
27-Mar-19	Harris Creek	CONTROL_2 (H17), EXCEDES_GOAL_2012 (H13), Seed_46 (H05), TREATMENT_2 (H09)	Versar	Patent Tong	1.61 sq m	Captain's Lady
28-Mar-19	Tred Avon	SO_01 (N/A), SO_05 (N/A), SO_08 (N/A), SO_13 (T04), SS_44 (T01)	Versar	Patent Tong	1.61 sq m	Captain's Lady
4-Apr-19	Little Choptank	CONT_SO_01 (L053), CONT_SO_02 (L054), CONT_SO_03 (L052), SO_17 (L003)	Versar	Patent Tong	1.61 sq m	Captain's Lady

Table App A1. Sampling dates and sites surveyed for the 2018 monitoring season.

Prior to 2018, the efficiency and effectiveness of both patent tong and diver sampling methods were assumed to be similar when comparing all sampled reef habitat types from previous monitoring years. These assumptions were based on limited published accounts comparing data collected from natural oyster reefs using both gears (Chai et al[2]). Limited information exists comparing these gears when sampling restored oyster reefs of various ages. In 2019, a similar field comparison on restored reefs[1] was conducted, and the resulting report is nearing completion as of the drafting of this report. Full study results and review are pending; therefore, it is not possible to use this new study to inform the oyster density and biomass estimates in this document. For the purposes of this report, no adjustments were made on gear efficiency, and results are reported on each specific gear type.

Oyster Density

Oyster Metrics success criteria:

- Minimum threshold = 15 oysters per m^2 over 30% of the reef area
- Target = 50 oysters per m^2 over 30% of the reef area

Method:

Oyster density was calculated as the number of individual live oysters collected in the area of a patent-tong grab or diver quadrat standardized to a square meter. To meet the Oyster Metrics threshold or target, at least 30% of the samples collected must have a density of at least 15 or 50 oysters per m^2, respectively. This represents a change from the previous survey design in which the sampled grid cells meeting the target or threshold must have been equal to or greater than 30% of the reef area. Past years of monitoring data were analyzed using this method to ensure that the methods are comparable.

Oyster Biomass

Oyster Metrics success criteria:

- Minimum threshold = 15 grams dry weight per m^2 over 30% of the reef area
- Target = 50 grams dry weight per m^2 over 30% of the reef area

Method:

Oyster biomass per m^2 was calculated from the size of individual live oysters within each sample, using the equation $W = 0.000423 * L1.7475$ where W = dry tissue weight in g and L = shell height in mm.[3] Biomass was then summed for the entire sample and standardized to a square meter. The same approach as oyster density (above) was employed, in which at least 30% of samples collected had to meet the threshold or target. Past years of monitoring data were analyzed using this method to ensure that the methods are comparable.

Multiple Year Classes

Oyster Metrics success criterion:

- Presence of two or more year classes of live oysters

Methods:

Year-class presence was approximated by examining length frequency data of all oyster heights measured at each reef. Sampling teams are trained to measure and record all oysters, regardless of size. For simplicity, a reef was determined to have multiple year classes when oysters from at least two standard size class categories (market: 76 mm; small: 40–75 mm; spat <40 mm) were present. There is no differentiation between hatchery-produced oysters and natural oysters.

Shell Budget

Oyster Metrics success criterion:

- Neutral or positive shell budget on the reef

Method:

Changes to the shell budget at individual reefs were analyzed using shell volume data from 2015 and 2018, as no base-

line data exist. Replicates were examined at the reef-level, and sites that did not have significant differences between measurements in 2015 and measurements in 2018 were assumed to have a stable shell budget.

Statistical Analysis for Biological Metrics

Oyster density estimates were standardized to number per m^2 from the area sampled by patent tong or by diver quadrat. Total counts of live oysters or other variables (e.g., oyster size class, shell volume) were averaged over all samples collected at the individual reef.

Total sampled shell and surface shell volume were estimated for each individual oyster reef sampled by patent tong. Field measurements of shell resources included total shell volume and the percent of black (buried) shell estimated in a sample. Average shell volumes were standardized by the area sampled by patent tong. Total sampled shell volume was calculated using average sampled shell volume multiplied by the sampled area. Surface shell estimates were calculated as the percent of the total sampled shell volume that was not considered black shell for patent-tong samples, as shown below:

*Surface shell volume=Total shell volume-(Total shell volume*Percent Black Shell)*

Total sampled shell volume was estimated for each individual oyster reef sampled by divers. Average shell volumes were standardized by diver quadrat area. Total sampled shell volume was calculated using average sampled shell volume multiplied by the sampled area. In some instances, estimates of shell volume were very high due to the presence of mixed or fossil shell deployed in the construction process at alternate substrate sites. Surface shell volume could not be calculated from diver samples because percent black shell was not assessed with the dive methods.

2018 represents the first year in which the shell budget metric was assessed. In order to determine a change in shell budget, all samples were examined at the reef level for reefs that were six years old in 2018. The Workgroup determined that total shell volume was a more appropriate metric than surface shell volume to reduce bias. Analysis of variance was used, followed by Tukey HSD post-hoc, to determine significant differences between years. Sites that did not have significant differences between measurements in 2015 and measurements in 2018 were concluded to have a stable shell budget.

A2: Methods for determining success relative to Oyster Metrics reef structural criteria (reef footprint; reef height)

Staff from the NOAA Chesapeake Bay Office conducted multibeam bathymetric (depth) surveys following the construction of substrate + seed reefs and again three and six years post restoration (fall 2018). For the planting years 2012-2015, seed-only reefs were not targeted for survey because bathymetric updates to nautical charts were not required. In a few instances, survey of substrate and seed reefs overlapped with seed-only sites, allowing collection of some post-seeding survey data from seed-only reefs. Seed-only plantings from 2016 through the end of restoration were surveyed with multibeam to evaluate the structural metrics for all restoration sites. These survey data were acquired and processed to the standards set forth in NOS Hydrographic Surveys Specifications and Deliverables, 2017[4]. Surfaces derived from the processed data are exported from QPS Qimera bathymetry processing software at a 0.25 m resolution rasterized grid using the Cube Mean Depth, a repeatable method.

Reef Footprint (Spatial Extent)

Oyster Metrics success criterion:

- Neutral or positive change in reef spatial extent (footprint) as compared to baseline measurements

Methods:

- Substrate + Seed Reefs: Perimeter change was evaluated between the postconstruction bathymetric surface and the three years postconstruction bathymetric surface. The surfaces were visually compared to identify differences that may have resulted from a portion of the reef being lost due to subsidence or removal. If no observable loss was detected, the reef spatial extent was reported as meeting the metric.
- Seed-Only Reefs: Bathymetric surface data was not collected on seed-only reef sites following seed planting from 2012-2014. In 2015, most but not all seed-only reefs were surveyed. 2018 represents the first year in which it could be determined whether or not a majority of the seed-only reef cohort met the reef footprint success criteria. The bathymetric surface data collected at the three-year postrestoration mark (fall 2015 and subsequent years) will be

compared against bathymetric surface data collected at the six-year post restoration mark where available (fall 2018 and subsequent years). At that time, evaluation of the two data sets will follow the methods above for the substrate + seed restoration sites. The success or failure of this metric on seed-only reefs is therefore noted as 'TBD.'

Reef Height

Oyster Metrics success criterion:

- Neutral or positive change in reef height as compared to baseline measurements

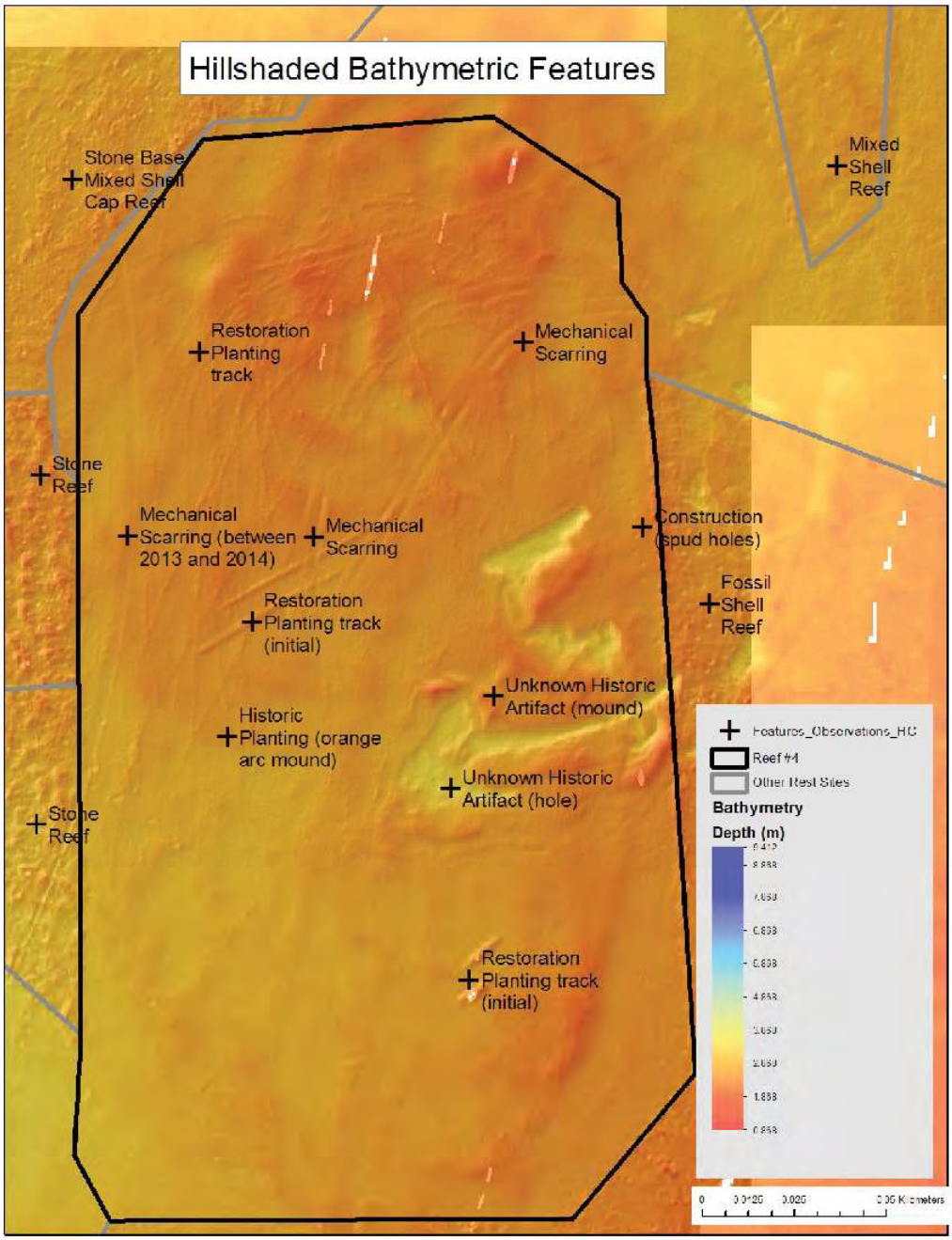
Methods:

- Substrate + Seed Reefs: To evaluate reef height, the difference between the postconstruction surface and the three-years-postconstruction surface is calculated by subtracting the former from the latter. To establish a common baseline elevation between multiple surfaces, the depth values for the two sources are compared at eight points around the outside of the restored site. The mean difference from the eight points is calculated and used to adjust the two surfaces to be on a common elevation; this helps to remove any tidal artifacts between the two surveys. ArcGIS Spatial Analyst extension raster math tool calculates differences between all of the cells within the restoration site polygon. Differences in the bottom on the reef can be attributed to oyster growth as well as moving construction equipment, deposition of seed, scouring from currents, deposition of sediments, loss from poaching, loss from subsidence of the site base, or artifacts within the sonar data. If the mean calculated difference for the surface within the site boundary was neutral or positive, then the reef height was reported as meeting the metric. A greater than two-centimeter change must be observed in either growth or subsidence in order to be deemed a meaningful change to reef height. See Table App A2.
- Seed-Only Reefs: Refer to description of Seed-only metrics for reef extent above.

Table App A2: Determination of whether a reef is considered successful relative to the reef height metric. 'Reef height change' is the difference, per sonar surveys, between mean reef height after construction and mean reef height three years post restoration.

Mean Reef Height Change	Did the reef meet the reef height success metric?
Positive change (growth)	Yes
Neutral (no change)	Yes
Negative change of up to 2 cm (survey error)	Yes
Negative change greater than 2 cm	No

Figure App A1: Interpretation of bathymetric features visible in sonar images of treated oyster reefs.



References for Appendix A

1. Slacum H. W., Liang D., Wilberg M., Paynter K., and Zaveta D. "Implementing Oyster Restoration Monitoring Recommendations," Sustainable Fisheries Goal Implementation Team Biannual Meeting, 17 December 2018, The Mariner's Museum, Newport News, VA.
2. Chai A., Homer M., Tsai C., Goulletquer P. (1992). Evaluation of oyster sampling efficiency of patent tongs and an oyster dredge. *North American Journal of Fisheries Management*, 12, 825-832.
3. Mann R. and Evans D. A., "Estimation Of Oyster, Crassostrea Virginica, Standing Stock, Larval Production And Advective Loss In Relation To Observed Recruitment In The James River, Virginia" (1998). VIMS Articles. 495.
4. Office of Coast Survey, National Ocean Service, National Oceanic and Atmospheric Administration. Hydrographic Surveys Specifications and Deliverables. 2017. Available from www.nauticalcharts.noaa.gov/hsd/specs/specs.htm.

Appendix B: Reef Pages: Detailed Information and Sonar Images for Each Reef

All information for each reef, by reef, including sonar images and graphics of oyster shell height distributions, is on the following pages.

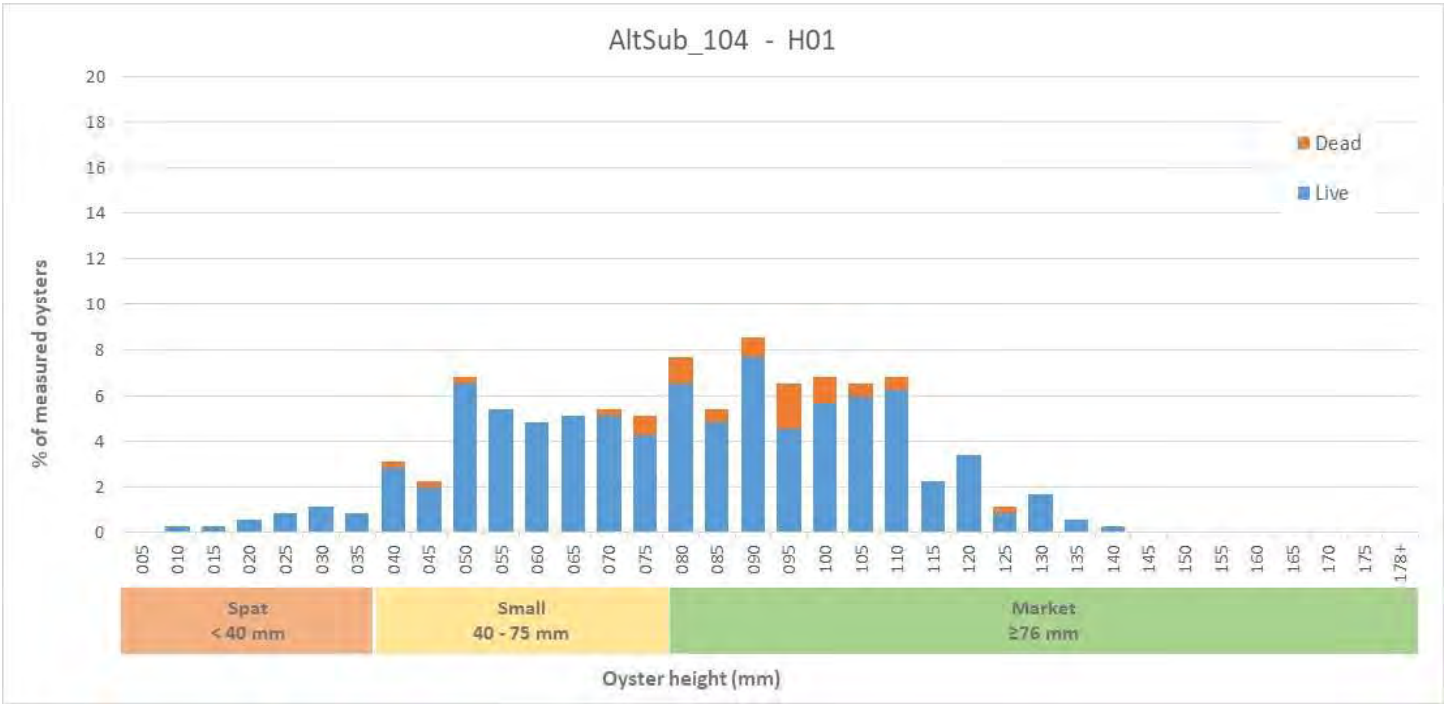
Reef H01 AltSub_104

Reef Information	**Report reef ID**	**H01**
	Geodatabase Site_ID	AltSub_104
	Tributary	Harris Creek
	Reef area (acres)	3.37
Restoration Treatment	Restoration treatment	Substrate & Seed
	Substrate type added	Mixed Shell
	Average planned reef height*	12
	Year planted with spat (initial planting)	2012
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/3/2019
	# samples taken	10
	# live oysters measured	319
	# live oysters counted	493
	# dead oysters counted	34
	% of oysters that were dead	6%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	30.62
	Standard error of live density (#/m^2)	3.47
	Number of samples meeting minimum threshold density (m^2)	10
	Percent of samples meeting minimum threshold density (%)	100%
	Number of samples meeting target density (m^2)	1
	Percent of samples meeting target density (%)	10%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	55.81
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	10
	Reef area meeting minimum threshold biomass (%)	100%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	1
	Reef area meeting target biomass (%)	10%
	Average live biomass across reef (g dry weight per m^2)	33.07
	Standard error of live biomass	4.64
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	66.09
Shell Volume	Is the shell budget stable/ increasing?	No
	Average shell volume across entire reef (liters per m^2)	9.69
	Standard error of shell volume	1.22
	Average brown shell across all samples (%)	80%
	Total volume change (liters per m^2)	-4.07
	% Change in total volume from 2015	-35%
	Surface shell volume change (liters per m^2)	-3.09
	% change in surface shell volume change	-29%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	-0.02
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H01 AltSub_104

Percent of Measured Oysters in the Market, Small, and Spat Categories

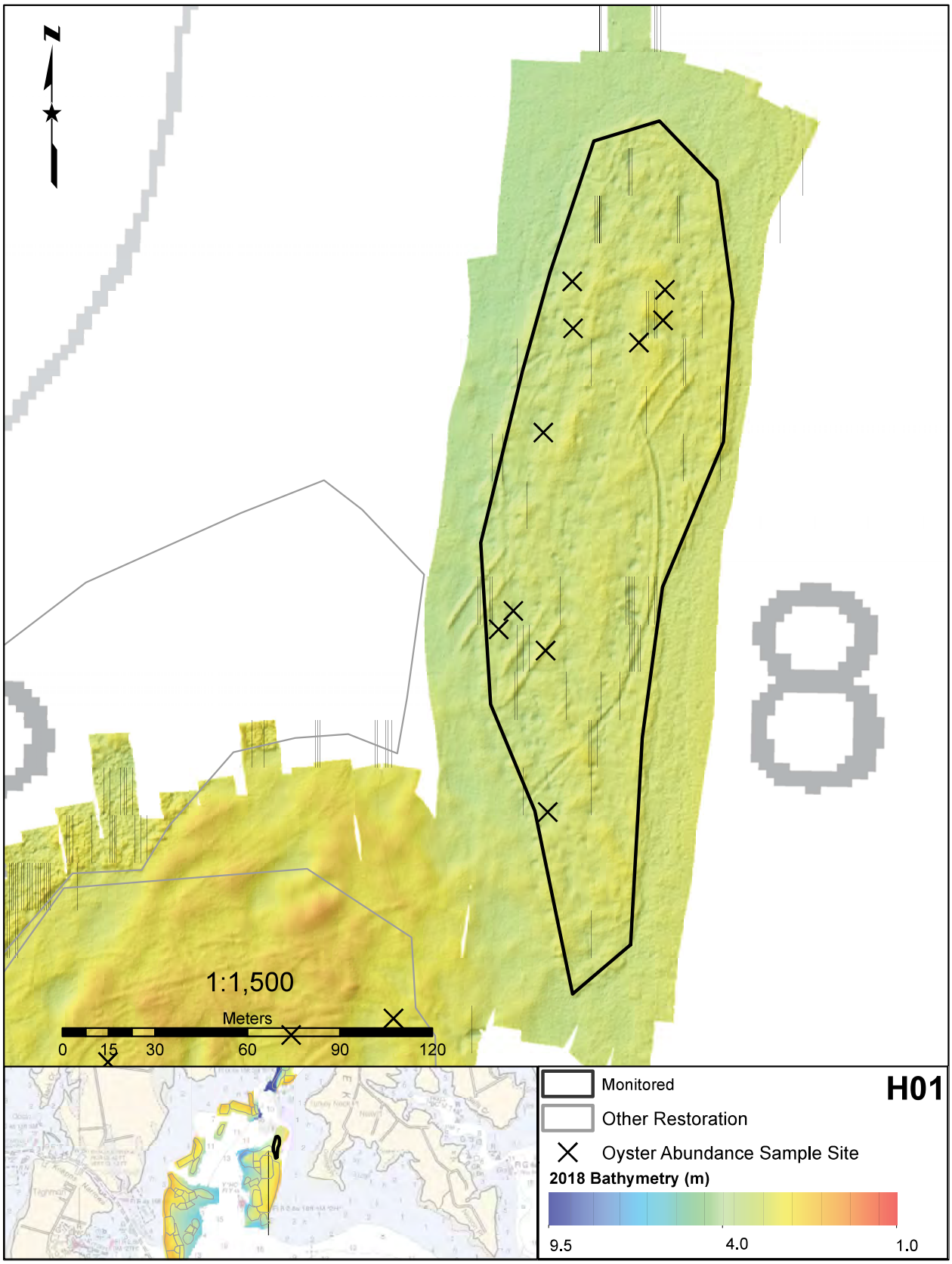
Shell Height of Oysters Measured on Reef



Reef H01 AltSub_104

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

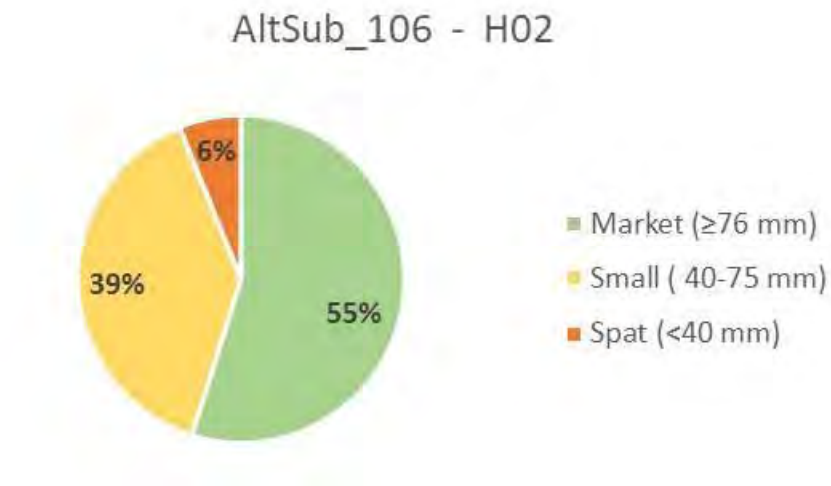


Reef H02 AltSub_106

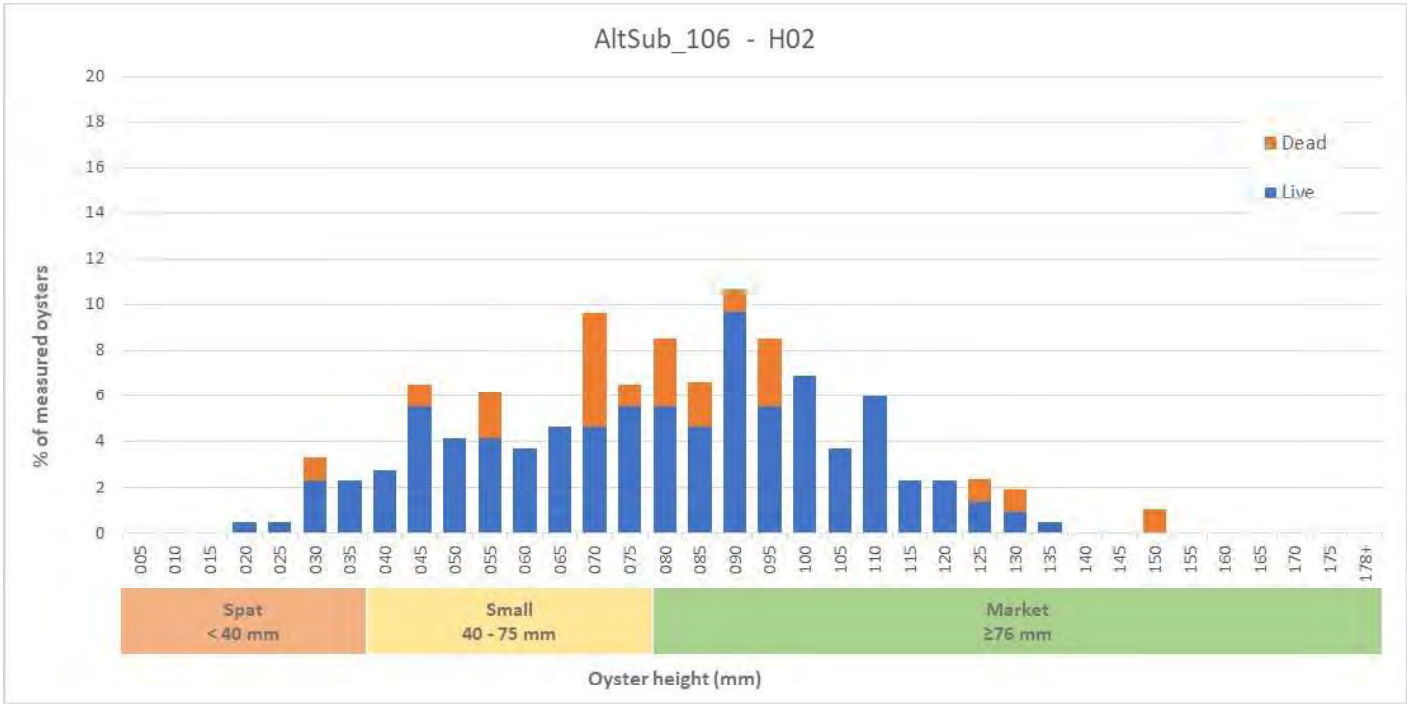
Reef Information	**Report reef ID**	**H02**
	Geodatabase Site_ID	AltSub_106
	Tributary	Harris Creek
	Reef area (acres)	2.14
Restoration Treatment	Restoration treatment	Substrate & Seed
	Substrate type added	Mixed Shell
	Average planned reef height*	12
	Year planted with spat (initial planting)	2012
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/13/2019
	# samples taken	7
	# live oysters measured	195
	# live oysters counted	414
	# dead oysters counted	22
	% of oysters that were dead	5%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	36.73
	Standard error of live density (#/m^2)	9.04
	Number of samples meeting minimum threshold density (m^2)	6
	Percent of samples meeting minimum threshold density (%)	86%
	Number of samples meeting target density (m^2)	2
	Percent of samples meeting target density (%)	29%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	47.76
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	6
	Reef area meeting minimum threshold biomass (%)	86%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	2
	Reef area meeting target biomass (%)	29%
	Average live biomass across reef (g dry weight per m^2)	37.74
	Standard error of live biomass	9.29
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	41.82
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	10.57
	Standard error of shell volume	1.47
	Average brown shell across all samples (%)	98%
	Total volume change (liters per m^2)	0.51
	% Change in total volume from 2015	5%
	Surface shell volume change (liters per m^2)	3.05
	% change in surface shell volume change	42%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.048
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H02 AltSub_106

Percent of Measured Oysters in the Market, Small, and Spat Categories



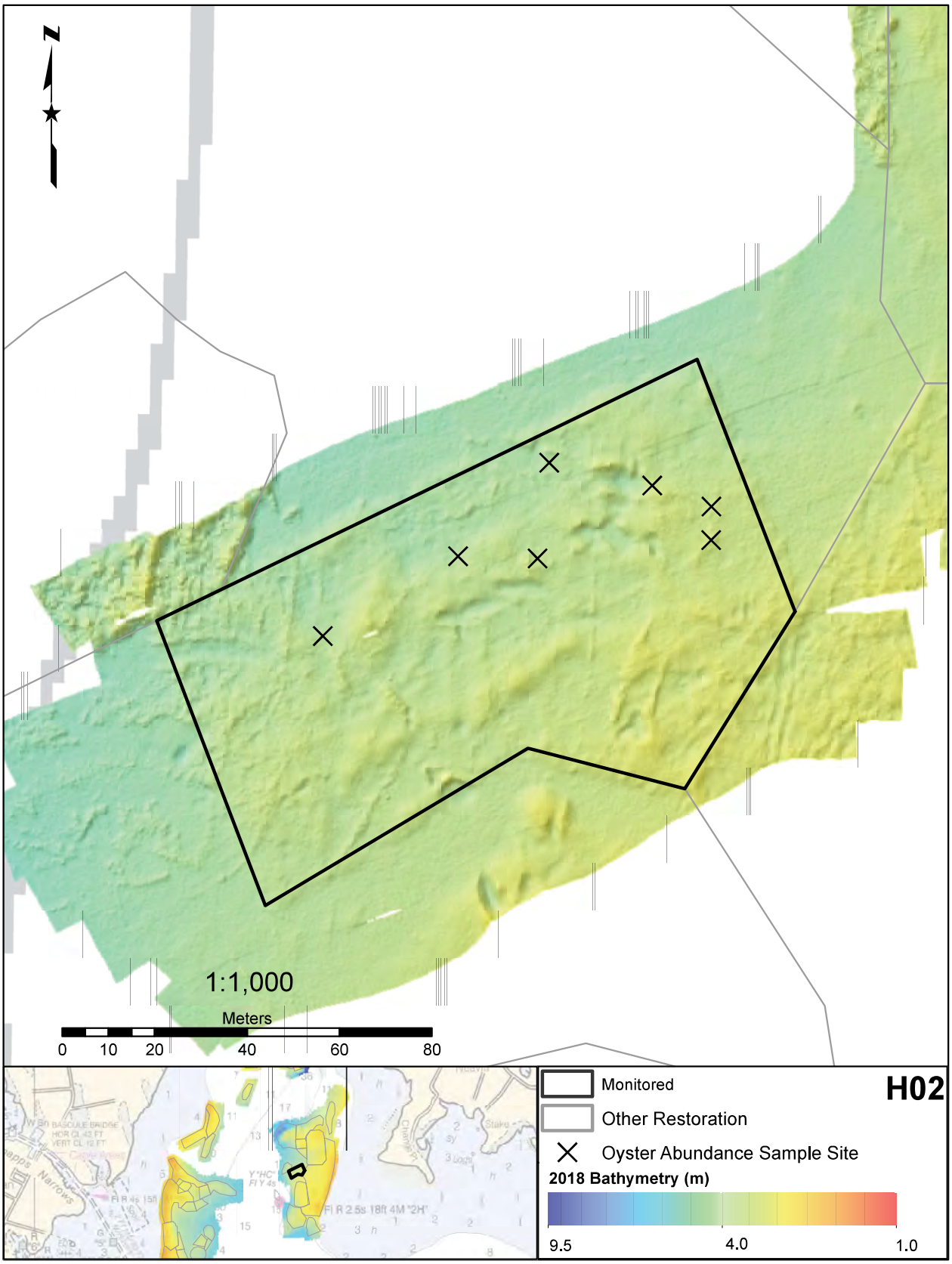
Shell Height of Oysters Measured on Reef



Reef H02 AltSub_106

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

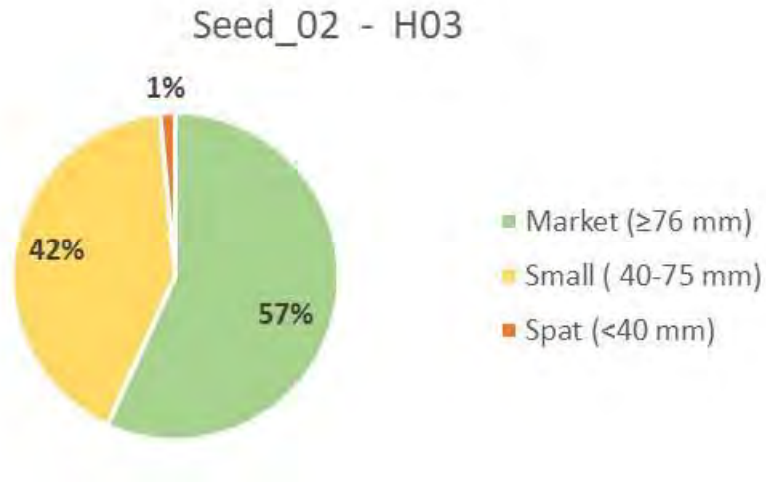


Reef H03 Seed_02

Reef Information	**Report reef ID**	**H03**
	Geodatabase Site_ID	Seed_02
	Tributary	Harris Creek
	Reef area (acres)	6.56
Restoration Treatment	Restoration treatment	Seed Only
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	2012
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/11/2019
	# samples taken	16
	# live oysters measured	262
	# live oysters counted	336
	# dead oysters counted	65
	% of oysters that were dead	16%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	13.04
	Standard error of live density (#/m^2)	3.58
	Number of samples meeting minimum threshold density (m^2)	6
	Percent of samples meeting minimum threshold density (%)	38%
	Number of samples meeting target density (m^2)	0
	Percent of samples meeting target density (%)	0%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	32.86
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	8
	Reef area meeting minimum threshold biomass (%)	50%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	1
	Reef area meeting target biomass (%)	6%
	Average live biomass across reef (g dry weight per m^2)	16.76
	Standard error of live biomass	3.95
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	33.42
Shell Volume	Is the shell budget stable/ increasing?	No
	Average shell volume across entire reef (liters per m^2)	5.41
	Standard error of shell volume	1.46
	Average brown shell across all samples (%)	73%
	Total volume change (liters per m^2)	-3.08
	% Change in total volume from 2015	-36%
	Surface shell volume change (liters per m^2)	-1.56
	% change in surface shell volume change	-25%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	-0.012
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H03 Seed_02

Percent of Measured Oysters in the Market, Small, and Spat Categories

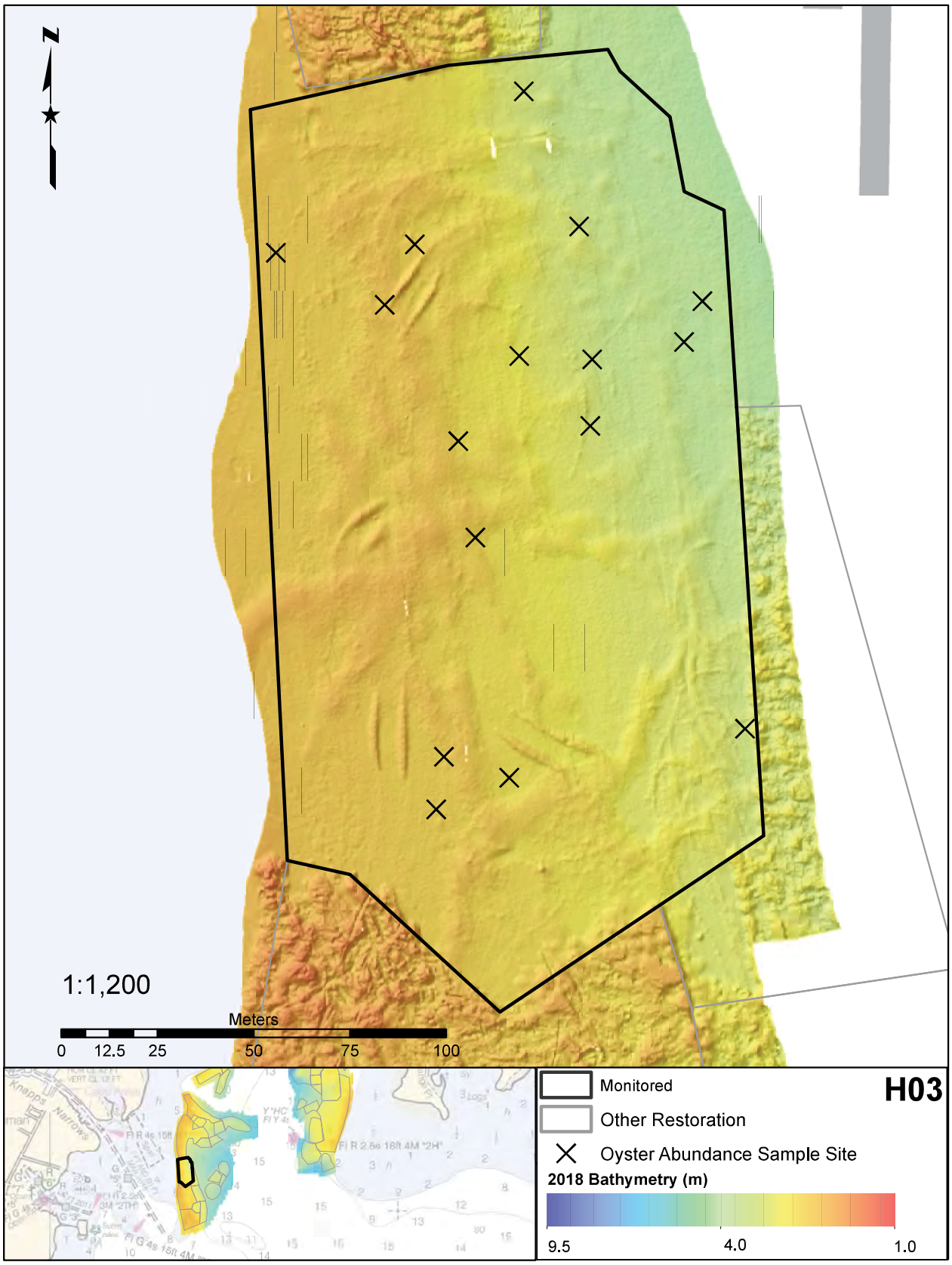


Shell Height of Oysters Measured on Reef

Reef H03 Seed_02

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

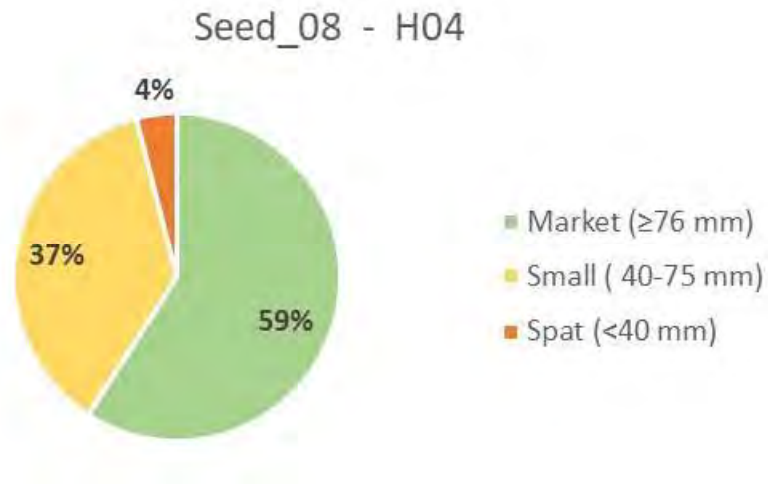


Reef H04 Seed_08

Reef Information	**Report reef ID**	**H04**
	Geodatabase Site_ID	Seed_08
	Tributary	Harris Creek
	Reef area (acres)	11.24
Restoration Treatment	Restoration treatment	Seed Only
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	2012
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/13/2019
	# samples taken	11
	# live oysters measured	274
	# live oysters counted	444
	# dead oysters counted	41
	% of oysters that were dead	8%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	25.07
	Standard error of live density (#/m^2)	4.99
	Number of samples meeting minimum threshold density (m^2)	8
	Percent of samples meeting minimum threshold density (%)	73%
	Number of samples meeting target density (m^2)	1
	Percent of samples meeting target density (%)	9%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	38.96
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	8
	Reef area meeting minimum threshold biomass (%)	73%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	1
	Reef area meeting target biomass (%)	9%
	Average live biomass across reef (g dry weight per m^2)	28.26
	Standard error of live biomass	5.39
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	37.97
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	10.42
	Standard error of shell volume	1.94
	Average brown shell across all samples (%)	86%
	Total volume change (liters per m^2)	1.04
	% Change in total volume from 2015	8%
	Surface shell volume change (liters per m^2)	2.86
	% change in surface shell volume change	42%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.008
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H04 Seed_08

Percent of Measured Oysters in the Market, Small, and Spat Categories



Shell Height of Oysters Measured on Reef

Reef H04 Seed_08

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

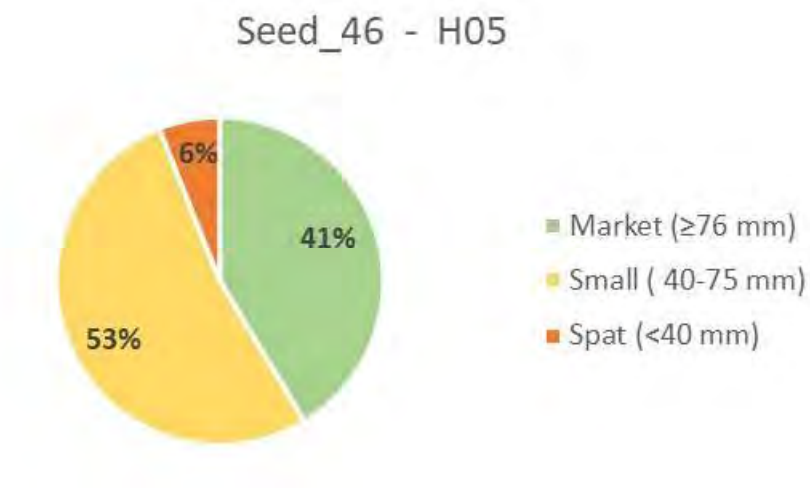
For interpretations of features in sonar imagery, see Appendix A: Methods.

Reef H05 Seed_46

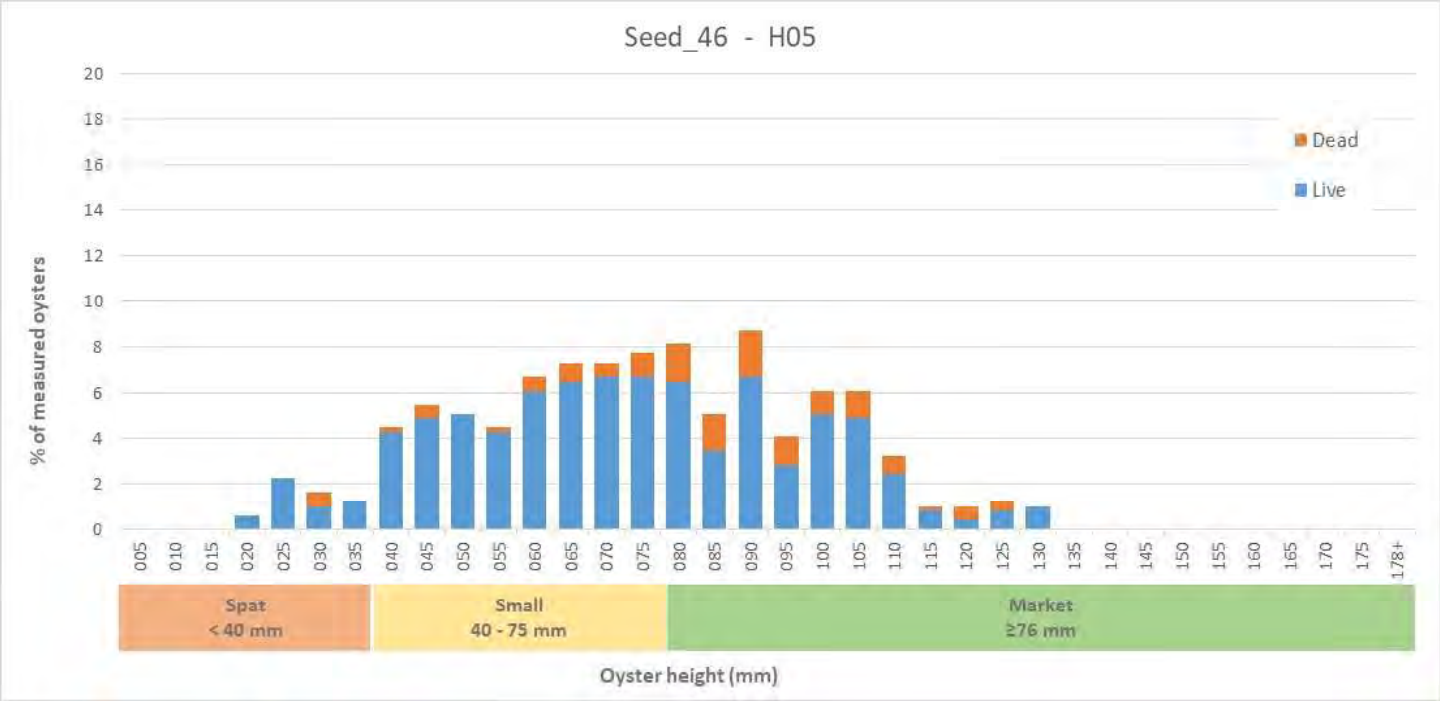
Reef Information	**Report reef ID**	**H05**
	Geodatabase Site_ID	Seed_46
	Tributary	Harris Creek
	Reef area (acres)	15.65
Restoration Treatment	Restoration treatment	Seed Only
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	2012
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/27/2019
	# samples taken	14
	# live oysters measured	416
	# live oysters counted	982
	# dead oysters counted	87
	% of oysters that were dead	8%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	43.57
	Standard error of live density (#/m^2)	7.16
	Number of samples meeting minimum threshold density (m^2)	12
	Percent of samples meeting minimum threshold density (%)	86%
	Number of samples meeting target density (m^2)	4
	Percent of samples meeting target density (%)	29%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	47.15
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	12
	Reef area meeting minimum threshold biomass (%)	86%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	6
	Reef area meeting target biomass (%)	43%
	Average live biomass across reef (g dry weight per m^2)	42.32
	Standard error of live biomass	6.63
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	45.75
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	13.58
	Standard error of shell volume	1.67
	Average brown shell across all samples (%)	83%
	Total volume change (liters per m^2)	0.77
	% Change in total volume from 2015	2%
	Surface shell volume change (liters per m^2)	3.55
	% change in surface shell volume change	45%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.004
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H05 Seed_46

Percent of Measured Oysters in the Market, Small, and Spat Categories



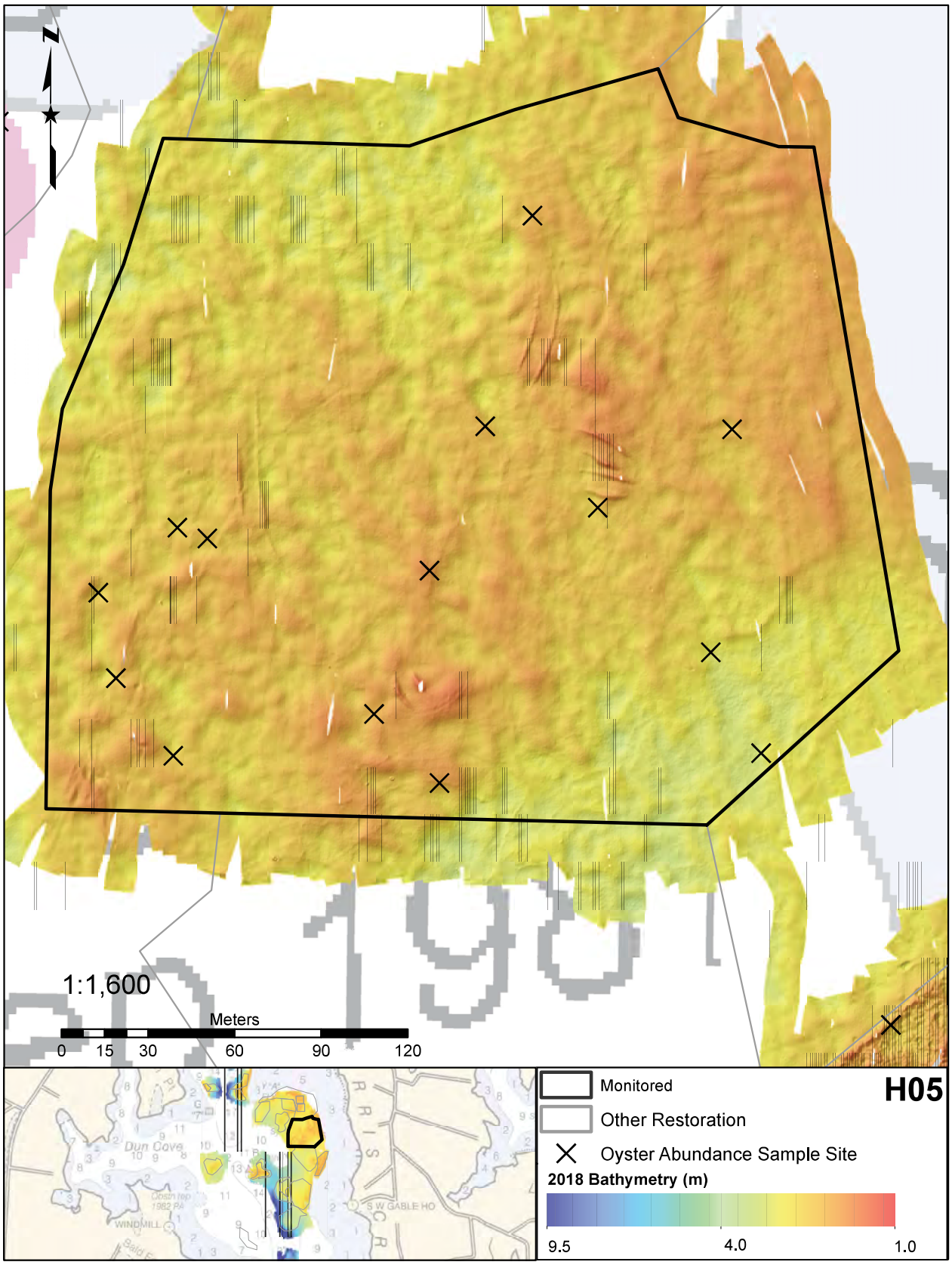
Shell Height of Oysters Measured on Reef



Reef H05 Seed_46

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

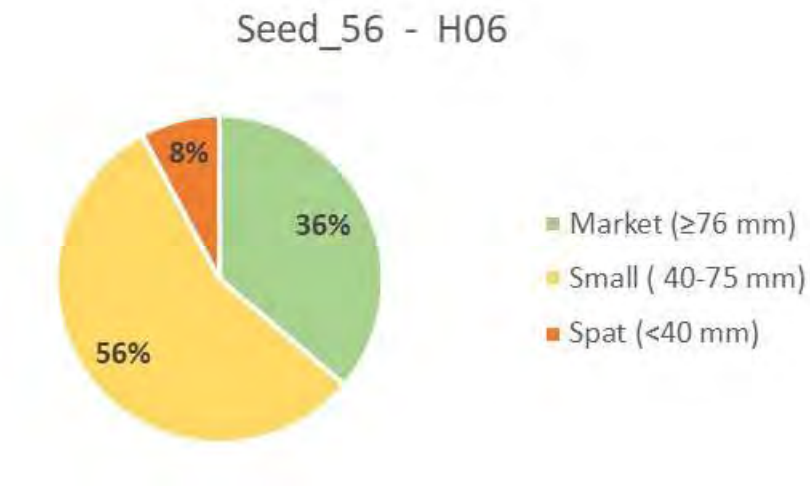


Reef H06 Seed_56

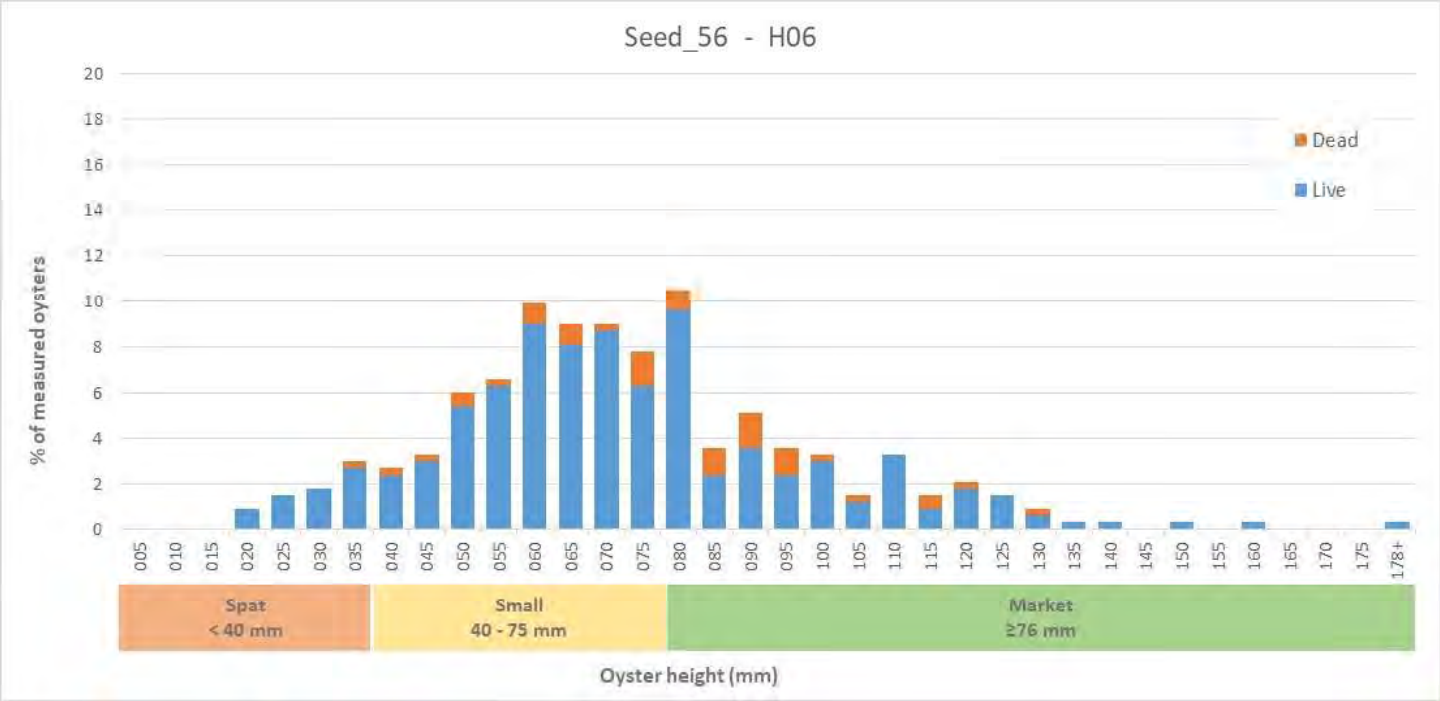
Reef Information	**Report reef ID**	**H06**
	Geodatabase Site_ID	Seed_56
	Tributary	Harris Creek
	Reef area (acres)	7.19
Restoration Treatment	Restoration treatment	Seed Only
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	2011 & 2013
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/20/2019
	# samples taken	9
	# live oysters measured	293
	# live oysters counted	578
	# dead oysters counted	48
	% of oysters that were dead	8%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	39.89
	Standard error of live density (#/m^2)	7.57
	Number of samples meeting minimum threshold density (m^2)	8
	Percent of samples meeting minimum threshold density (%)	89%
	Number of samples meeting target density (m^2)	2
	Percent of samples meeting target density (%)	22%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	47.11
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	8
	Reef area meeting minimum threshold biomass (%)	89%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	2
	Reef area meeting target biomass (%)	22%
	Average live biomass across reef (g dry weight per m^2)	38.01
	Standard error of live biomass	8.05
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	41.72
Shell Volume	Is the shell budget stable/ increasing?	No
	Average shell volume across entire reef (liters per m^2)	11.18
	Standard error of shell volume	1.84
	Average brown shell across all samples (%)	72%
	Total volume change (liters per m^2)	-3.79
	% Change in total volume from 2015	-25%
	Surface shell volume change (liters per m^2)	-2.74
	% change in surface shell volume change	-26%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.013
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H06 Seed_56

Percent of Measured Oysters in the Market, Small, and Spat Categories



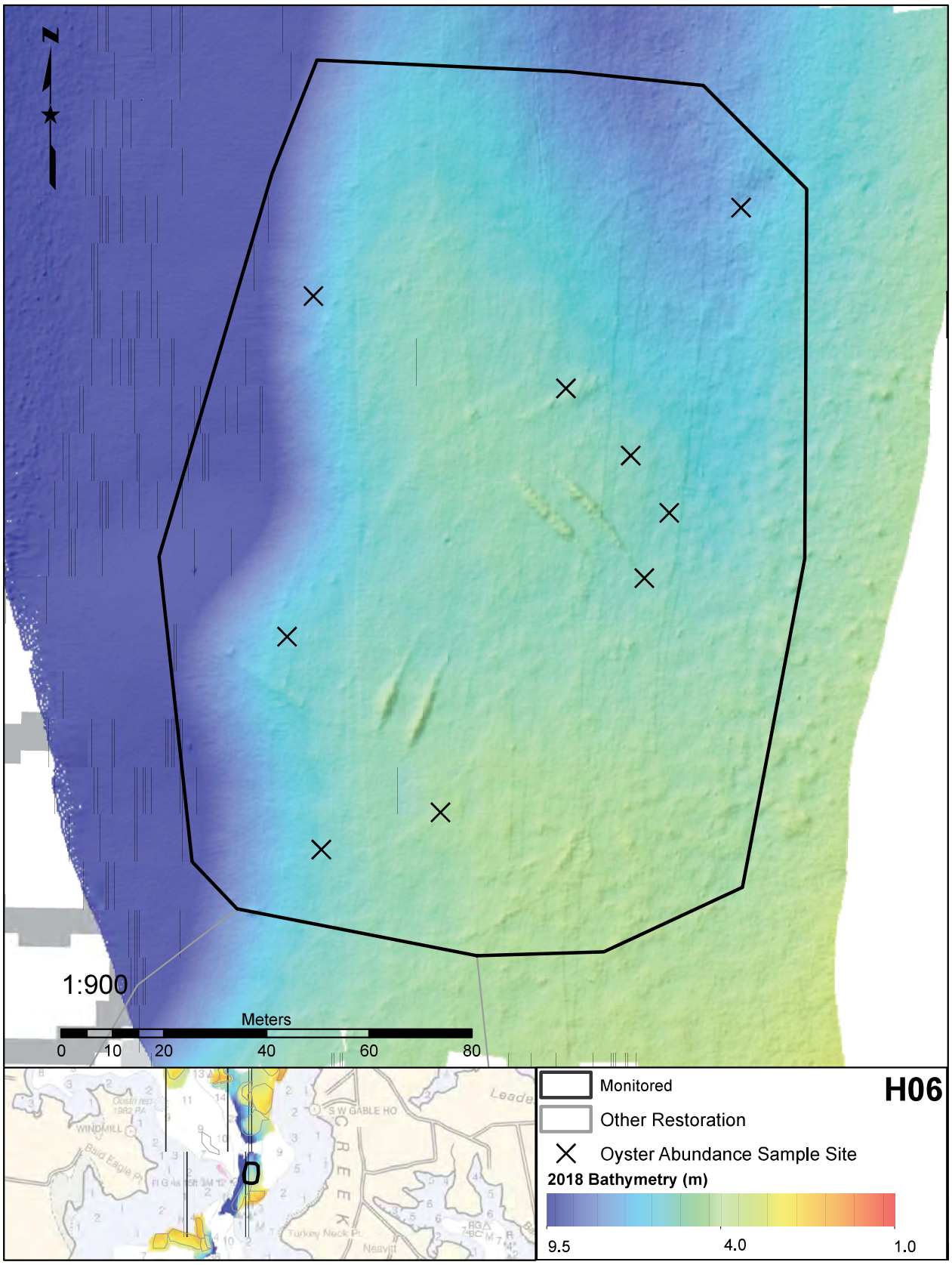
Shell Height of Oysters Measured on Reef



Reef H06 Seed_56

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

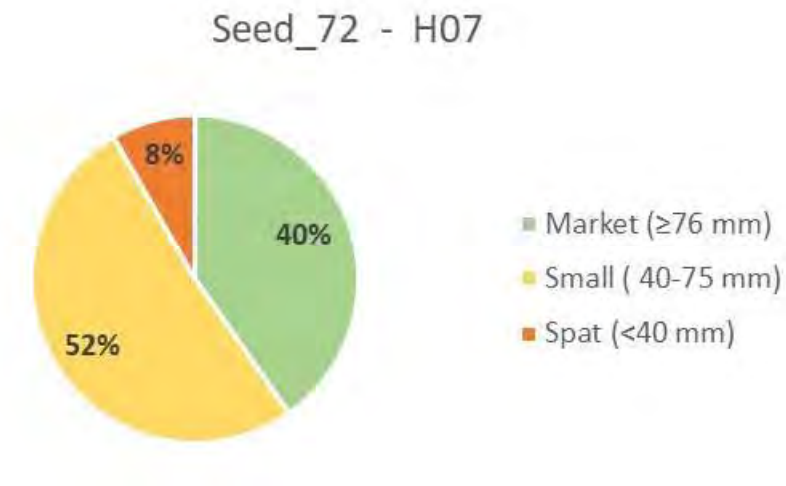


Reef H07 Seed_72

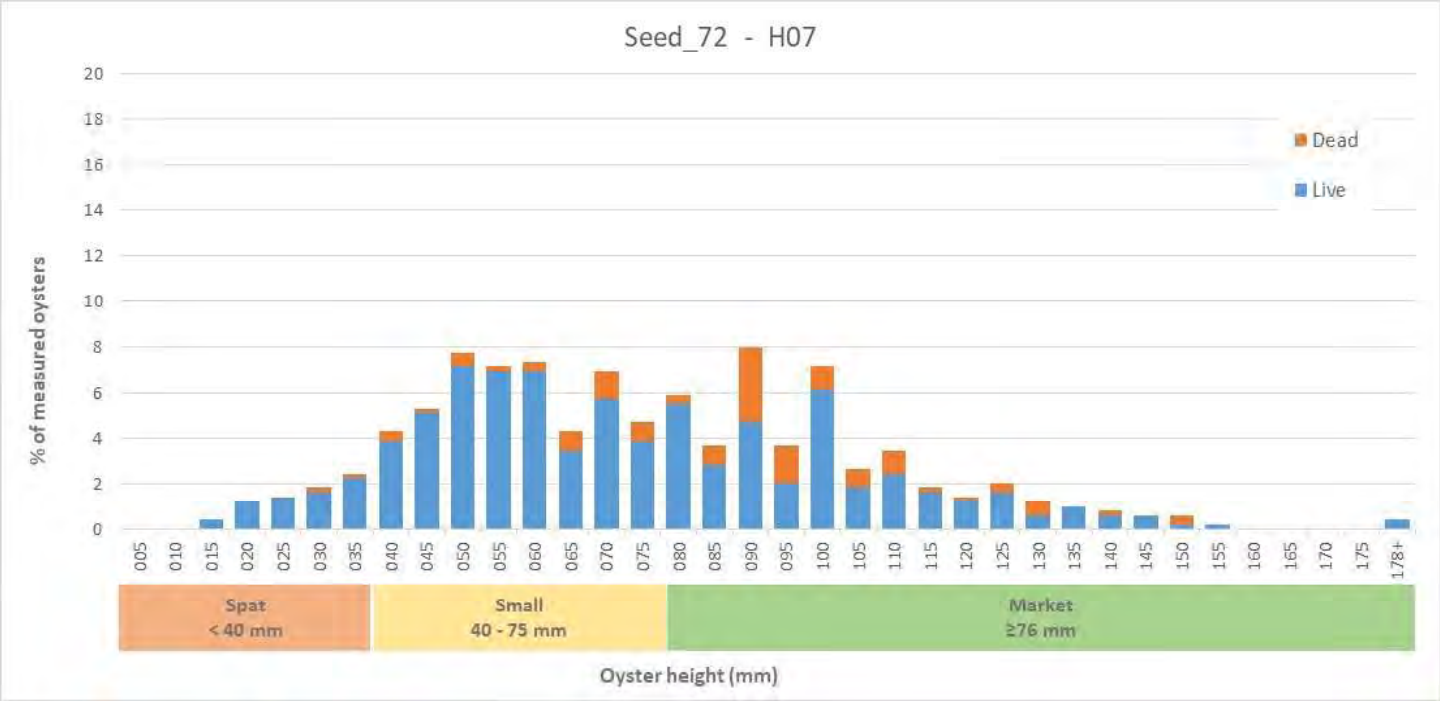
Reef Information	**Report reef ID**	**H07**
	Geodatabase Site_ID	Seed_72
	Tributary	Harris Creek
	Reef area (acres)	10.95
Restoration Treatment	Restoration treatment	Seed Only
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	2012
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/12/2019
	# samples taken	13
	# live oysters measured	410
	# live oysters counted	899
	# dead oysters counted	110
	% of oysters that were dead	11%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	42.95
	Standard error of live density (#/m^2)	6.74
	Number of samples meeting minimum threshold density (m^2)	10
	Percent of samples meeting minimum threshold density (%)	77%
	Number of samples meeting target density (m^2)	6
	Percent of samples meeting target density (%)	46%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	29.95
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	11
	Reef area meeting minimum threshold biomass (%)	85%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	8
	Reef area meeting target biomass (%)	62%
	Average live biomass across reef (g dry weight per m^2)	44.12
	Standard error of live biomass	6.47
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	31.72
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	12.31
	Standard error of shell volume	1.68
	Average brown shell across all samples (%)	51%
	Total volume change (liters per m^2)	2.84
	% Change in total volume from 2015	20%
	Surface shell volume change (liters per m^2)	2.41
	% change in surface shell volume change	52%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.01
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H07 Seed_72

Percent of Measured Oysters in the Market, Small, and Spat Categories



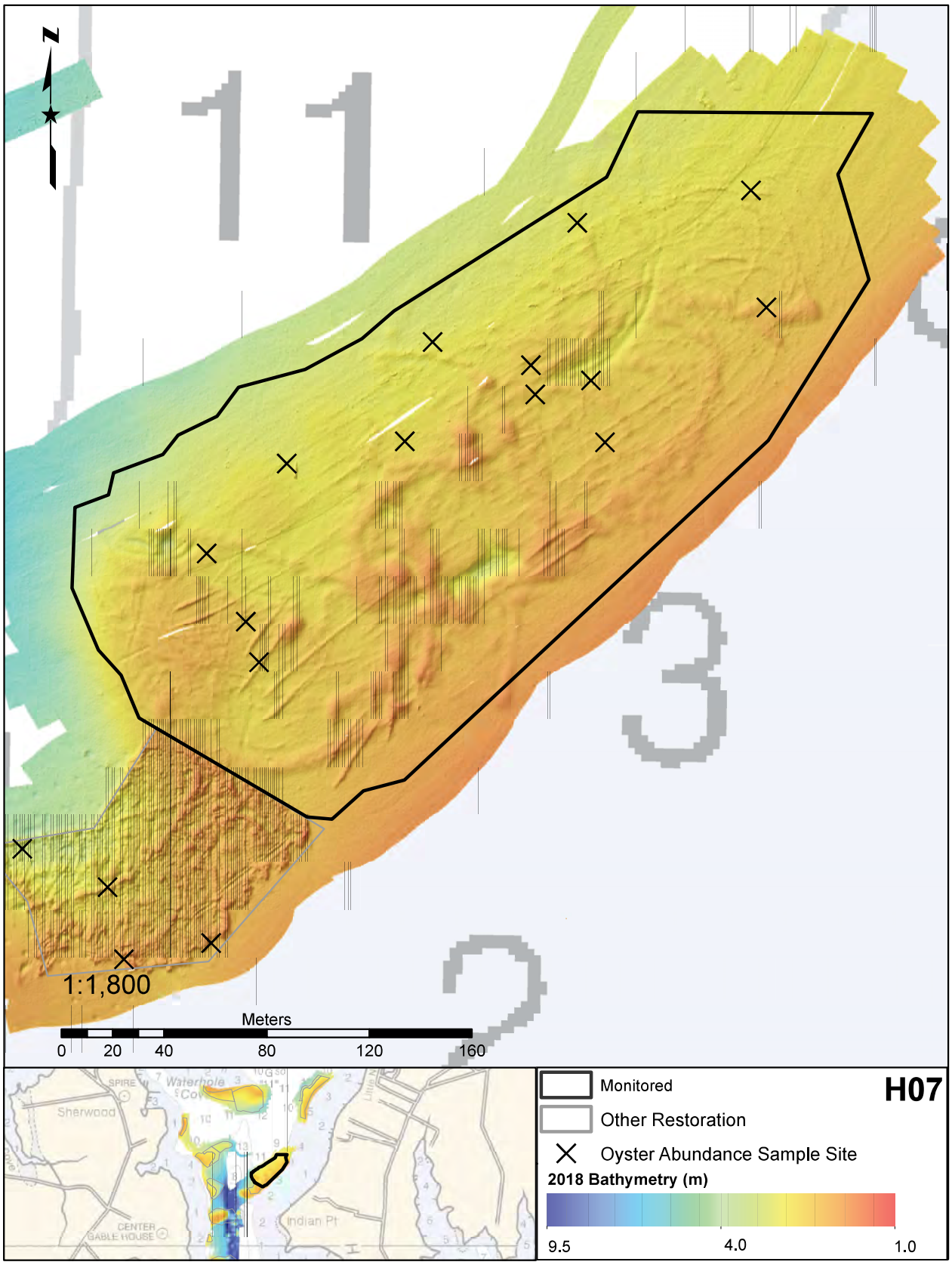
Shell Height of Oysters Measured on Reef



Reef H07 Seed_72

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

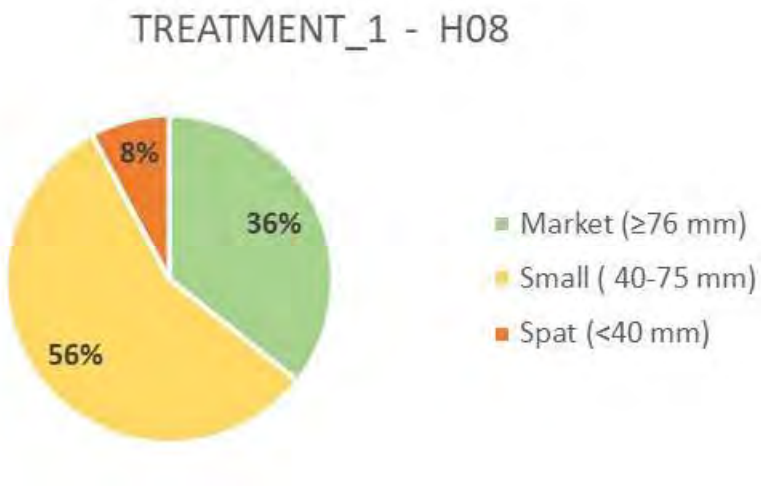


Reef H08 TREATMENT_I

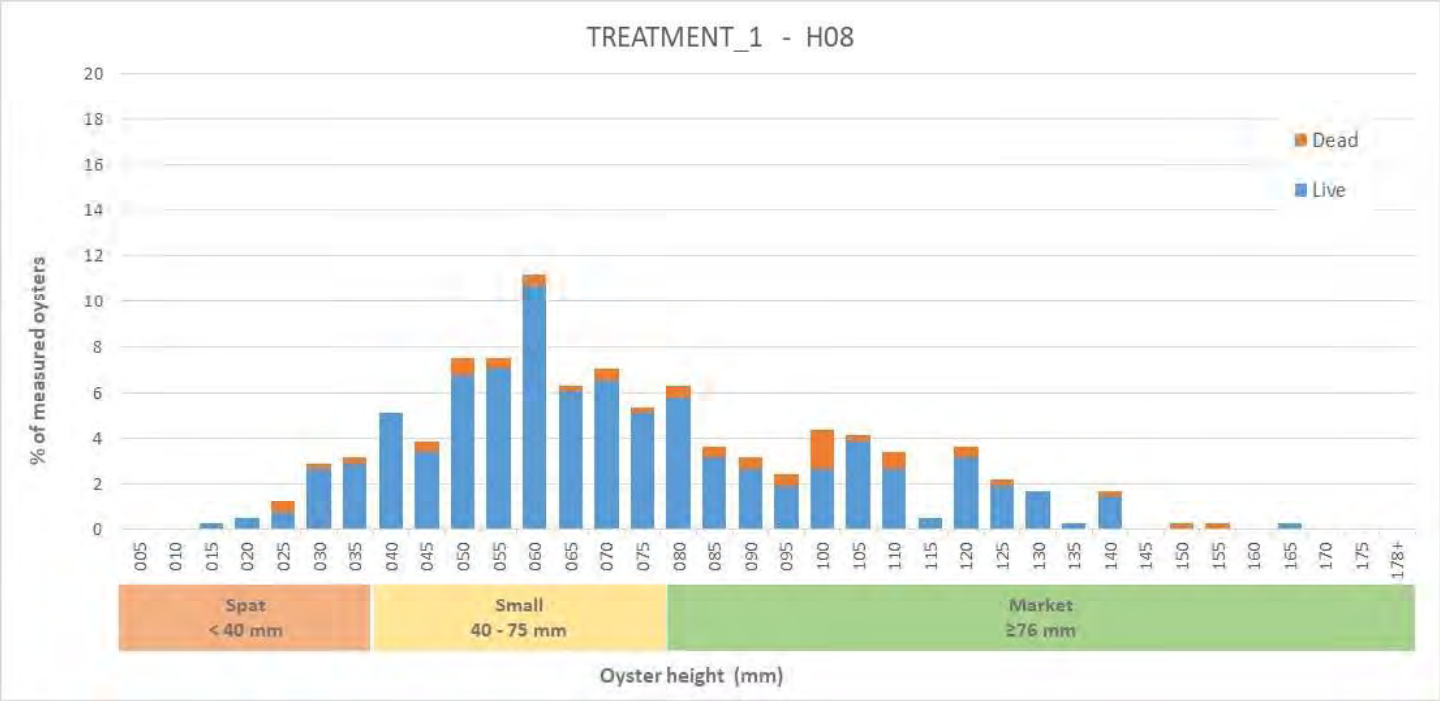
Reef Information	**Report reef ID**	**H08**
	Geodatabase Site_ID	TREATMENT_1
	Tributary	Harris Creek
	Reef area (acres)	7.34
Restoration Treatment	Restoration treatment	Seed Only
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	2012
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/12/2019
	# samples taken	14
	# live oysters measured	370
	# live oysters counted	918
	# dead oysters counted	50
	% of oysters that were dead	5%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	40.73
	Standard error of live density (#/m^2)	10.21
	Number of samples meeting minimum threshold density (m^2)	11
	Percent of samples meeting minimum threshold density (%)	79%
	Number of samples meeting target density (m^2)	5
	Percent of samples meeting target density (%)	36%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	24.11
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	10
	Reef area meeting minimum threshold biomass (%)	71%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	5
	Reef area meeting target biomass (%)	36%
	Average live biomass across reef (g dry weight per m^2)	36.47
	Standard error of live biomass	8.38
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	26.6
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	8.93
	Standard error of shell volume	1.72
	Average brown shell across all samples (%)	84%
	Total volume change (liters per m^2)	1.04
	% Change in total volume from 2015	-20%
	Surface shell volume change (liters per m^2)	1.46
	% change in surface shell volume change	26%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	-0.031
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H08 TREATMENT_I

Percent of Measured Oysters in the Market, Small, and Spat Categories



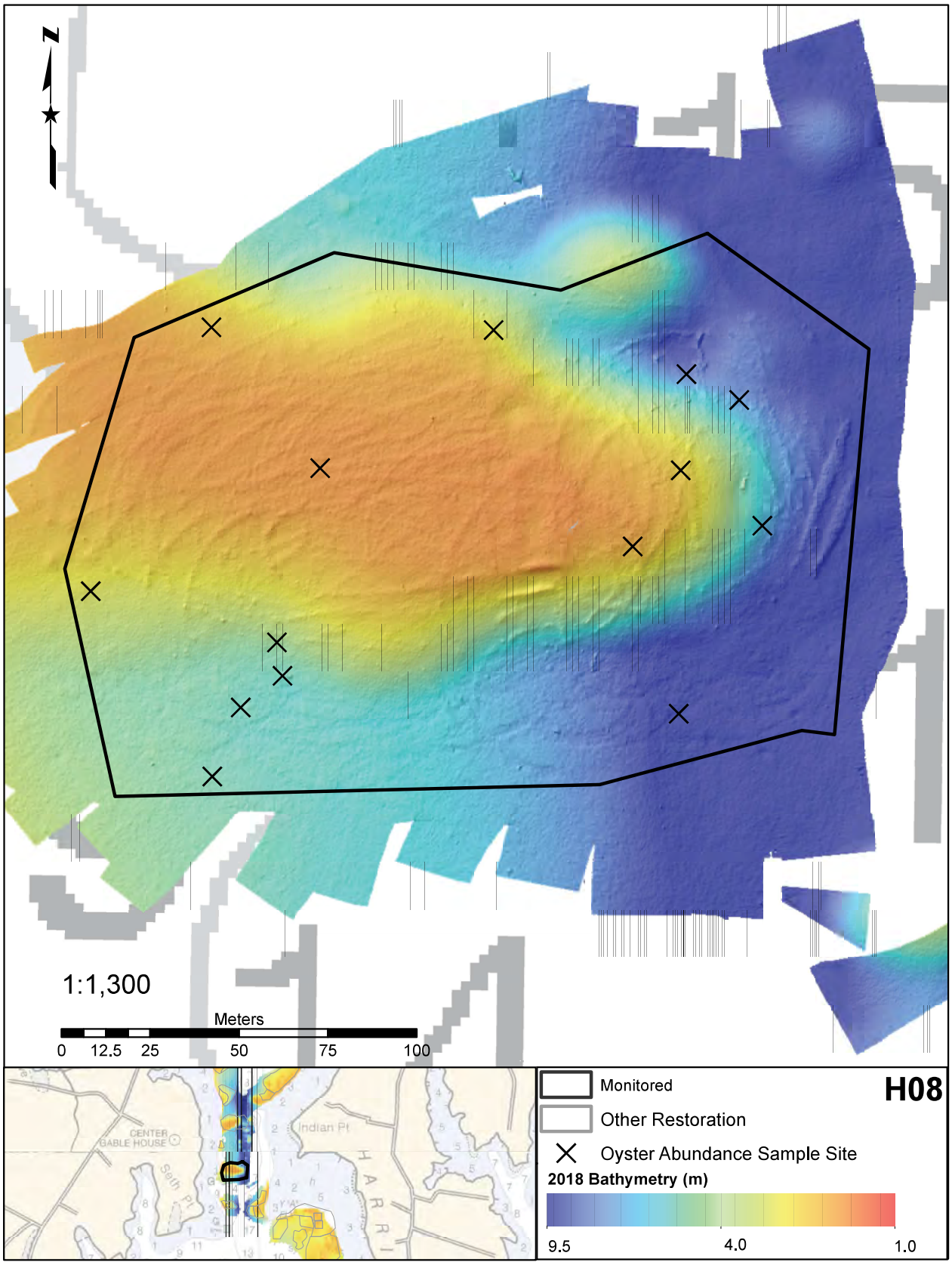
Shell Height of Oysters Measured on Reef



Reef H08 TREATMENT_I

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

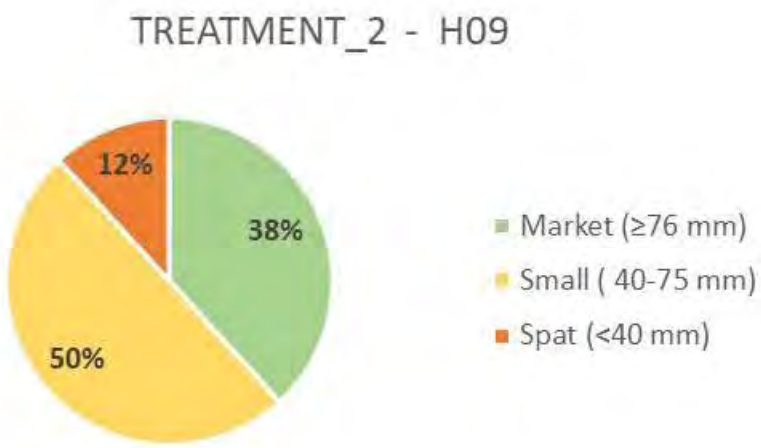


Reef H09 TREATMENT_2

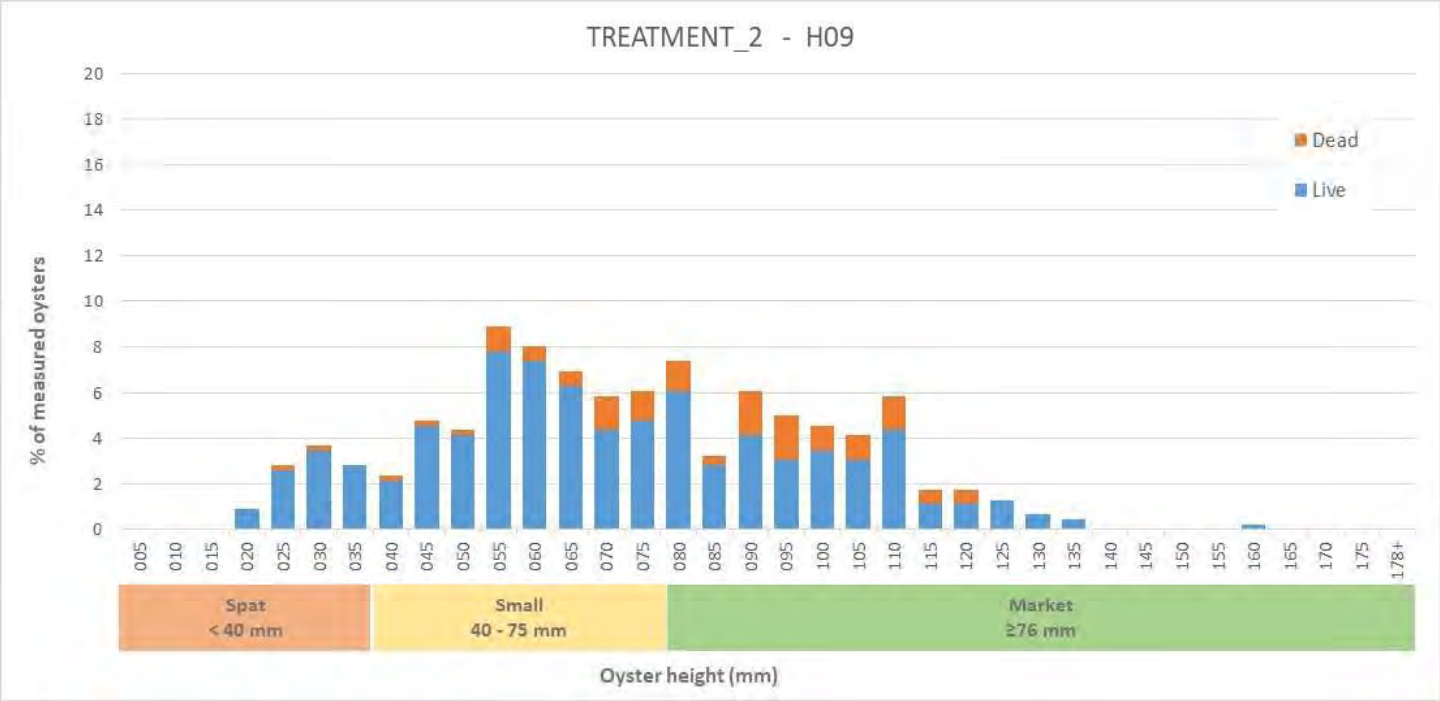
Reef Information	**Report reef ID**	**H09**
	Geodatabase Site_ID	TREATMENT_2
	Tributary	Harris Creek
	Reef area (acres)	12.29
Restoration Treatment	Restoration treatment	Seed Only
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	2012
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/27/2019
	# samples taken	16
	# live oysters measured	382
	# live oysters counted	803
	# dead oysters counted	94
	% of oysters that were dead	10%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	31.17
	Standard error of live density (#/m^2)	6.01
	Number of samples meeting minimum threshold density (m^2)	12
	Percent of samples meeting minimum threshold density (%)	75%
	Number of samples meeting target density (m^2)	4
	Percent of samples meeting target density (%)	25%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	32.18
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	12
	Reef area meeting minimum threshold biomass (%)	75%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	2
	Reef area meeting target biomass (%)	13%
	Average live biomass across reef (g dry weight per m^2)	30.06
	Standard error of live biomass	5.42
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	30.01
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	10.10
	Standard error of shell volume	1.59
	Average brown shell across all samples (%)	75%
	Total volume change (liters per m^2)	2.28
	% Change in total volume from 2015	5%
	Surface shell volume change (liters per m^2)	3.12
	% change in surface shell volume change	81%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.005
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H09 TREATMENT_2

Percent of Measured Oysters in the Market, Small, and Spat Categories



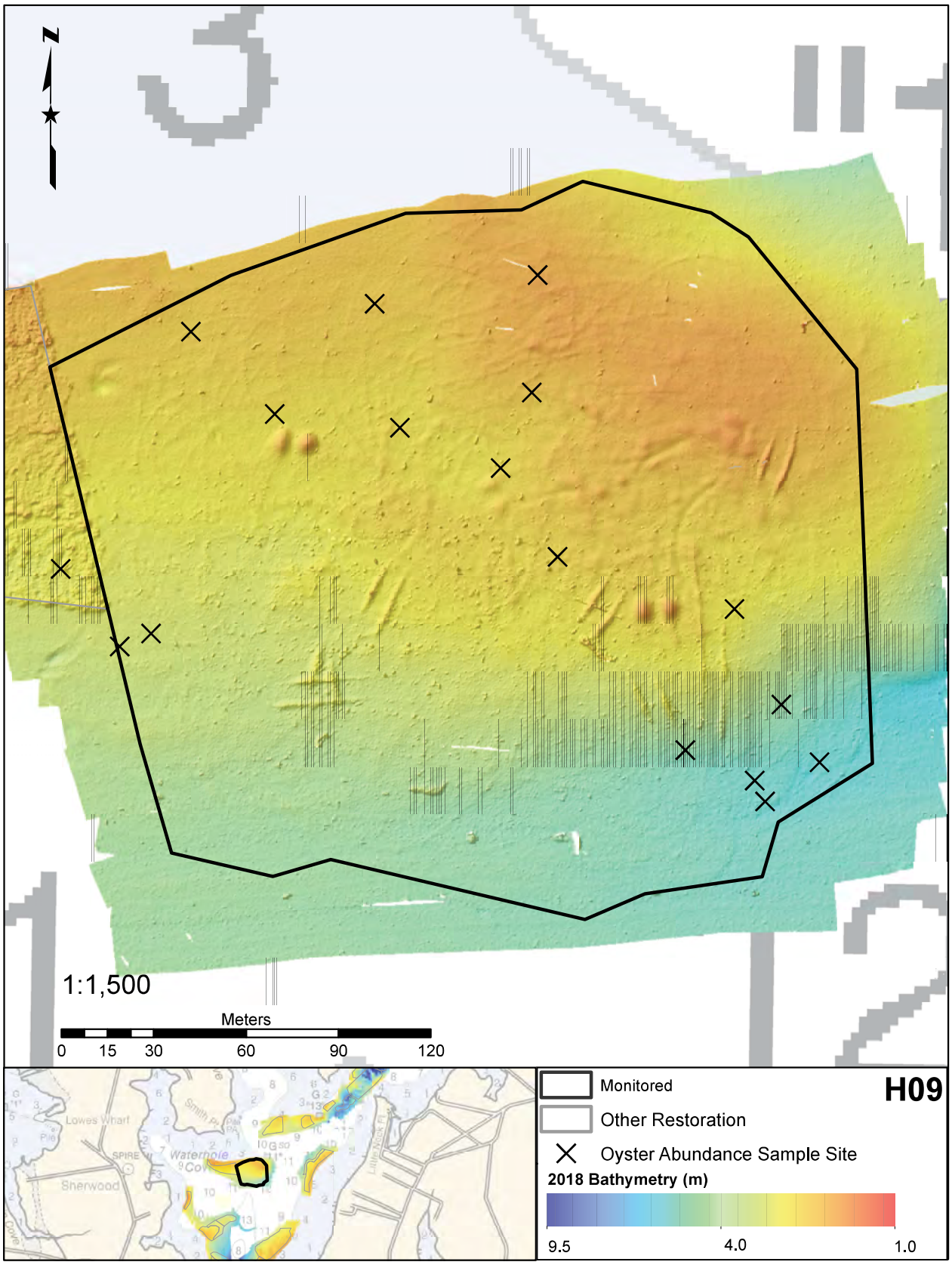
Shell Height of Oysters Measured on Reef



Reef H09 TREATMENT_2

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

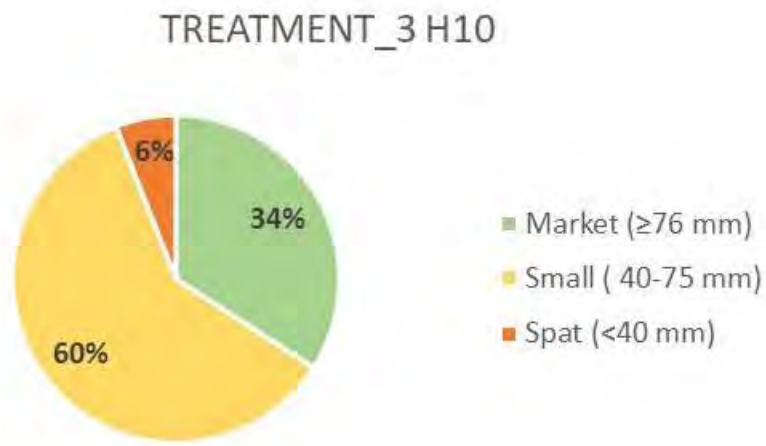


Reef H10 TREATMENT_3

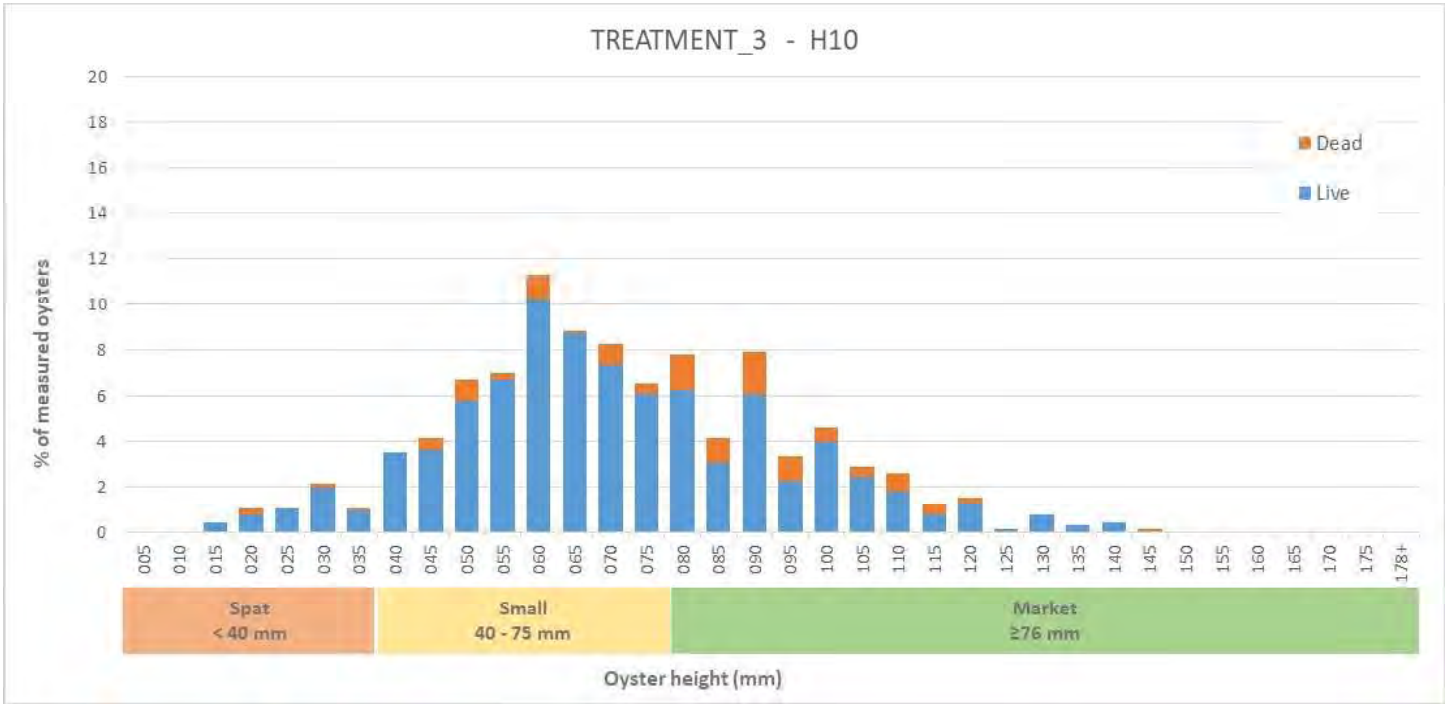
Reef Information	**Report reef ID**	**H10**
	Geodatabase Site_ID	TREATMENT_3
	Tributary	Harris Creek
	Reef area (acres)	10.88
Restoration Treatment	Restoration treatment	Seed Only
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	2012
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/14/2019
	# samples taken	15
	# live oysters measured	569
	# live oysters counted	2335
	# dead oysters counted	174
	% of oysters that were dead	7%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	96.69
	Standard error of live density (#/m^2)	10.78
	Number of samples meeting minimum threshold density (m^2)	14
	Percent of samples meeting minimum threshold density (%)	93%
	Number of samples meeting target density (m^2)	13
	Percent of samples meeting target density (%)	87%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	58.1
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	14
	Reef area meeting minimum threshold biomass (%)	93%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	13
	Reef area meeting target biomass (%)	87%
	Average live biomass across reef (g dry weight per m^2)	86.21
	Standard error of live biomass	9.57
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	62.72
Shell Volume	Is the shell budget stable/ increasing?	No
	Average shell volume across entire reef (liters per m^2)	14.16
	Standard error of shell volume	1.48
	Average brown shell across all samples (%)	78%
	Total volume change (liters per m^2)	-4.26
	% Change in total volume from 2015	-23%
	Surface shell volume change (liters per m^2)	0.73
	% change in surface shell volume change	7%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	-0.024
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H10 TREATMENT_3

Percent of Measured Oysters in the Market, Small, and Spat Categories



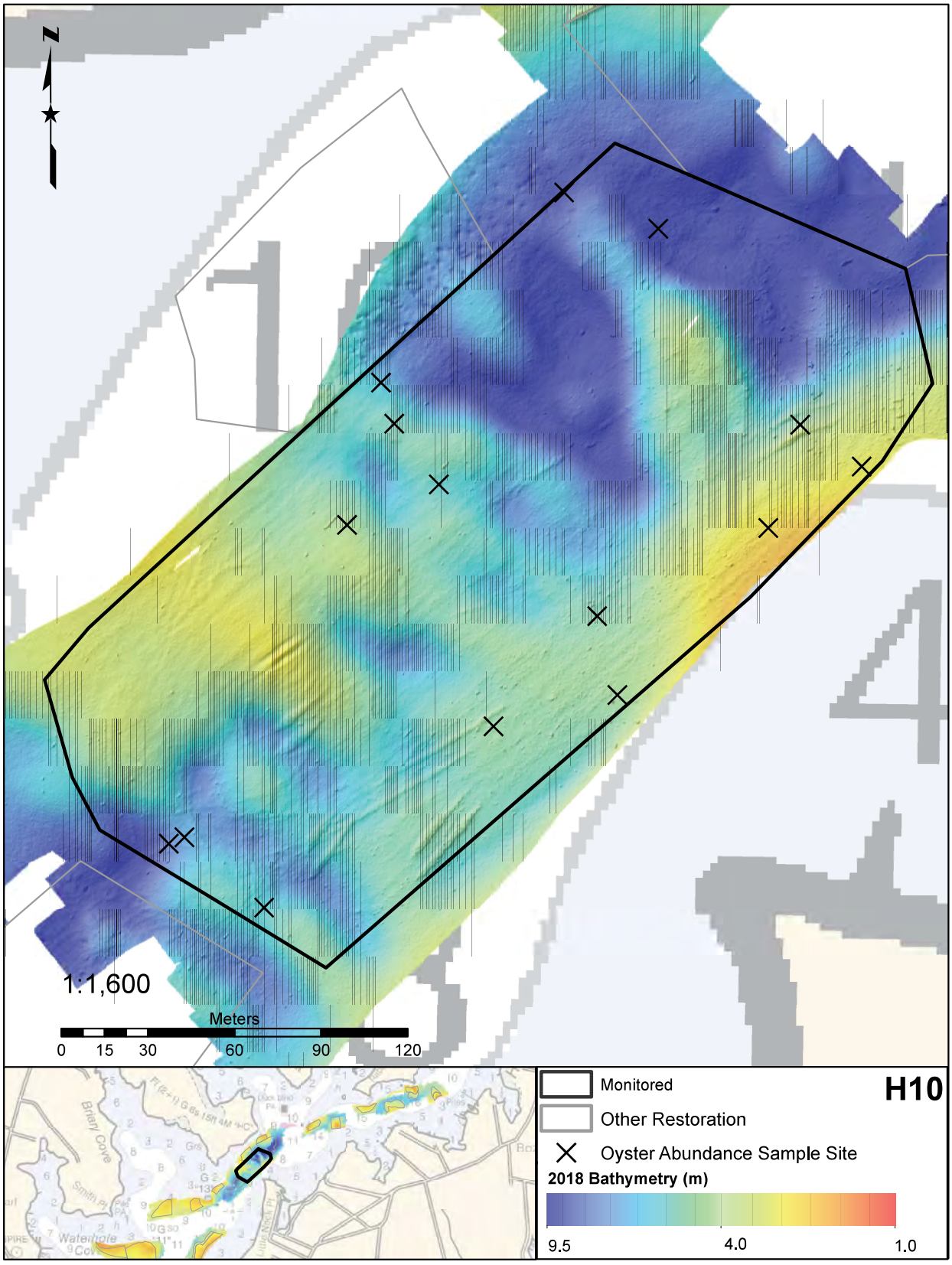
Shell Height of Oysters Measured on Reef



Reef H10 TREATMENT_3

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

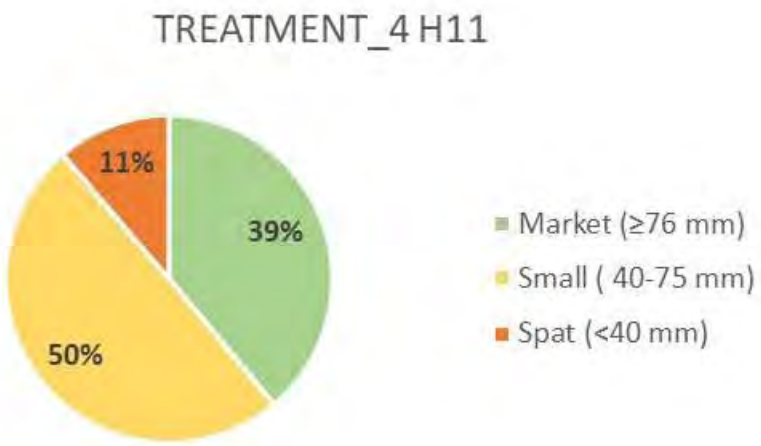


Reef H I I TREATMENT_3

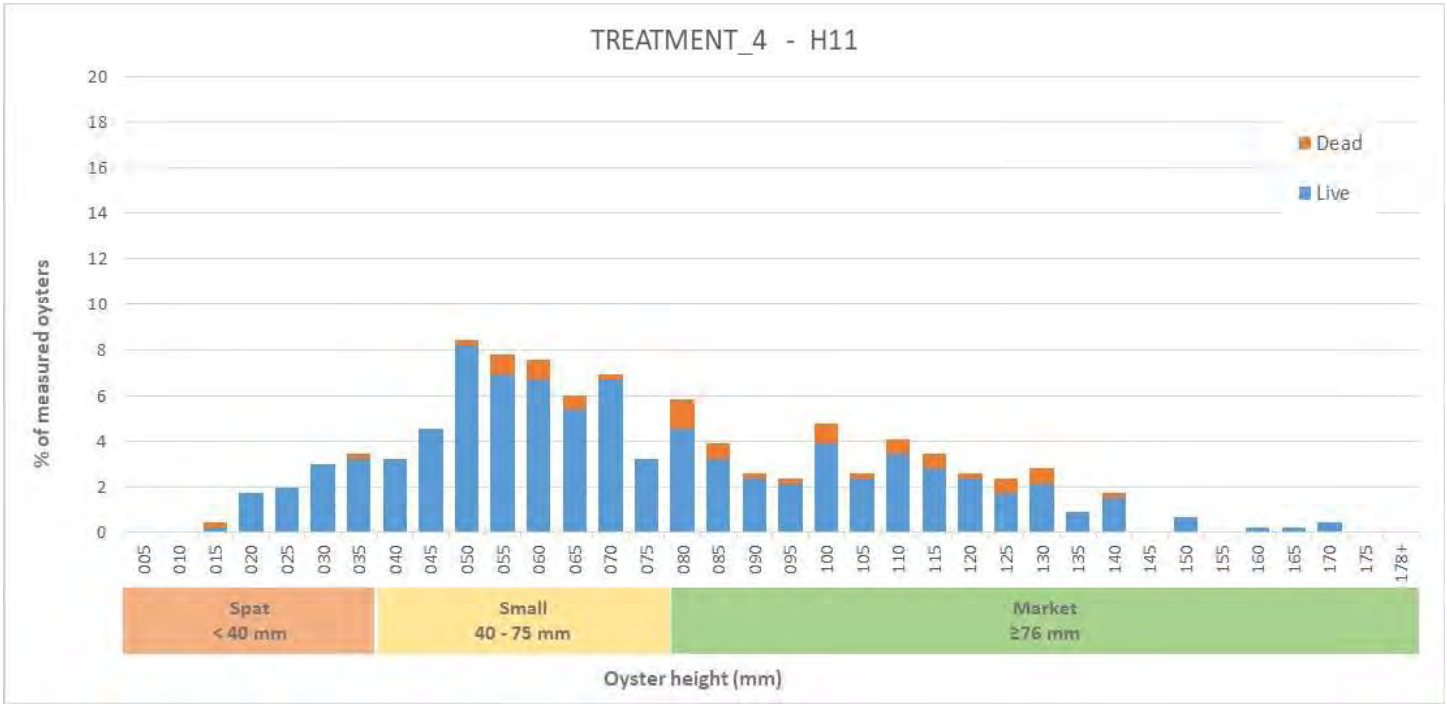
Reef Information	**Report reef ID**	**H11**
	Geodatabase Site_ID	TREATMENT_4
	Tributary	Harris Creek
	Reef area (acres)	6.53
Restoration Treatment	Restoration treatment	Seed Only
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	2012
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/12/2019
	# samples taken	13
	# live oysters measured	417
	# live oysters counted	1195
	# dead oysters counted	68
	% of oysters that were dead	5%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	57.10
	Standard error of live density (#/m^2)	11.15
	Number of samples meeting minimum threshold density (m^2)	10
	Percent of samples meeting minimum threshold density (%)	77%
	Number of samples meeting target density (m^2)	7
	Percent of samples meeting target density (%)	54%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	20.39
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	10
	Reef area meeting minimum threshold biomass (%)	77%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	7
	Reef area meeting target biomass (%)	54%
	Average live biomass across reef (g dry weight per m^2)	53.62
	Standard error of live biomass	9.56
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	22.96
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	12.89
	Standard error of shell volume	1.61
	Average brown shell across all samples (%)	69%
	Total volume change (liters per m^2)	5.17
	% Change in total volume from 2015	52%
	Surface shell volume change (liters per m^2)	5.24
	% change in surface shell volume change	125%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.007
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H I I TREATMENT_4

Percent of Measured Oysters in the Market, Small, and Spat Categories



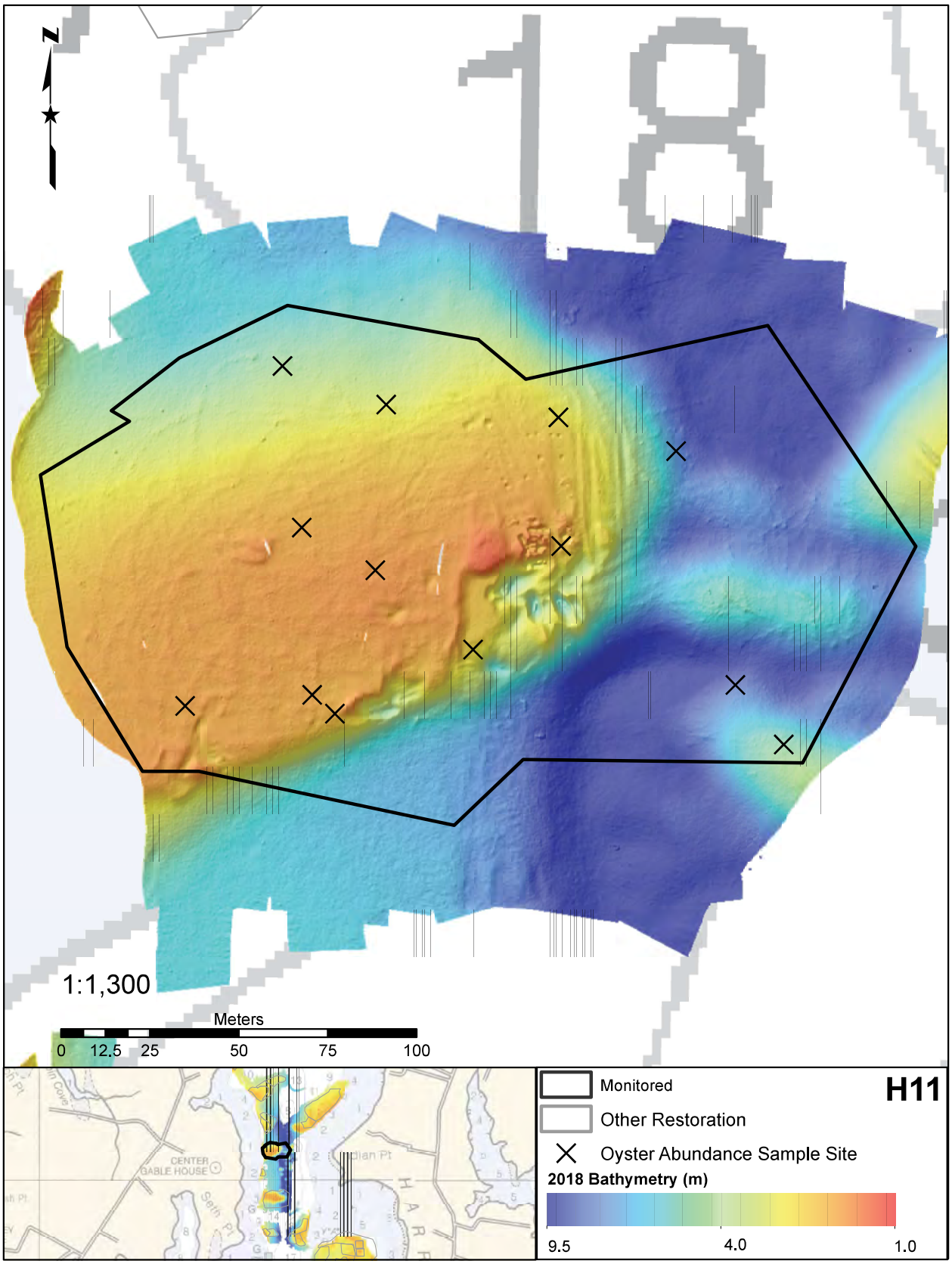
Shell Height of Oysters Measured on Reef



Reef H11 TREATMENT_4

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

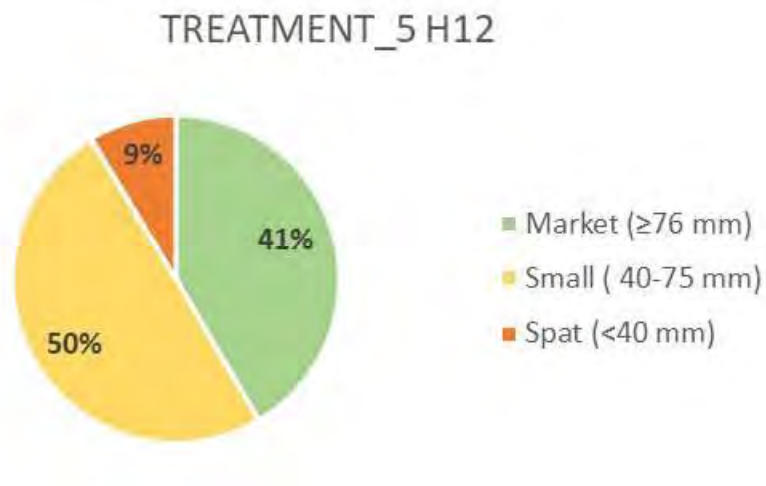


Reef H12 TREATMENT_5

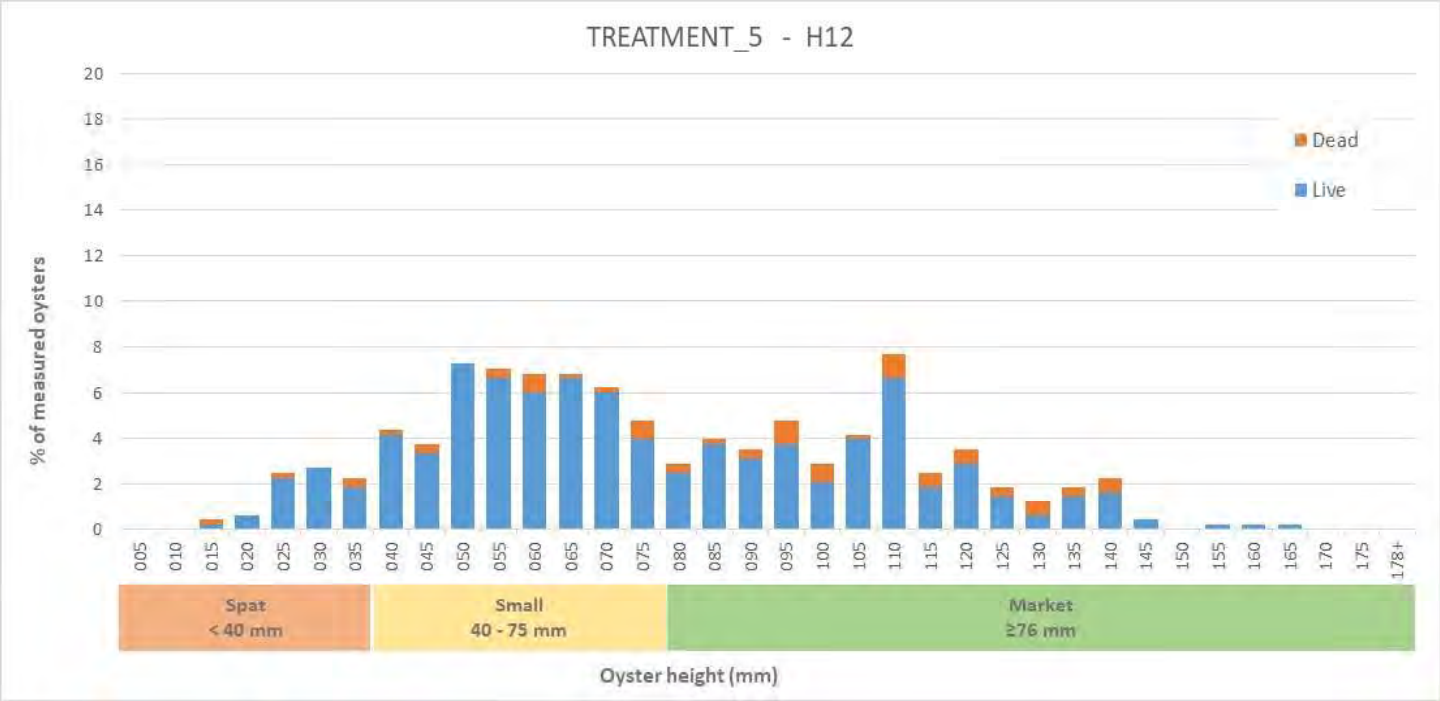
Reef Information	**Report reef ID**	**H12**
	Geodatabase Site_ID	TREATMENT_5
	Tributary	Harris Creek
	Reef area (acres)	7.83
Restoration Treatment	Restoration treatment	Seed Only
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	2012
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/20/2019
	# samples taken	14
	# live oysters measured	426
	# live oysters counted	773
	# dead oysters counted	64
	% of oysters that were dead	8%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	34.29
	Standard error of live density (#/m^2)	5.28
	Number of samples meeting minimum threshold density (m^2)	11
	Percent of samples meeting minimum threshold density (%)	79%
	Number of samples meeting target density (m^2)	3
	Percent of samples meeting target density (%)	21%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	16.53
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	11
	Reef area meeting minimum threshold biomass (%)	79%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	2
	Reef area meeting target biomass (%)	14%
	Average live biomass across reef (g dry weight per m^2)	35.43
	Standard error of live biomass	5.14
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	20.53
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	10.29
	Standard error of shell volume	1.36
	Average brown shell across all samples (%)	78%
	Total volume change (liters per m^2)	4.25
	% Change in total volume from 2015	70%
	Surface shell volume change (liters per m^2)	4.57
	% change in surface shell volume change	150%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.036
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H12 TREATMENT_5

Percent of Measured Oysters in the Market, Small, and Spat Categories



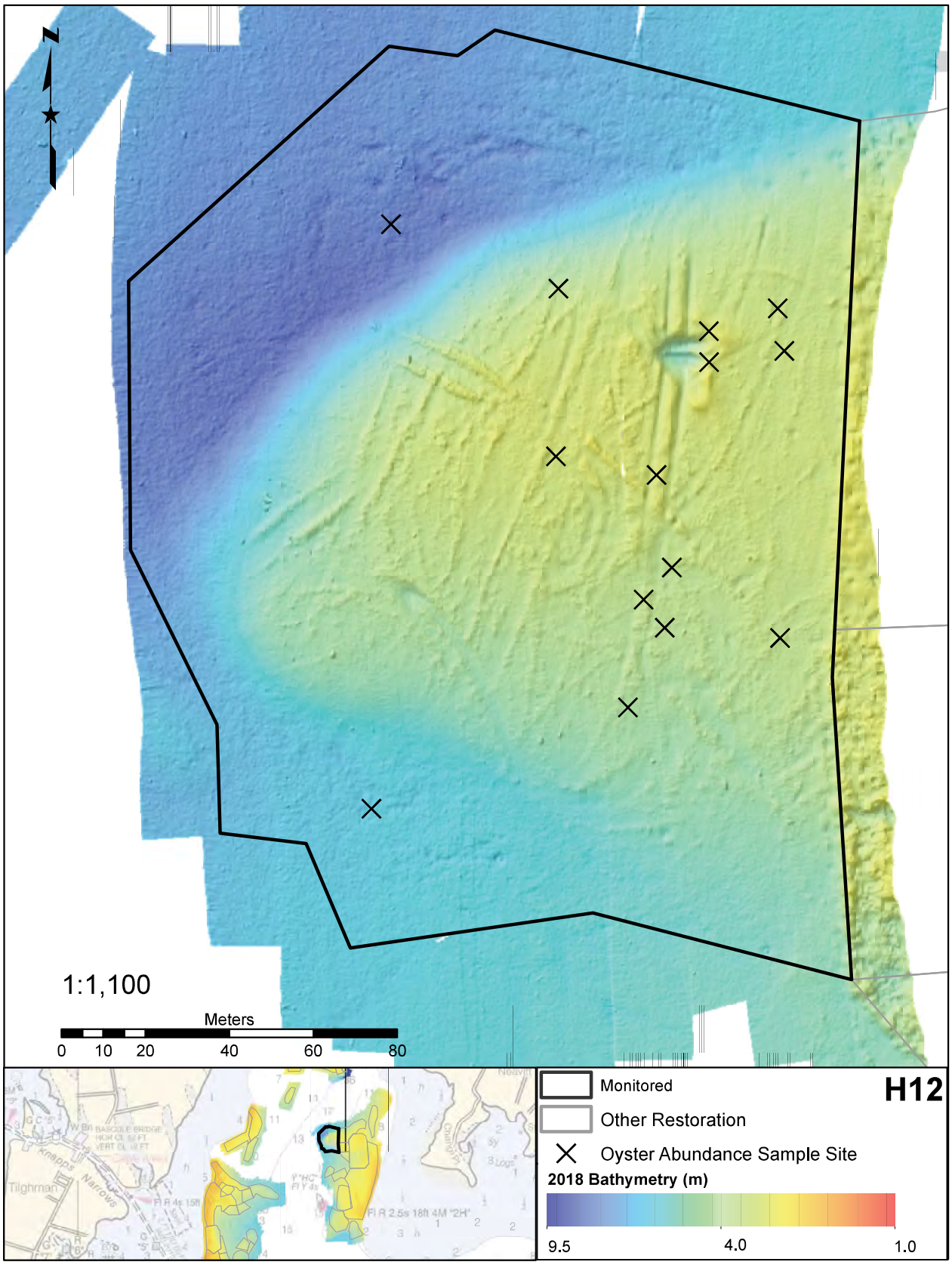
Shell Height of Oysters Measured on Reef



Reef H12 TREATMENT_5

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

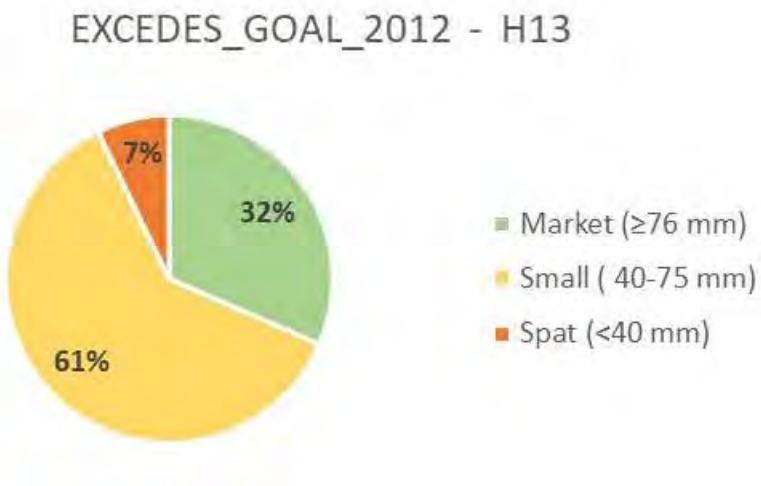


Reef H13 EXCEEDS_GOAL_2012

Reef Information	**Report reef ID**	**H13**
	Geodatabase Site_ID	EXCEDES_GOAL_2012
	Tributary	Harris Creek
	Reef area (acres)	3.4
Restoration Treatment	Restoration treatment	Seed Only
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	2011
	Second year class replanting	2017
Monitoring Information	Monitoring type	Sentinel
	Sample method	Patent Tong
	Sample date	3/27/2019
	# samples taken	10
	# live oysters measured	349
	# live oysters counted	721
	# dead oysters counted	51
	% of oysters that were dead	7%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	44.78
	Standard error of live density (#/m^2)	7.03
	Number of samples meeting minimum threshold density (m^2)	10
	Percent of samples meeting minimum threshold density (%)	100%
	Number of samples meeting target density (m^2)	4
	Percent of samples meeting target density (%)	40%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	9
	Reef area meeting minimum threshold biomass (%)	90%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	1
	Reef area meeting target biomass (%)	10%
	Average live biomass across reef (g dry weight per m^2)	36.14
	Standard error of live biomass	4.53
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	12.67
	Standard error of shell volume	1.39
	Average brown shell across all samples (%)	76%
	Total volume change (liters per m^2)	1.22
	% Change in total volume from 2015	11%
	Surface shell volume change (liters per m^2)	2.46
	% change in surface shell volume change	36%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	No data in 2018
Reef Height	Is reef height stable/increasing?	No data in 2019
	3 years post restoration (cm)	
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H13 EXCEEDS_GOAL_2012

Percent of Measured Oysters in the Market, Small, and Spat Categories



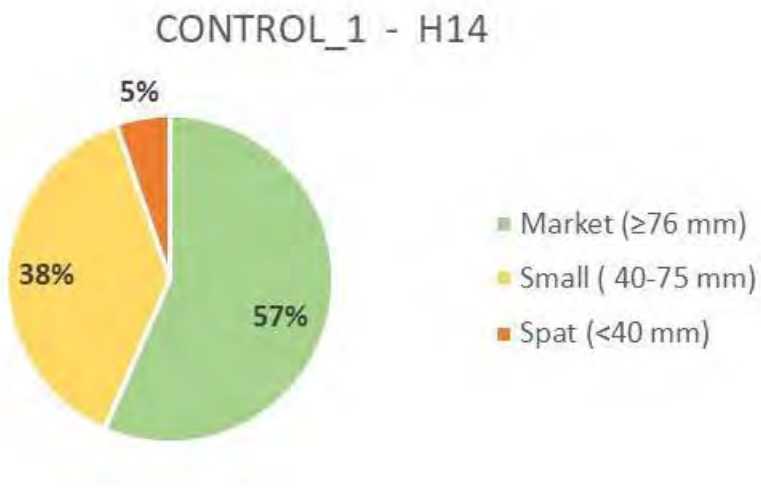
Shell Height of Oysters Measured on Reef

Reef H14 CONTROL_1

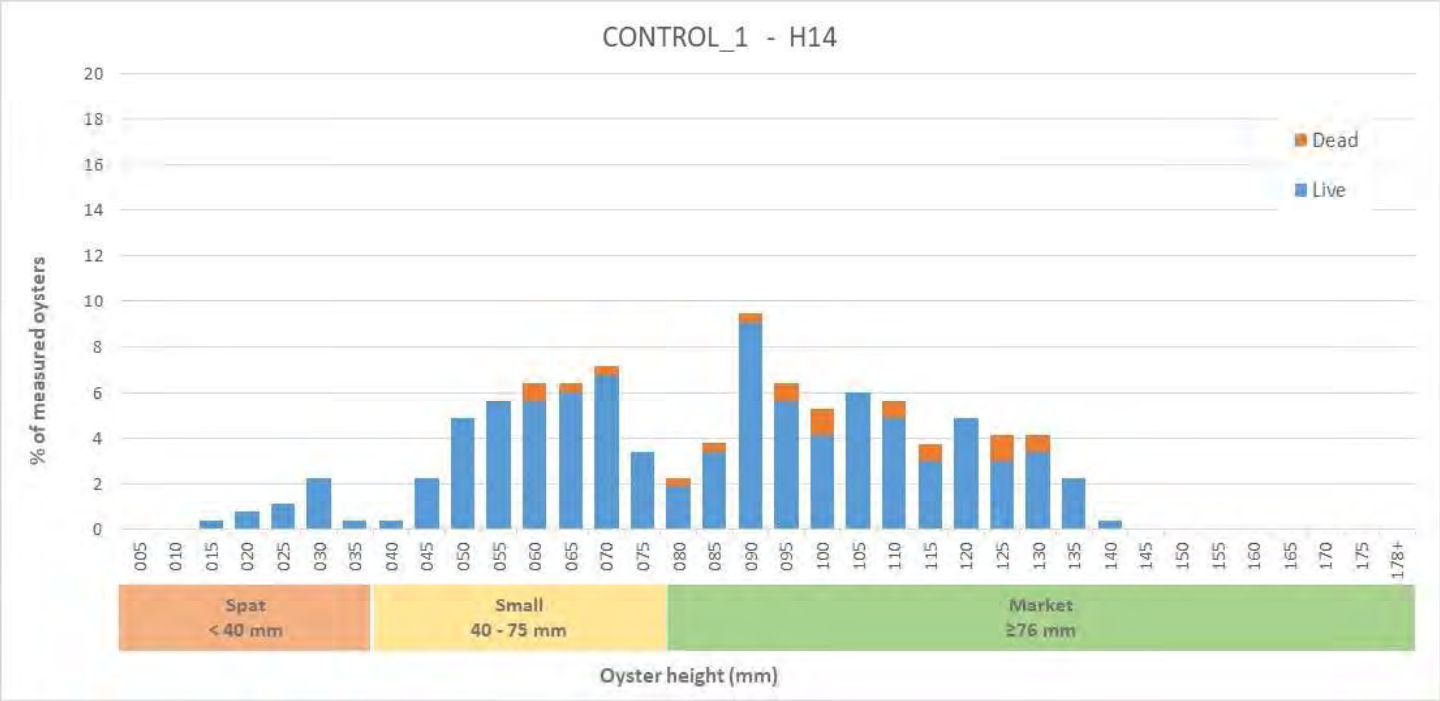
Reef Information	Report reef ID	H14
	Geodatabase Site_ID	CONTROL_1
	Tributary	Harris Creek
	Reef area (acres)	3.47
Restoration Treatment	Restoration treatment	None (control site)
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	N/A
	Second year class replanting	N/A
Monitoring Information	Monitoring type	Reference
	Sample method	Patent Tong
	Sample date	3/20/2019
	# samples taken	9
	# live oysters measured	244
	# live oysters counted	370
	# dead oysters counted	21
	% of oysters that were dead	5%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	25.53
	Standard error of live density (#/m^2)	6.09
	Number of samples meeting minimum threshold density (m^2)	6
	Percent of samples meeting minimum threshold density (%)	67%
	Number of samples meeting target density (m^2)	1
	Percent of samples meeting target density (%)	11%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	6
	Reef area meeting minimum threshold biomass (%)	67%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	1
	Reef area meeting target biomass (%)	11%
	Average live biomass across reef (g dry weight per m^2)	30.25
	Standard error of live biomass	7.97
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	8.64
	Standard error of shell volume	1.49
	Average brown shell across all samples (%)	77%
	Total volume change (liters per m^2)	2.97
	% Change in total volume from 2015	42%
	Surface shell volume change (liters per m^2)	5.25
	% change in surface shell volume change	267%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	No data in 2018
Reef Height	Is reef height stable/increasing?	No data in 2019
	3 years post restoration (cm)	
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H14 CONTROL_I

Percent of Measured Oysters in the Market, Small, and Spat Categories



Shell Height of Oysters Measured on Reef



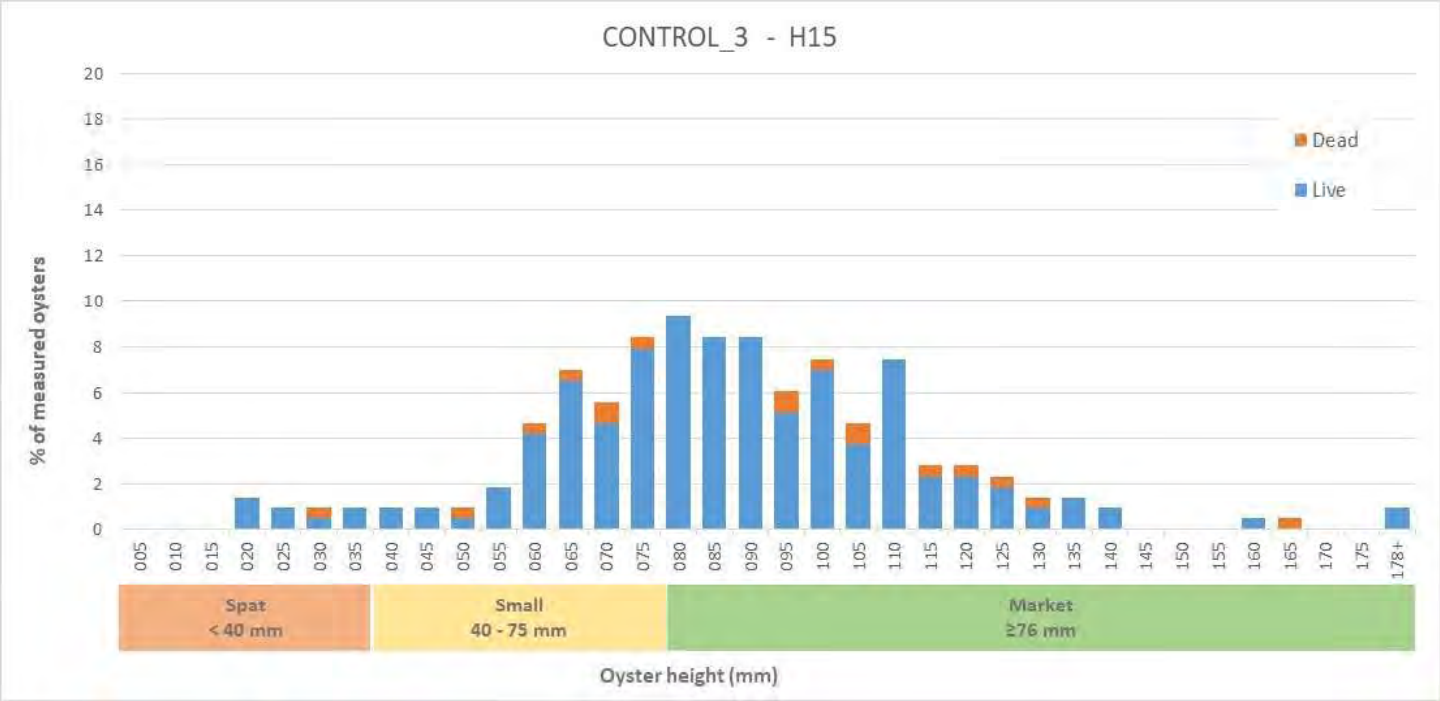
Reef H15 CONTROL_3

Reef Information	**Report reef ID**	**H15**
	Geodatabase Site_ID	CONTROL_3
	Tributary	Harris Creek
	Reef area (acres)	1.85
Restoration Treatment	Restoration treatment	None (control site)
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	N/A
	Second year class replanting	N/A
Monitoring Information	Monitoring type	Reference
	Sample method	Patent Tong
	Sample date	3/14/2019
	# samples taken	8
	# live oysters measured	197
	# live oysters counted	244
	# dead oysters counted	17
	% of oysters that were dead	7%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	18.94
	Standard error of live density (#/m^2)	5.08
	Number of samples meeting minimum threshold density (m^2)	5
	Percent of samples meeting minimum threshold density (%)	63%
	Number of samples meeting target density (m^2)	0
	Percent of samples meeting target density (%)	0%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	5
	Reef area meeting minimum threshold biomass (%)	63%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	1
	Reef area meeting target biomass (%)	13%
	Average live biomass across reef (g dry weight per m^2)	22.67
	Standard error of live biomass	5.81
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	6.06
	Standard error of shell volume	0.90
	Average brown shell across all samples (%)	44%
	Total volume change (liters per m^2)	1.88
	% Change in total volume from 2015	14%
	Surface shell volume change (liters per m^2)	1.78
	% change in surface shell volume change	135%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	No data in 2018
Reef Height	Is reef height stable/increasing?	No data in 2019
	3 years post restoration (cm)	
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H15 CONTROL_3

Percent of Measured Oysters in the Market, Small, and Spat Categories

Shell Height of Oysters Measured on Reef



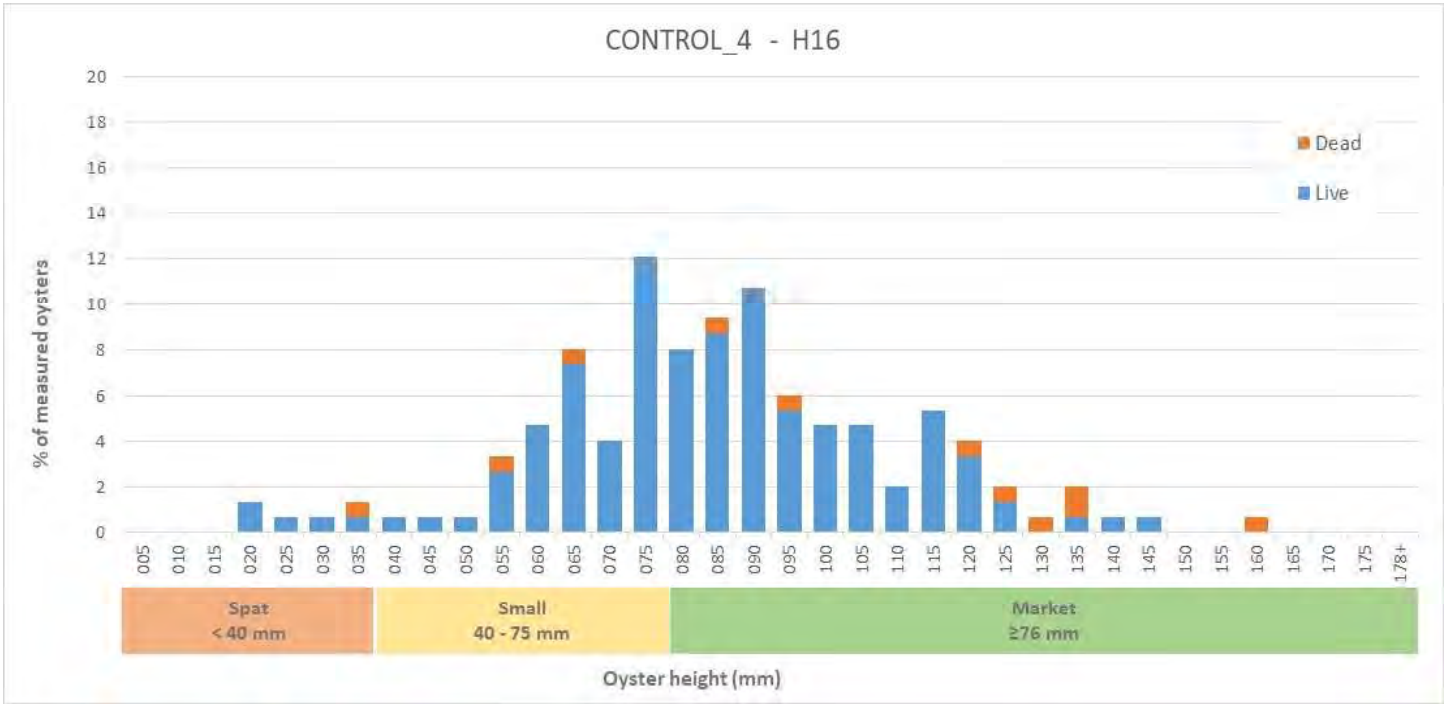
Reef H16 CONTROL_4

Reef Information	**Report reef ID**	**H16**
	Geodatabase Site_ID	CONTROL_4
	Tributary	Harris Creek
	Reef area (acres)	1.39
Restoration Treatment	Restoration treatment	None (control site)
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	N/A
	Second year class replanting	N/A
Monitoring Information	Monitoring type	Reference
	Sample method	Patent Tong
	Sample date	3/14/2019
	# samples taken	7
	# live oysters measured	138
	# live oysters counted	145
	# dead oysters counted	11
	% of oysters that were dead	7%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	12.87
	Standard error of live density (#/m^2)	3.41
	Number of samples meeting minimum threshold density (m^2)	4
	Percent of samples meeting minimum threshold density (%)	57%
	Number of samples meeting target density (m^2)	0
	Percent of samples meeting target density (%)	0%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	3
	Reef area meeting minimum threshold biomass (%)	43%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	0
	Reef area meeting target biomass (%)	0%
	Average live biomass across reef (g dry weight per m^2)	14.71
	Standard error of live biomass	3.76
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	6.12
	Standard error of shell volume	1.22
	Average brown shell across all samples (%)	36%
	Total volume change (liters per m^2)	2.48
	% Change in total volume from 2015	44%
	Surface shell volume change (liters per m^2)	0.87
	% change in surface shell volume change	127%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	No data in 2018
Reef Height	Is reef height stable/increasing?	No data in 2019
	3 years post restoration (cm)	
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H16 CONTROL_4

Percent of Measured Oysters in the Market, Small, and Spat Categories

Shell Height of Oysters Measured on Reef

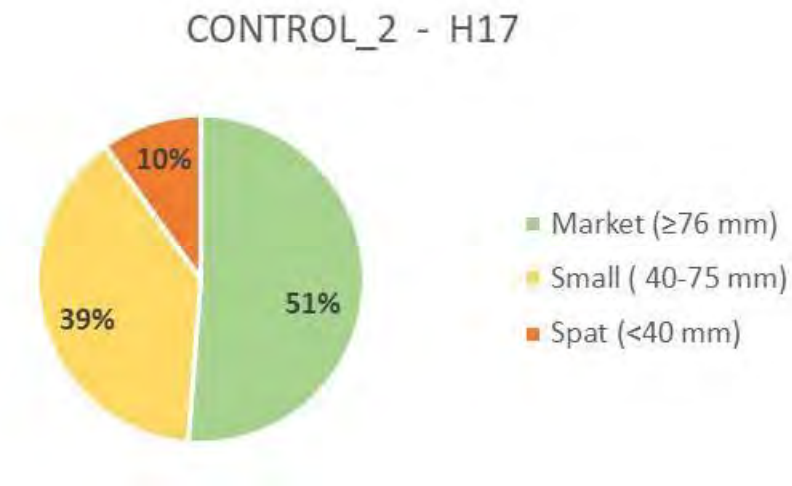


Reef H17 CONTROL_2

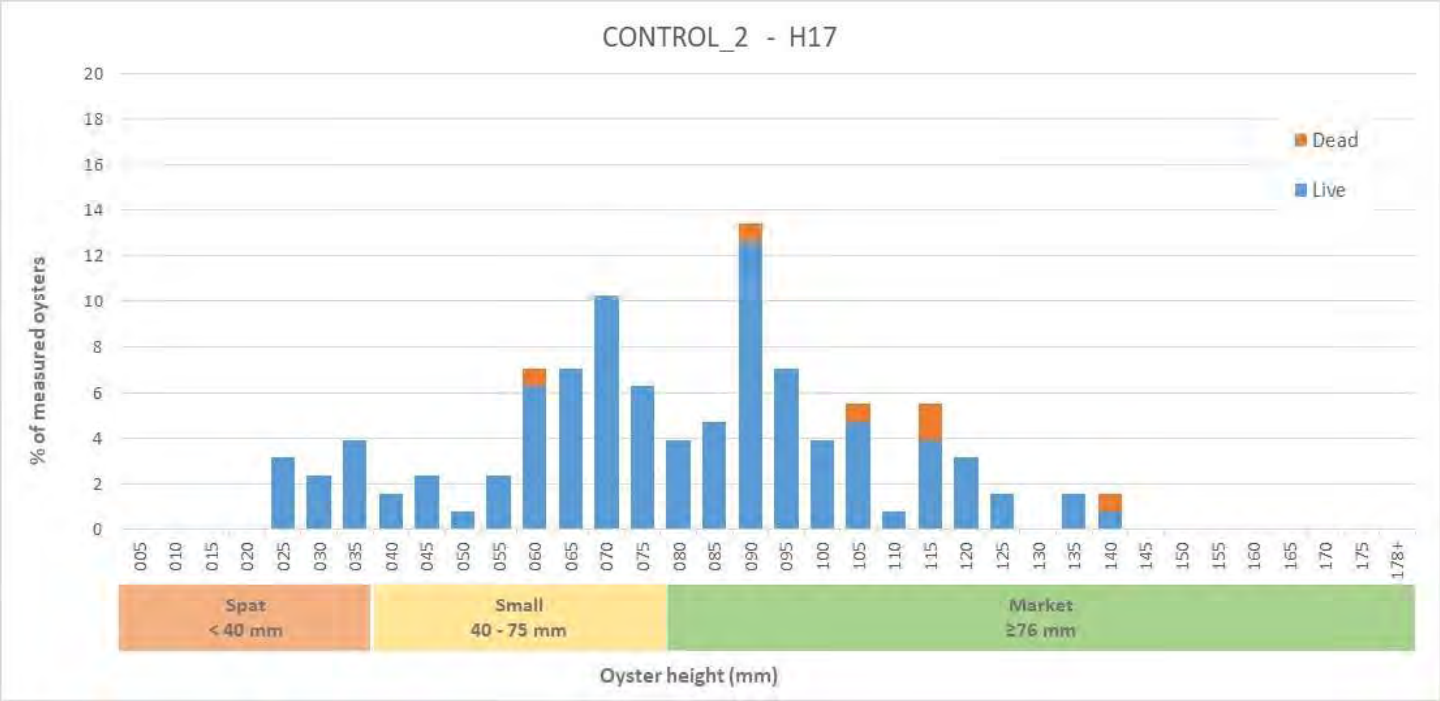
Reef Information	Report reef ID	H17
	Geodatabase Site_ID	CONTROL_2
	Tributary	Harris Creek
	Reef area (acres)	4.01
Restoration Treatment	Restoration treatment	None (control site)
	Substrate type added	None
	Average planned reef height*	N/A
	Year planted with spat (initial planting)	N/A
	Second year class replanting	N/A
Monitoring Information	Monitoring type	Reference
	Sample method	Patent Tong
	Sample date	3/27/2019
	# samples taken	10
	# live oysters measured	121
	# live oysters counted	159
	# dead oysters counted	6
	% of oysters that were dead	4%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	No
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	9.88
	Standard error of live density (#/m^2)	3.76
	Number of samples meeting minimum threshold density (m^2)	2
	Percent of samples meeting minimum threshold density (%)	20%
	Number of samples meeting target density (m^2)	0
	Percent of samples meeting target density (%)	0%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	No
	Number of samples meeting minimum threshold biomass	2
	Reef area meeting minimum threshold biomass (%)	20%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	0
	Reef area meeting target biomass (%)	0%
	Average live biomass across reef (g dry weight per m^2)	10.06
	Standard error of live biomass	4.14
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	Yes
	Average shell volume across entire reef (liters per m^2)	4.73
	Standard error of shell volume	1.20
	Average brown shell across all samples (%)	35%
	Total volume change (liters per m^2)	1.11
	% Change in total volume from 2015	8%
	Surface shell volume change (liters per m^2)	1.69
	% change in surface shell volume change	481%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	No data in 2018
Reef Height	Is reef height stable/increasing?	No data in 2019
	3 years post restoration (cm)	
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H17 CONTROL_2

Percent of Measured Oysters in the Market, Small, and Spat Categories



Shell Height of Oysters Measured on Reef

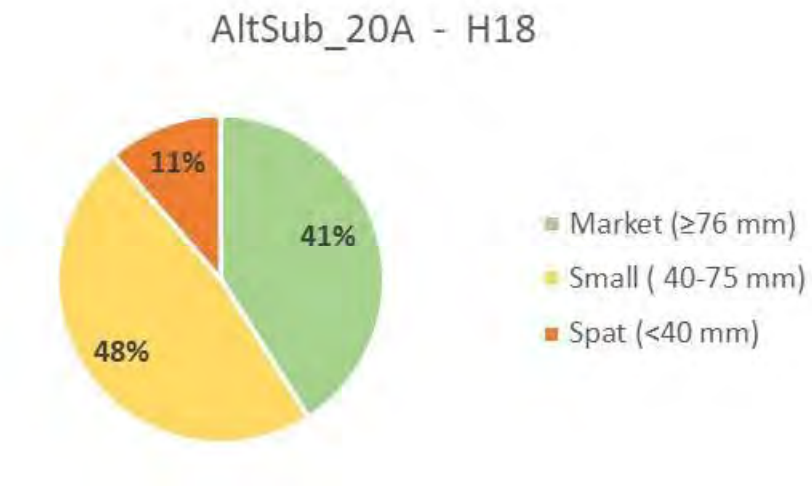


Reef H18 AltSub_20A

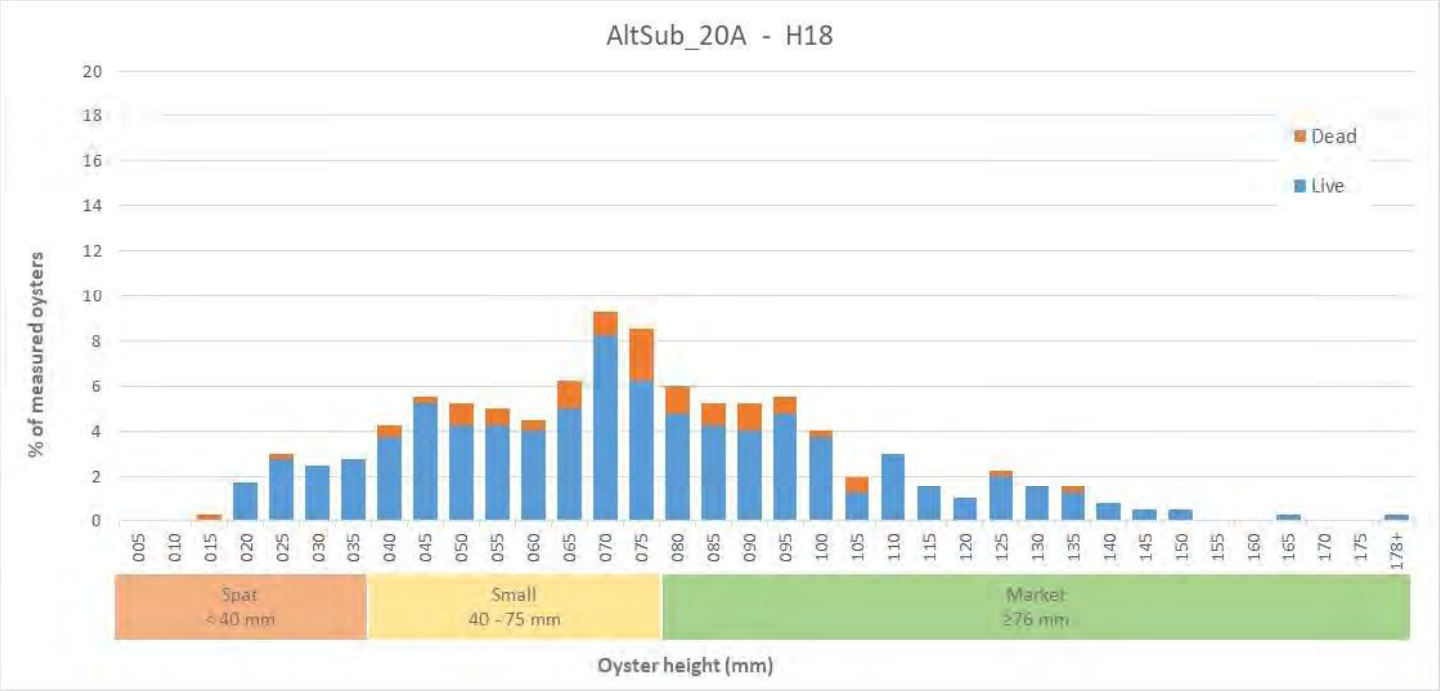
Reef Information	**Report reef ID**	**H01**
	Geodatabase Site_ID	AltSub_104
	Tributary	Harris Creek
	Reef area (acres)	3.37
Restoration Treatment	Restoration treatment	Substrate & Seed
	Substrate type added	Mixed Shell
	Average planned reef height*	12
	Year planted with spat (initial planting)	2012
	Second year class replanting	2017
Monitoring Information	Monitoring type	6 Year Cohort
	Sample method	Patent Tong
	Sample date	3/3/2019
	# samples taken	10
	# live oysters measured	319
	# live oysters counted	493
	# dead oysters counted	34
	% of oysters that were dead	6%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	No
	Average live density across reef (#/m^2)	30.62
	Standard error of live density (#/m^2)	3.47
	Number of samples meeting minimum threshold density (m^2)	10
	Percent of samples meeting minimum threshold density (%)	100%
	Number of samples meeting target density (m^2)	1
	Percent of samples meeting target density (%)	10%
	Average live density on stone (#/m^2)	N/A
	Standard error of live density on stone	N/A
	Average live density on shell--all shell types (#/m^2)	N/A
	Standard error of live density on shell-aall shell types	N/A
	Average live density on clam shell (#/m^2)	N/A
	Standard error of live density on clam shell	N/A
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	55.81
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	10
	Reef area meeting minimum threshold biomass (%)	100%
	Fall 2018: Did reef meet target oyster biomass?	No
	Number of samples meeting target biomass	1
	Reef area meeting target biomass (%)	10%
	Average live biomass across reef (g dry weight per m^2)	33.07
	Standard error of live biomass	4.64
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	66.09
Shell Volume	Is the shell budget stable/ increasing?	No
	Average shell volume across entire reef (liters per m^2)	9.69
	Standard error of shell volume	1.22
	Average brown shell across all samples (%)	80%
	Total volume change (liters per m^2)	-4.07
	% Change in total volume from 2015	-35%
	Surface shell volume change (liters per m^2)	-3.09
	% change in surface shell volume change	-29%
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	-0.02
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H18 AltSub_20A

Percent of Measured Oysters in the Market, Small, and Spat Categories



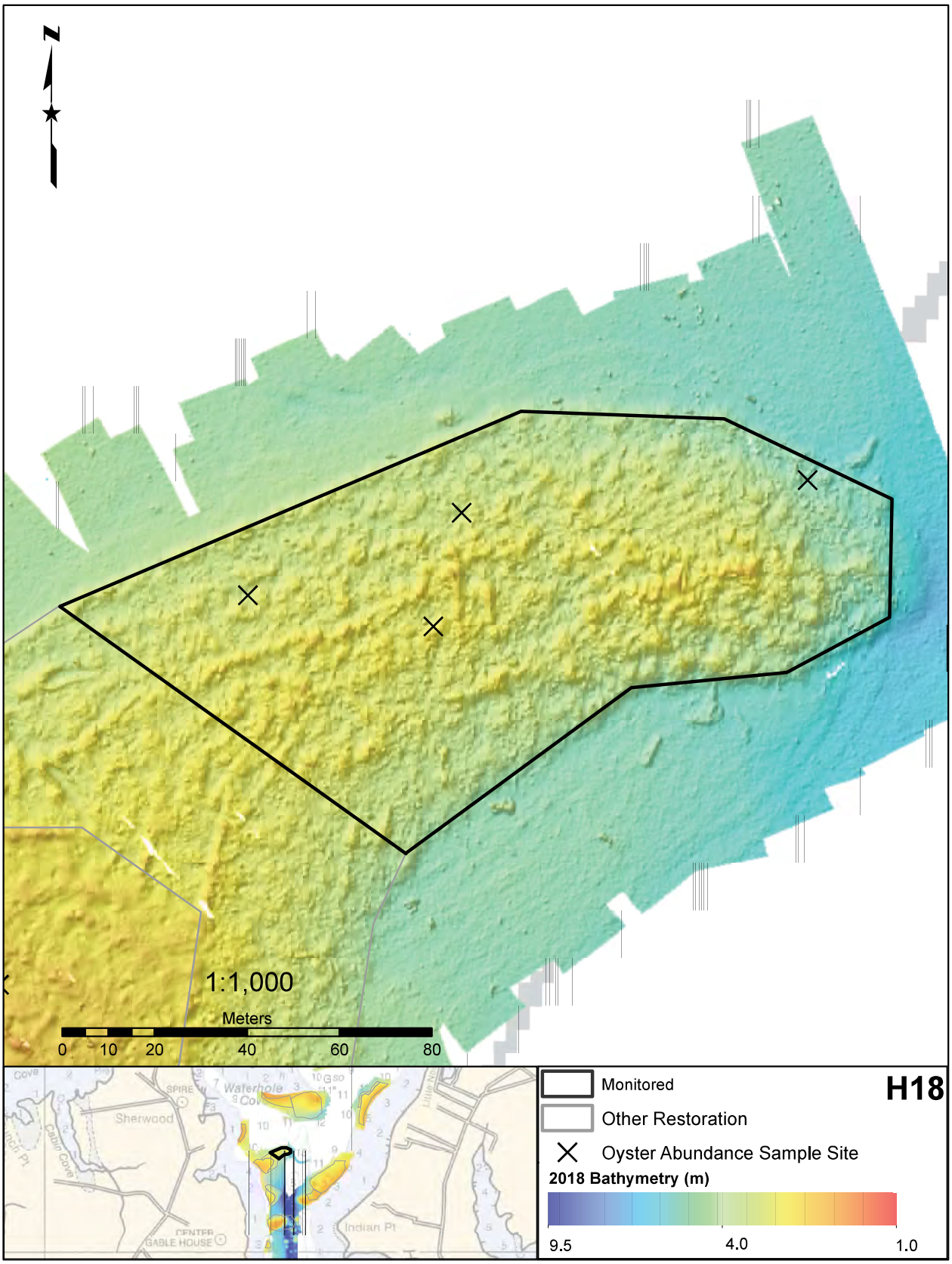
Shell Height of Oysters Measured on Reef



Reef H18 AltSub_20A

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

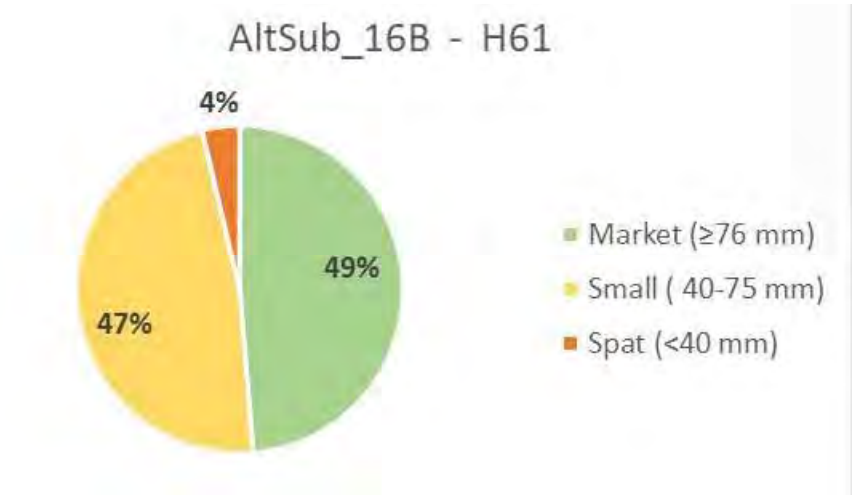


Reef H61 AltSub_16B

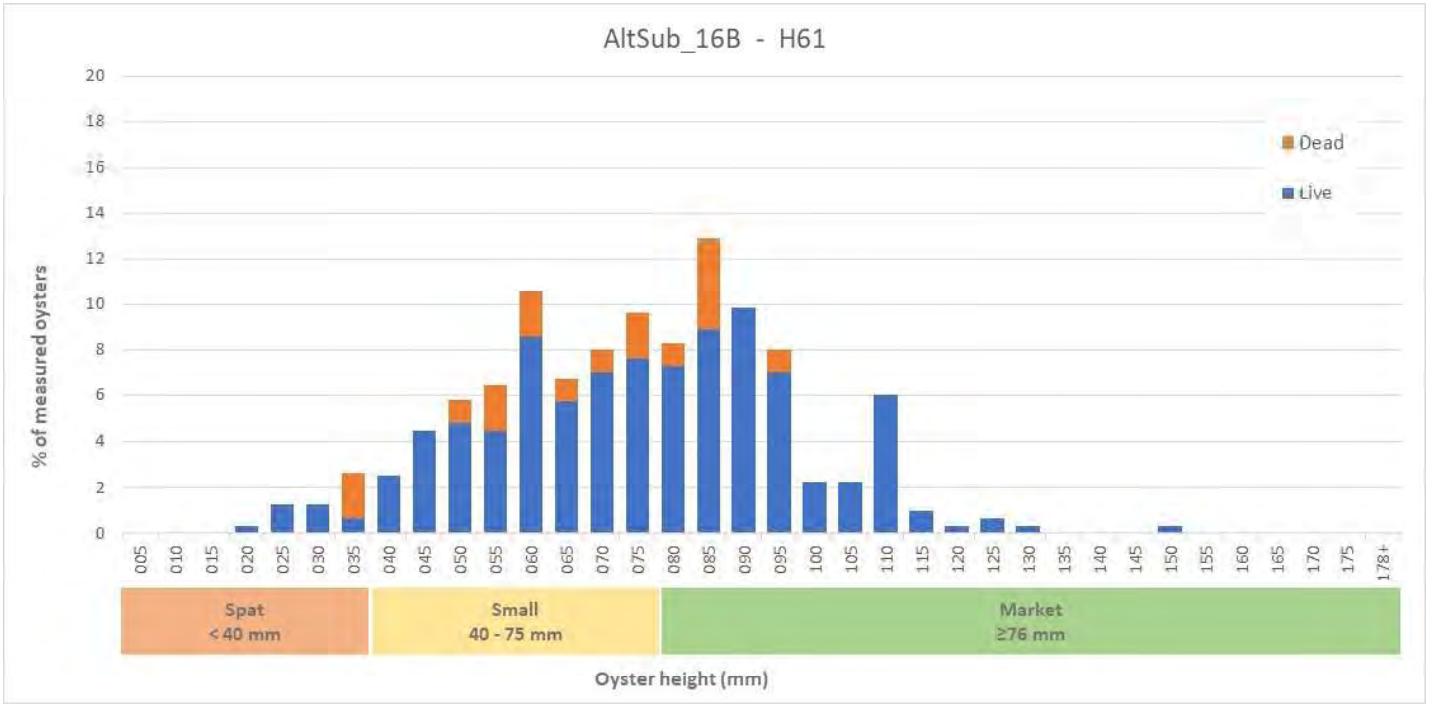
Reef Information	**Report reef ID**	**H61**
	Geodatabase Site_ID	AltSub_16B
	Tributary	Harris Creek
	Reef area (acres)	0.56
Restoration Treatment	Restoration treatment	Substrate & Seed
	Substrate type added	Stone base with mixed shell
	Average planned reef height*	12
	Year planted with spat (initial planting)	2014
	Second year class replanting	2015
Monitoring Information	Monitoring type	3 Year Cohort
	Sample method	Diver
	Sample date	1/8/2019
	# samples taken	5
	# live oysters measured	297
	# live oysters counted	341
	# dead oysters counted	18
	% of oysters that were dead	5%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	136.40
	Standard error of live density (#/m^2)	34.01
	Number of samples meeting minimum threshold density (m^2)	5
	Percent of samples meeting minimum threshold density (%)	100%
	Number of samples meeting target density (m^2)	5
	Percent of samples meeting target density (%)	100%
	Average live density on stone (#/m^2)	23.20
	Standard error of live density on stone	8.69
	Average live density on shell--all shell types (#/m^2)	76.40
	Standard error of live density on shell-aall shell types	38.65
	Average live density on clam shell (#/m^2)	36.80
	Standard error of live density on clam shell	13.06
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	5
	Reef area meeting minimum threshold biomass (%)	100%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	5
	Reef area meeting target biomass (%)	100%
	Average live biomass across reef (g dry weight per m^2)	118.01
	Standard error of live biomass	33.34
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	TBD in 2021
	Average shell volume across entire reef (liters per m^2)	87.60
	Standard error of shell volume	9.36
	Average brown shell across all samples (%)	83%
	Total volume change (liters per m^2)	-
	% Change in total volume from 2015	-
	Surface shell volume change (liters per m^2)	-
	% change in surface shell volume change	-
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.023
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H61 AltSub_16B

Percent of Measured Oysters in the Market, Small, and Spat Categories



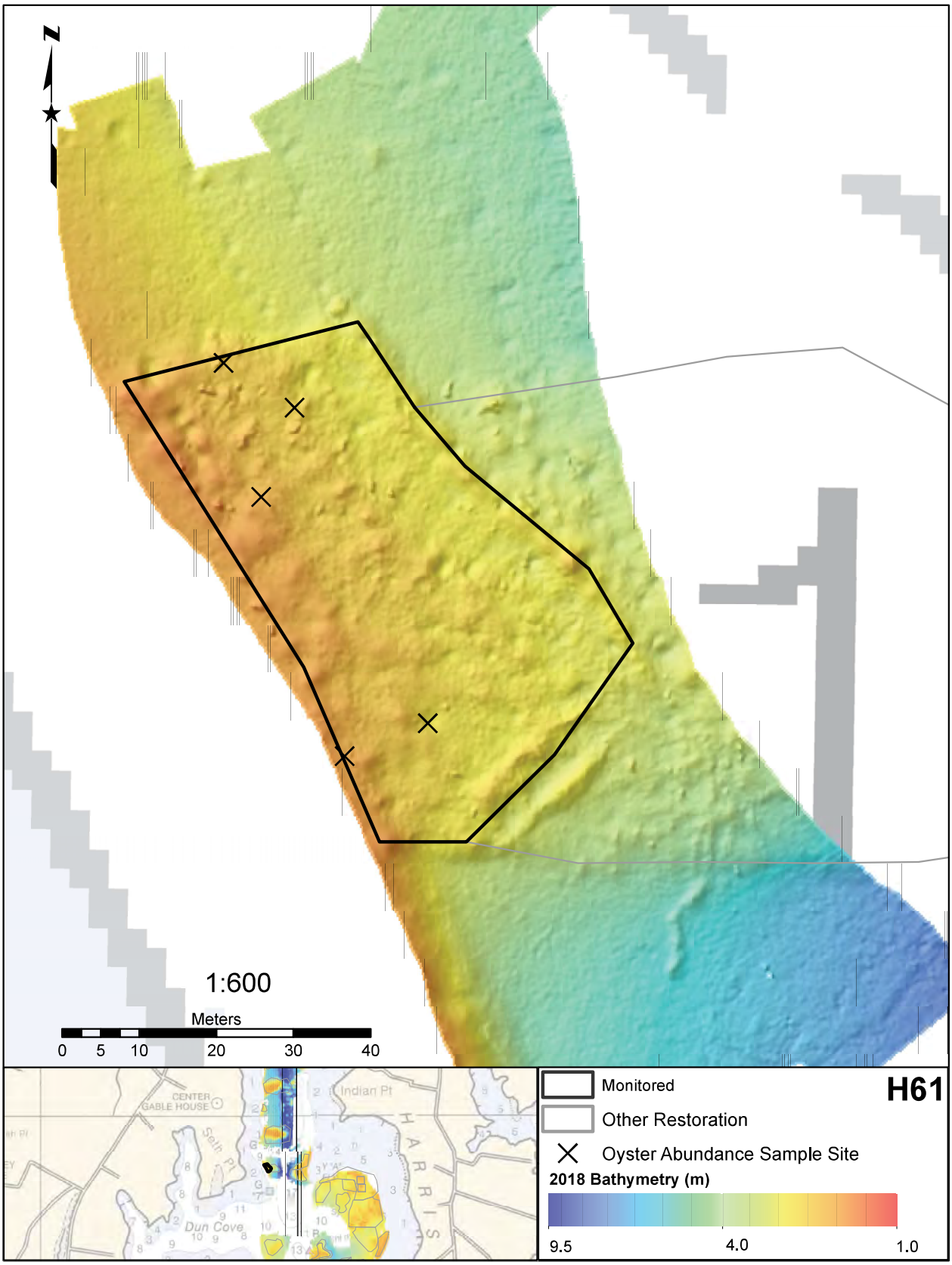
Shell Height of Oysters Measured on Reef



Reef H61 AltSub_16B

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

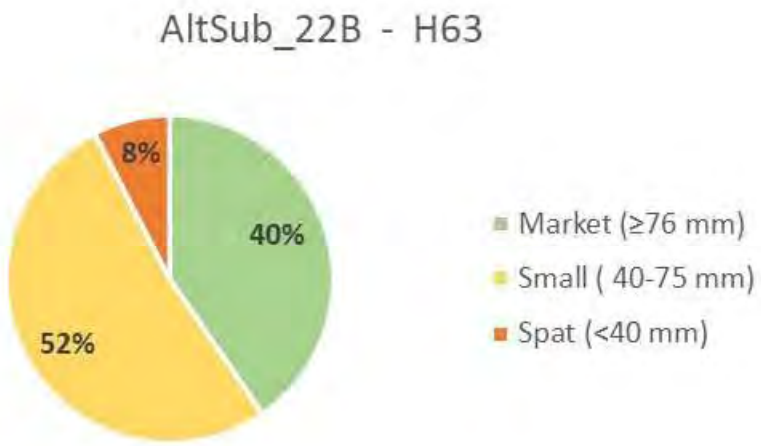


Reef H63 AltSub_22B

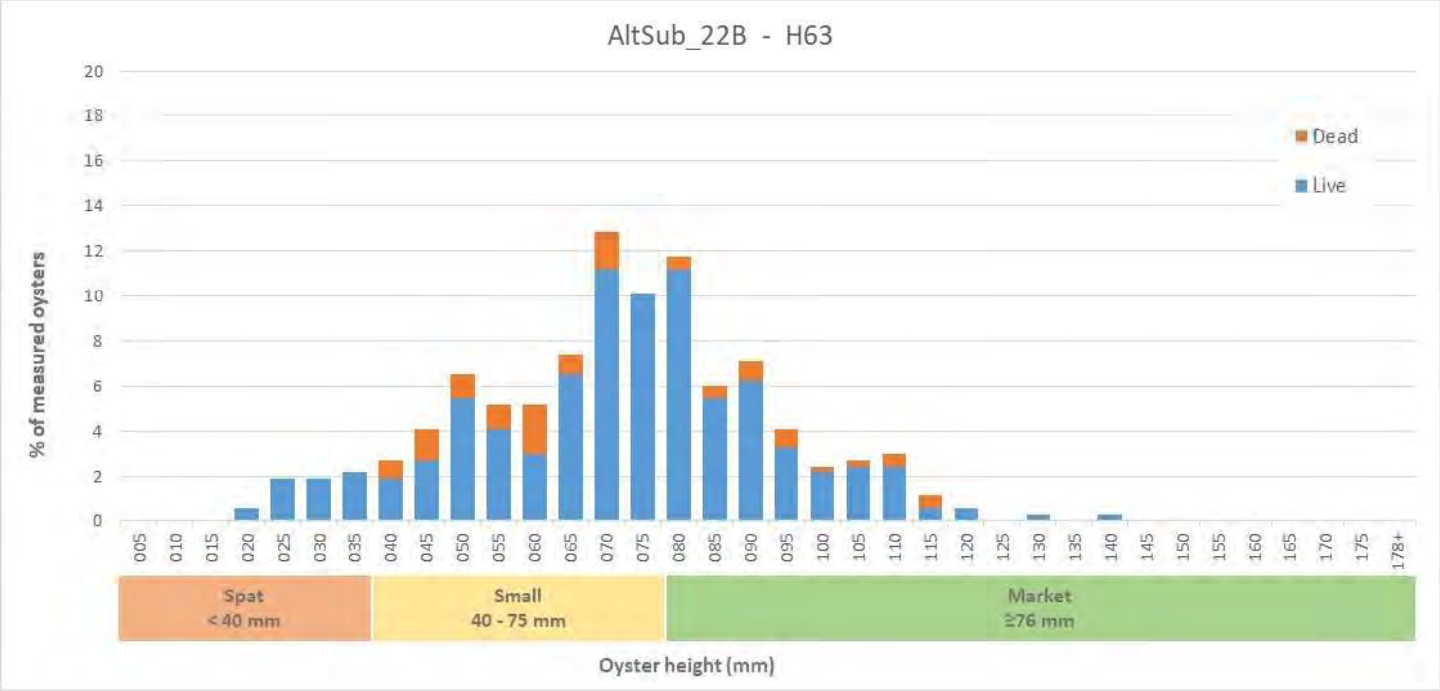
Reef Information	**Report reef ID**	**H63**
	Geodatabase Site_ID	AltSub_22B
	Tributary	Harris Creek
	Reef area (acres)	5.69
Restoration Treatment	Restoration treatment	Substrate & Seed
	Substrate type added	Stone base with mixed shell
	Average planned reef height*	12
	Year planted with spat (initial planting)	2015
	Second year class replanting	N/A
Monitoring Information	Monitoring type	3 Year Cohort
	Sample method	Diver
	Sample date	12/19/2018
	# samples taken	4
	# live oysters measured	317
	# live oysters counted	479
	# dead oysters counted	50
	% of oysters that were dead	9%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	239.50
	Standard error of live density (#/m^2)	43.66
	Number of samples meeting minimum threshold density (m^2)	4
	Percent of samples meeting minimum threshold density (%)	100%
	Number of samples meeting target density (m^2)	4
	Percent of samples meeting target density (%)	100%
	Average live density on stone (#/m^2)	19.50
	Standard error of live density on stone	16.88
	Average live density on shell--all shell types (#/m^2)	145.50
	Standard error of live density on shell-aall shell types	67.60
	Average live density on clam shell (#/m^2)	74.50
	Standard error of live density on clam shell	21.19
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	4
	Reef area meeting minimum threshold biomass (%)	100%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	4
	Reef area meeting target biomass (%)	100%
	Average live biomass across reef (g dry weight per m^2)	188.63
	Standard error of live biomass	29.75
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	TBD in 2021
	Average shell volume across entire reef (liters per m^2)	114.00
	Standard error of shell volume	6.92
	Average brown shell across all samples (%)	84%
	Total volume change (liters per m^2)	-
	% Change in total volume from 2015	-
	Surface shell volume change (liters per m^2)	-
	% change in surface shell volume change	-
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	-0.001
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H63 AltSub_22B

Percent of Measured Oysters in the Market, Small, and Spat Categories



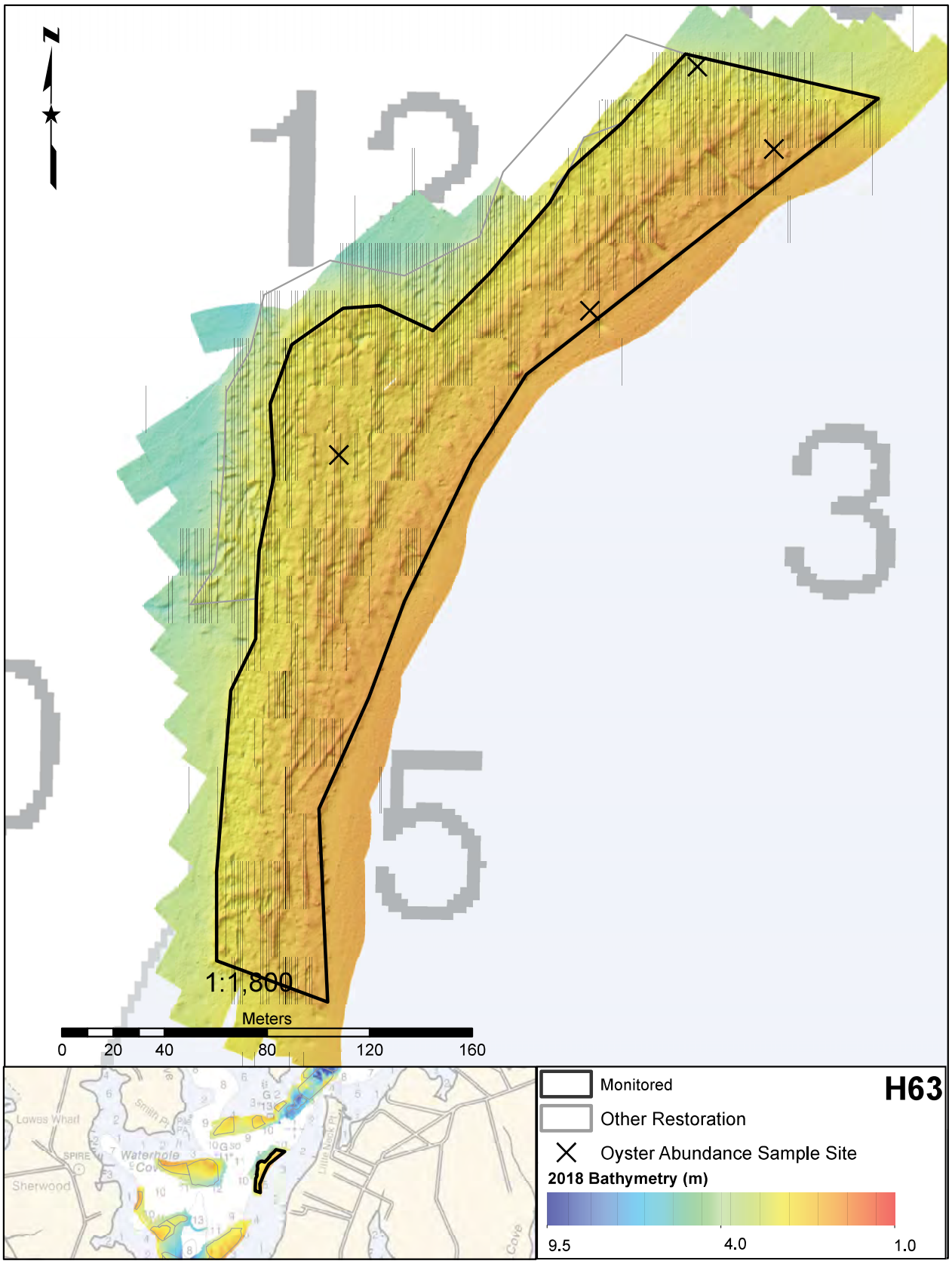
Shell Height of Oysters Measured on Reef



Reef H63 AltSub_22B

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.



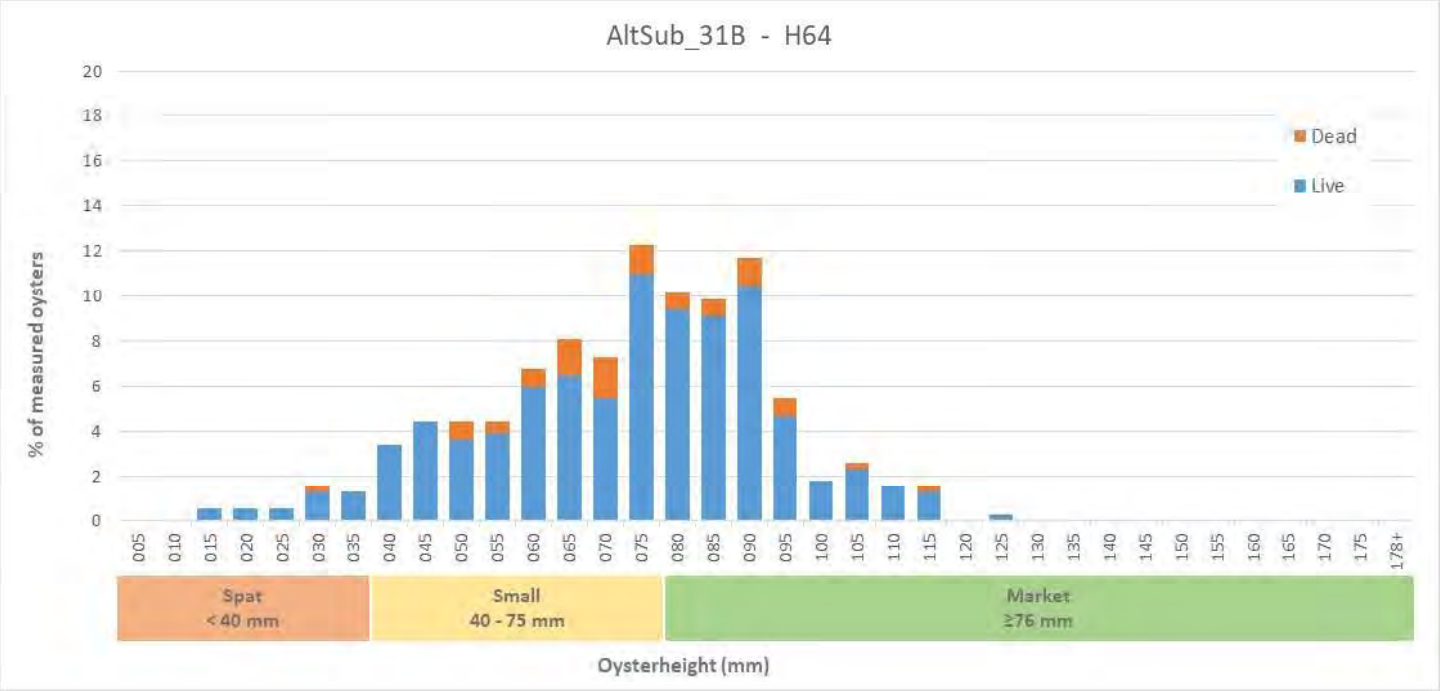
Reef H64 AltSub_31B

Reef Information	**Report reef ID**	**H64**
	Geodatabase Site_ID	AltSub_31B
	Tributary	Harris Creek
	Reef area (acres)	0.68
Restoration Treatment	Restoration treatment	Substrate & Seed
	Substrate type added	Stone base with mixed shell
	Average planned reef height*	12
	Year planted with spat (initial planting)	2013
	Second year class replanting	2015
Monitoring Information	Monitoring type	3 Year Cohort
	Sample method	Diver
	Sample date	9/27/2018
	# samples taken	5
	# live oysters measured	341
	# live oysters counted	798
	# dead oysters counted	46
	% of oysters that were dead	5%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	319.20
	Standard error of live density (#/m^2)	14.68
	Number of samples meeting minimum threshold density (m^2)	5
	Percent of samples meeting minimum threshold density (%)	100%
	Number of samples meeting target density (m^2)	5
	Percent of samples meeting target density (%)	100%
	Average live density on stone (#/m^2)	38.40
	Standard error of live density on stone	20.32
	Average live density on shell--all shell types (#/m^2)	117.60
	Standard error of live density on shell-aall shell types	30.73
	Average live density on clam shell (#/m^2)	162.80
	Standard error of live density on clam shell	35.10
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	5
	Reef area meeting minimum threshold biomass (%)	100%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	5
	Reef area meeting target biomass (%)	100%
	Average live biomass across reef (g dry weight per m^2)	260.01
	Standard error of live biomass	14.71
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	TBD in 2021
	Average shell volume across entire reef (liters per m^2)	56.80
	Standard error of shell volume	5.81
	Average brown shell across all samples (%)	68%
	Total volume change (liters per m^2)	-
	% Change in total volume from 2015	-
	Surface shell volume change (liters per m^2)	-
	% change in surface shell volume change	-
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	TBD in 2021
Reef Height	Is reef height stable/increasing?	TBD in 2022
	3 years post restoration (cm)	
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H64 AltSub_31B

Percent of Measured Oysters in the Market, Small, and Spat Categories

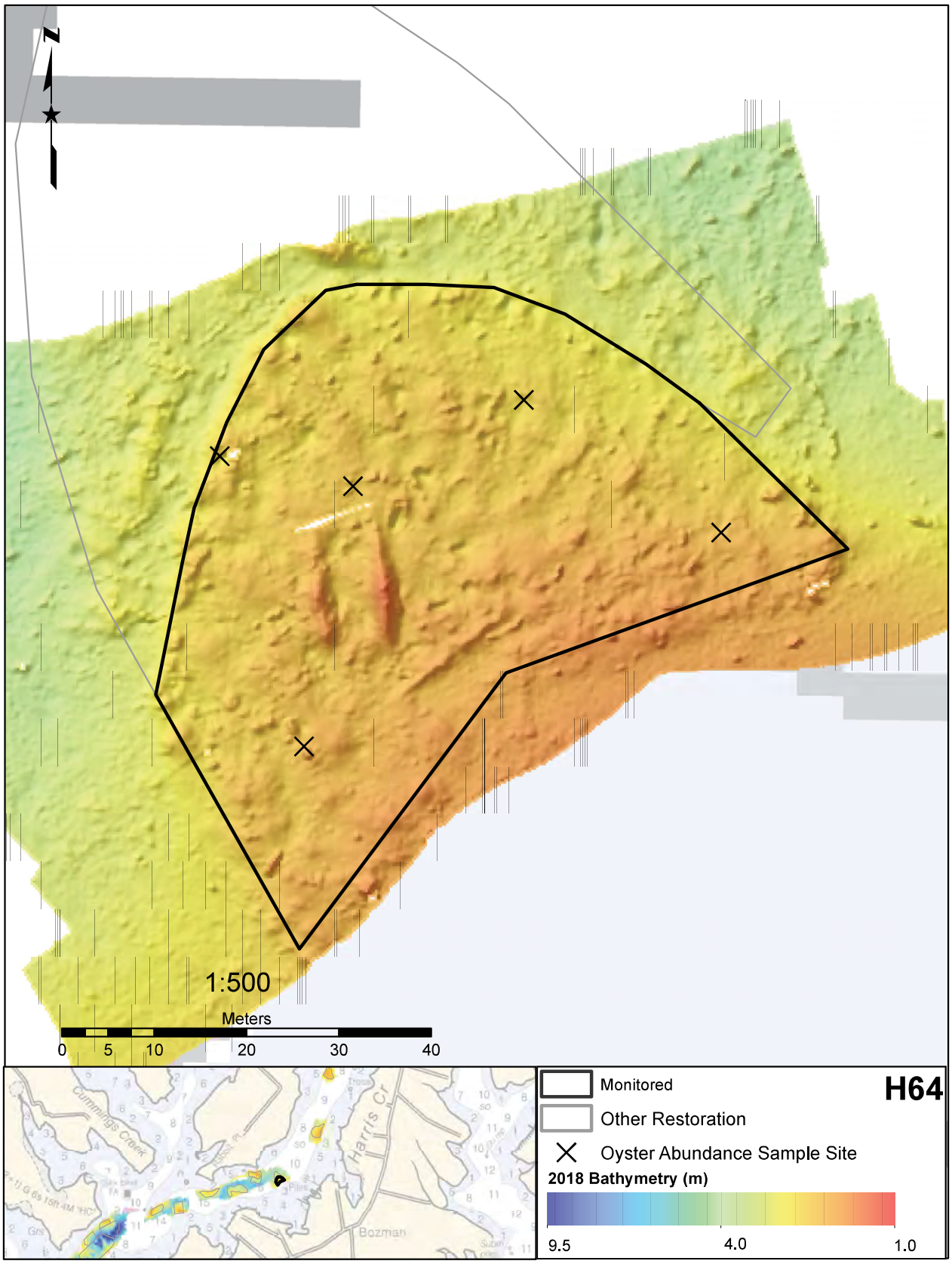
Shell Height of Oysters Measured on Reef



Reef H64 AltSub_3IB

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

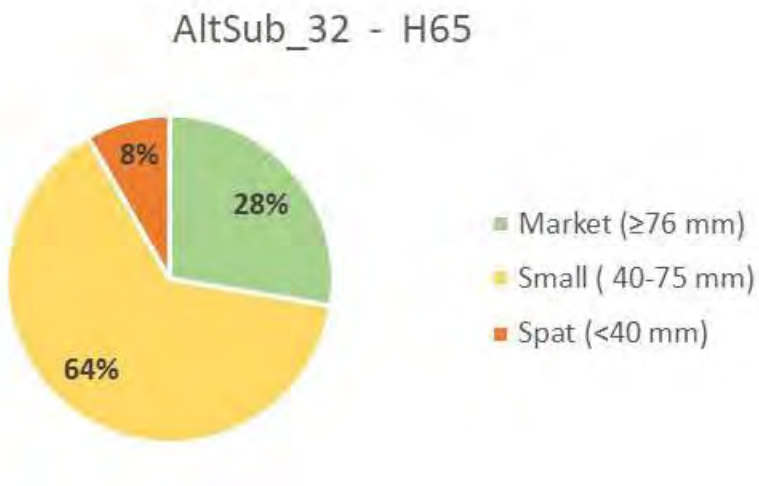


Reef H65 AltSub_32

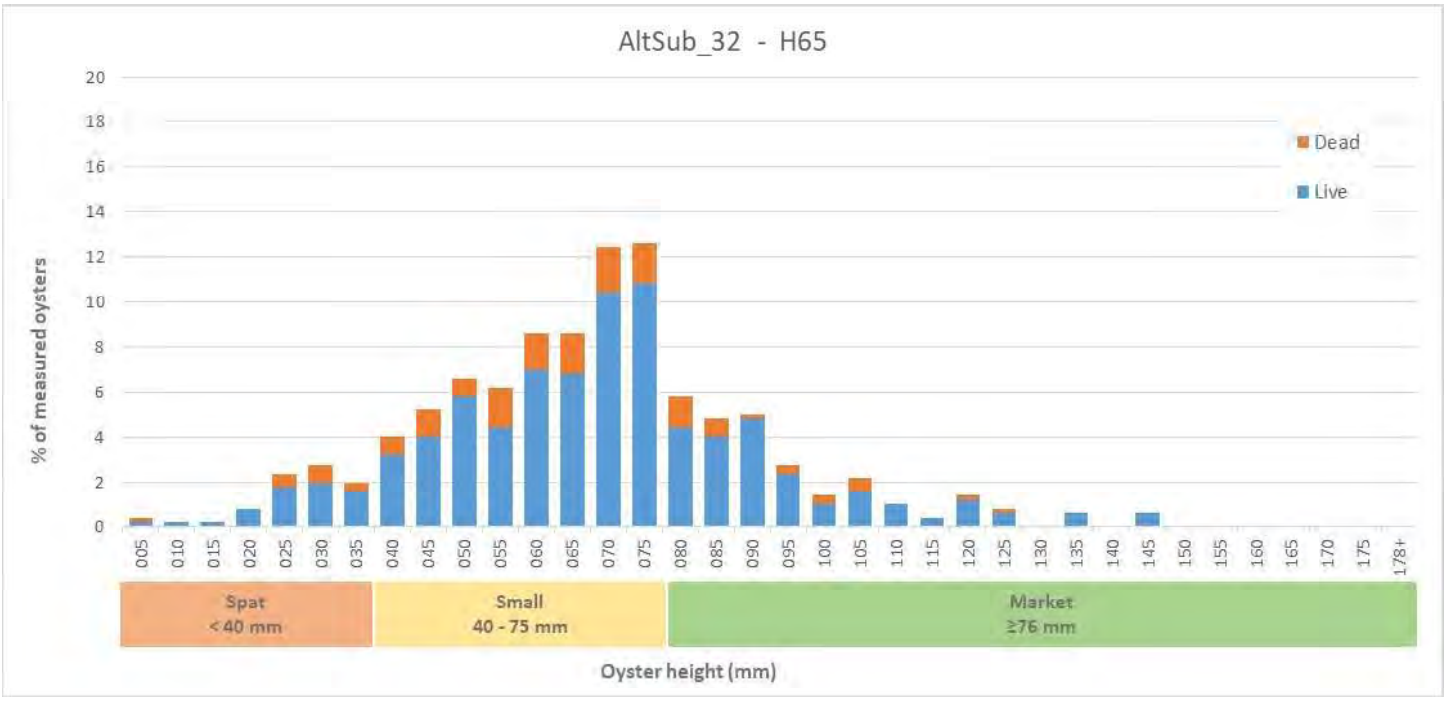
Reef Information	**Report reef ID**	**H65**
	Geodatabase Site_ID	AltSub_32
	Tributary	Harris Creek
	Reef area (acres)	3.28
Restoration Treatment	Restoration treatment	Substrate & Seed
	Substrate type added	Stone base with mixed shell
	Average planned reef height*	12
	Year planted with spat (initial planting)	2015
	Second year class replanting	N/A
Monitoring Information	Monitoring type	3 Year Cohort
	Sample method	Diver
	Sample date	12/12/2018
	# samples taken	5
	# live oysters measured	409
	# live oysters counted	725
	# dead oysters counted	81
	% of oysters that were dead	10%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	290.00
	Standard error of live density (#/m^2)	47.38
	Number of samples meeting minimum threshold density (m^2)	5
	Percent of samples meeting minimum threshold density (%)	100%
	Number of samples meeting target density (m^2)	5
	Percent of samples meeting target density (%)	100%
	Average live density on stone (#/m^2)	0.40
	Standard error of live density on stone	0.40
	Average live density on shell--all shell types (#/m^2)	174.00
	Standard error of live density on shell-aall shell types	50.77
	Average live density on clam shell (#/m^2)	114.80
	Standard error of live density on clam shell	28.75
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	5
	Reef area meeting minimum threshold biomass (%)	100%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	5
	Reef area meeting target biomass (%)	100%
	Average live biomass across reef (g dry weight per m^2)	209.96
	Standard error of live biomass	35.75
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	TBD in 2021
	Average shell volume across entire reef (liters per m^2)	98.80
	Standard error of shell volume	15.21
	Average brown shell across all samples (%)	87%
	Total volume change (liters per m^2)	-
	% Change in total volume from 2015	-
	Surface shell volume change (liters per m^2)	-
	% change in surface shell volume change	-
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.032
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H65 AltSub_32

Percent of Measured Oysters in the Market, Small, and Spat Categories



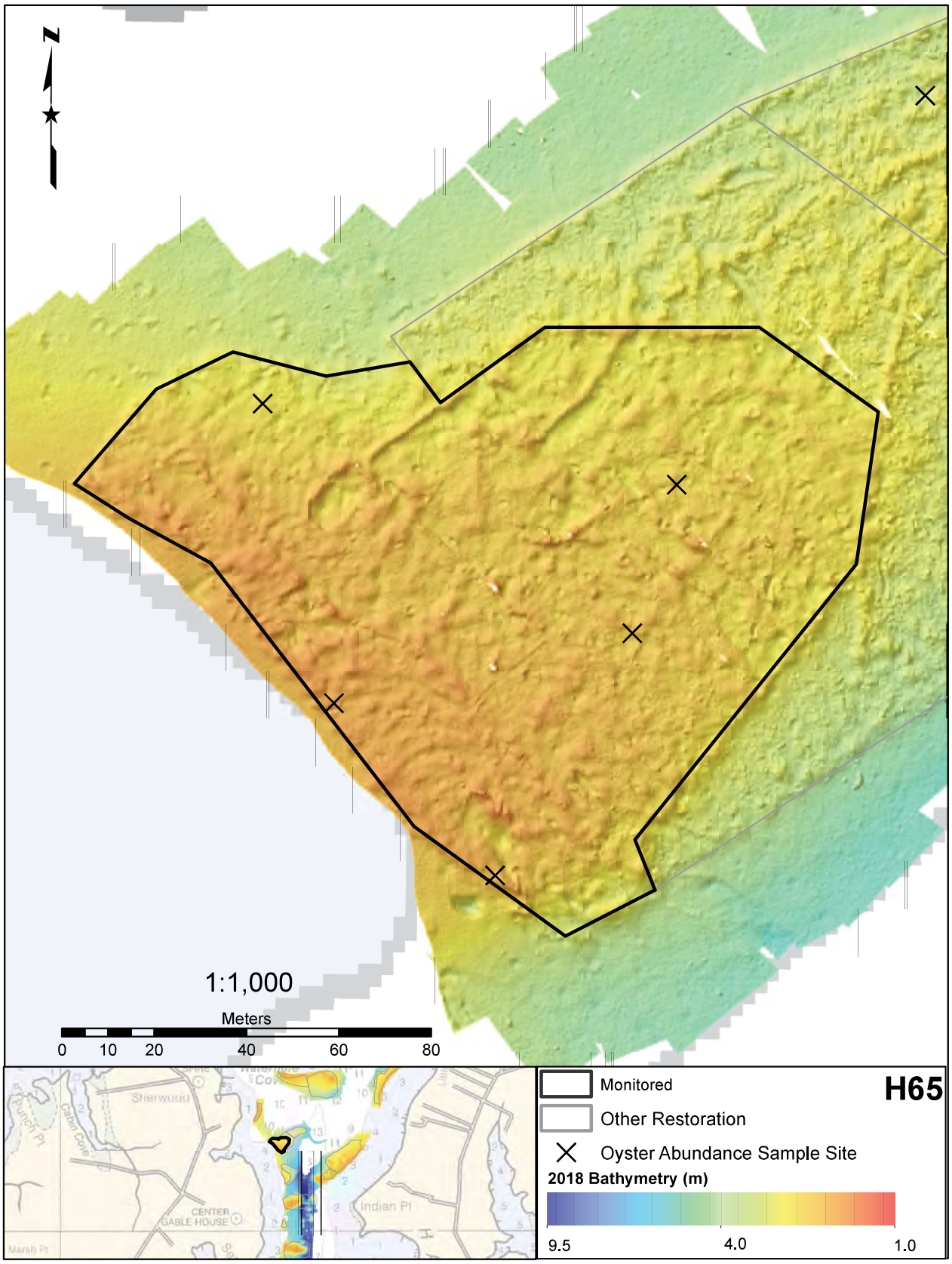
Shell Height of Oysters Measured on Reef



Reef H65 AltSub_32

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

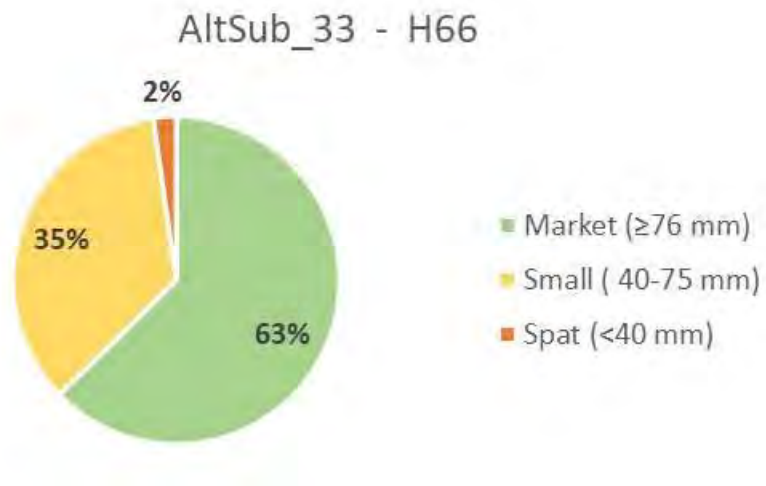


Reef H66 AltSub_33

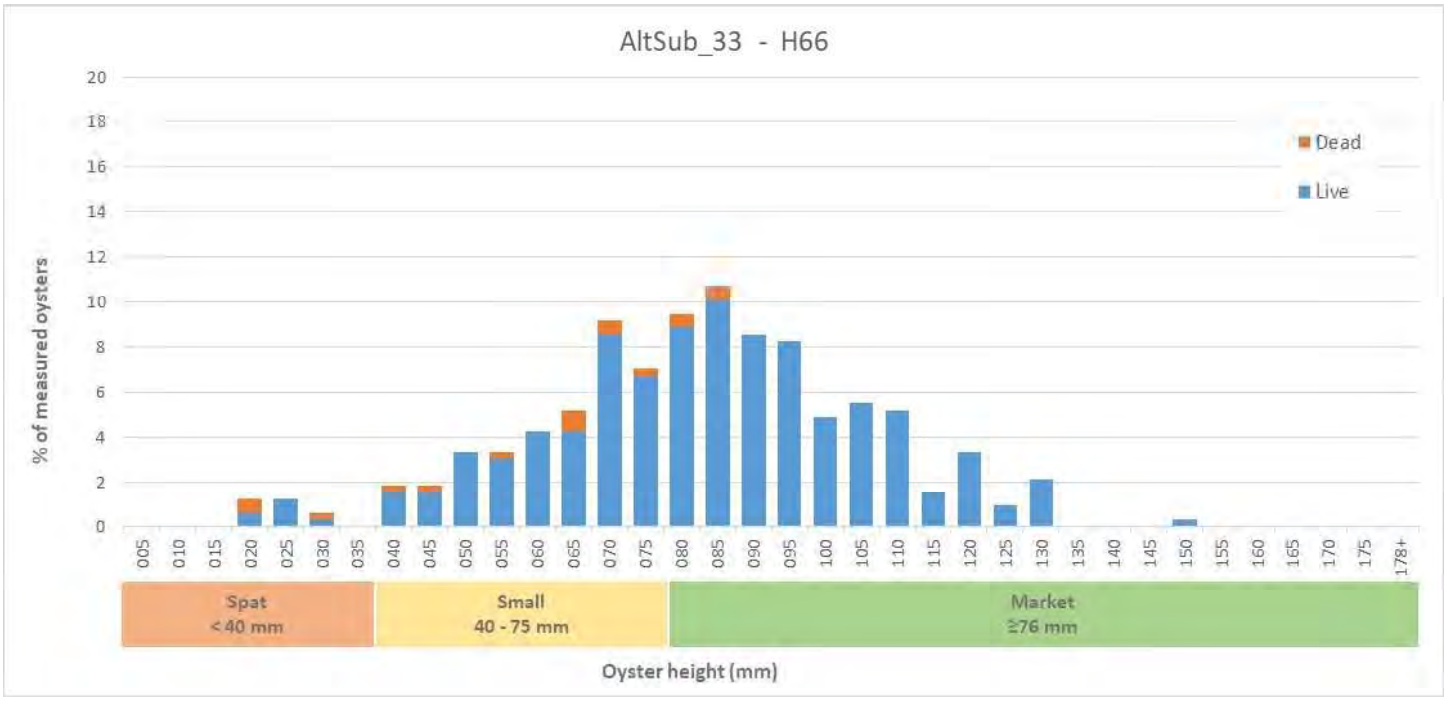
Reef Information	**Report reef ID**	**H66**
	Geodatabase Site_ID	AltSub_33
	Tributary	Harris Creek
	Reef area (acres)	7.01
Restoration Treatment	Restoration treatment	Substrate & Seed
	Substrate type added	Stone base with fossil shell
	Average planned reef height*	12
	Year planted with spat (initial planting)	2015
	Second year class replanting	N/A
Monitoring Information	Monitoring type	3 Year Cohort
	Sample method	Diver
	Sample date	10/3/2018
	# samples taken	4
	# live oysters measured	311
	# live oysters counted	421
	# dead oysters counted	18
	% of oysters that were dead	4%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	210.50
	Standard error of live density (#/m^2)	47.30
	Number of samples meeting minimum threshold density (m^2)	4
	Percent of samples meeting minimum threshold density (%)	100%
	Number of samples meeting target density (m^2)	4
	Percent of samples meeting target density (%)	100%
	Average live density on stone (#/m^2)	55.50
	Standard error of live density on stone	33.77
	Average live density on shell--all shell types (#/m^2)	105.50
	Standard error of live density on shell-aall shell types	35.60
	Average live density on clam shell (#/m^2)	0.00
	Standard error of live density on clam shell	0.00
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	4
	Reef area meeting minimum threshold biomass (%)	100%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	4
	Reef area meeting target biomass (%)	100%
	Average live biomass across reef (g dry weight per m^2)	213.33
	Standard error of live biomass	54.51
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	TBD in 2021
	Average shell volume across entire reef (liters per m^2)	117.00
	Standard error of shell volume	8.74
	Average brown shell across all samples (%)	89%
	Total volume change (liters per m^2)	-
	% Change in total volume from 2015	-
	Surface shell volume change (liters per m^2)	-
	% change in surface shell volume change	-
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.032
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H66 AltSub_33

Percent of Measured Oysters in the Market, Small, and Spat Categories



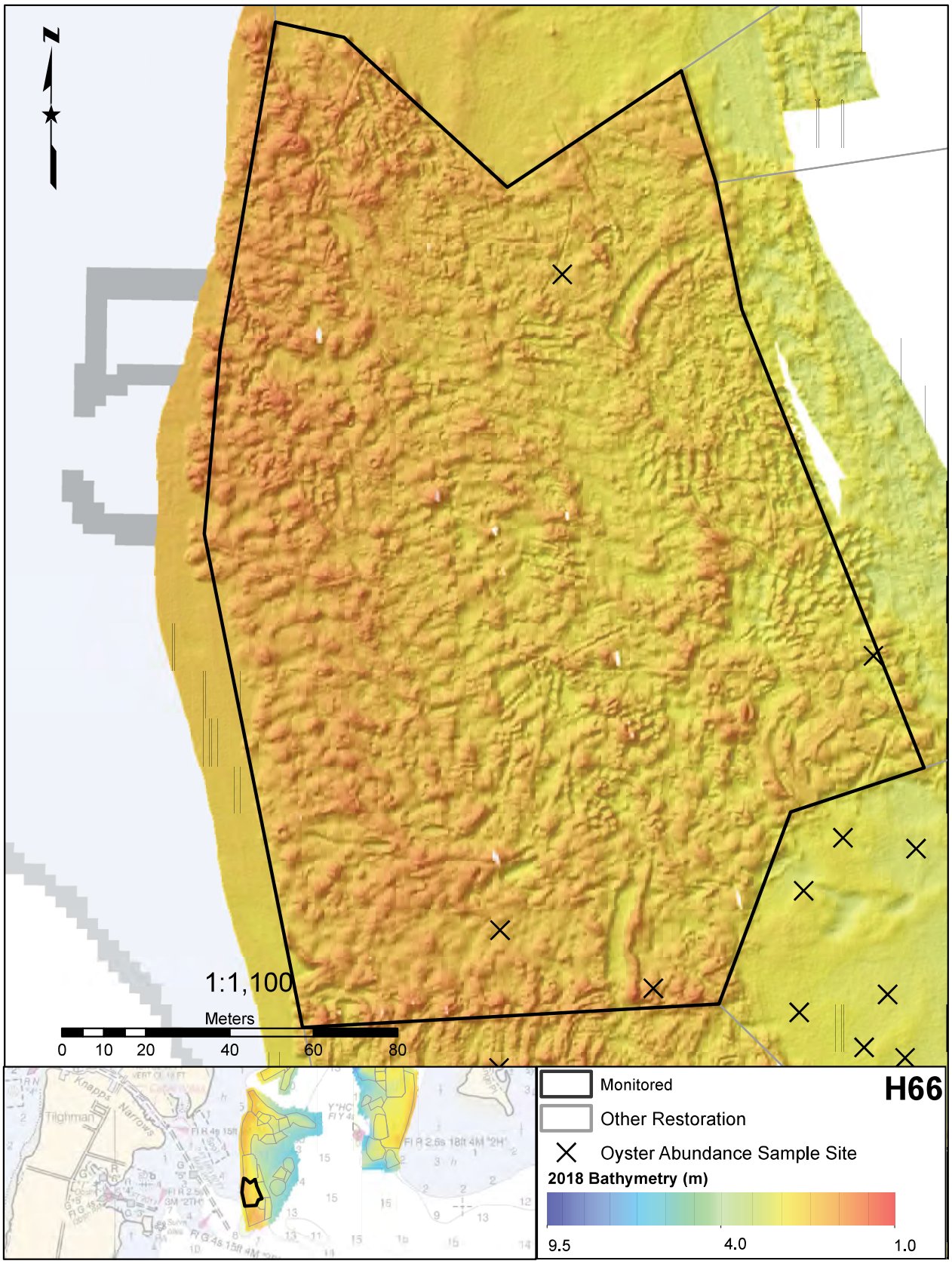
Shell Height of Oysters Measured on Reef



Reef H66 AltSub_33

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

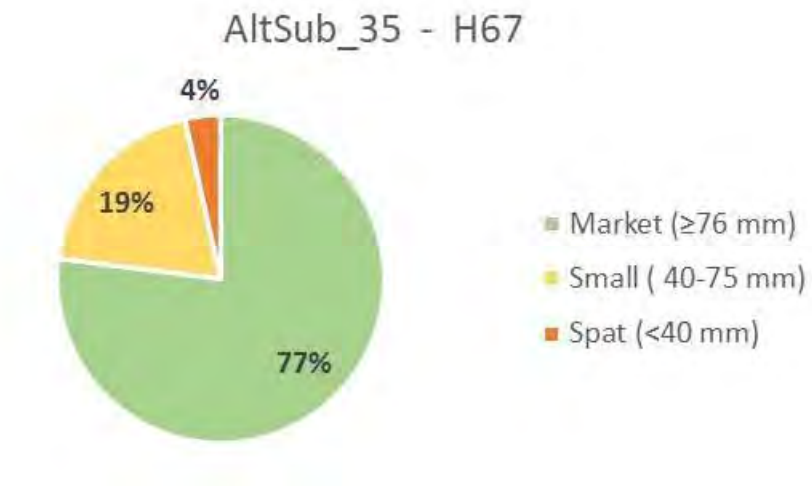


Reef H67 AltSub_35

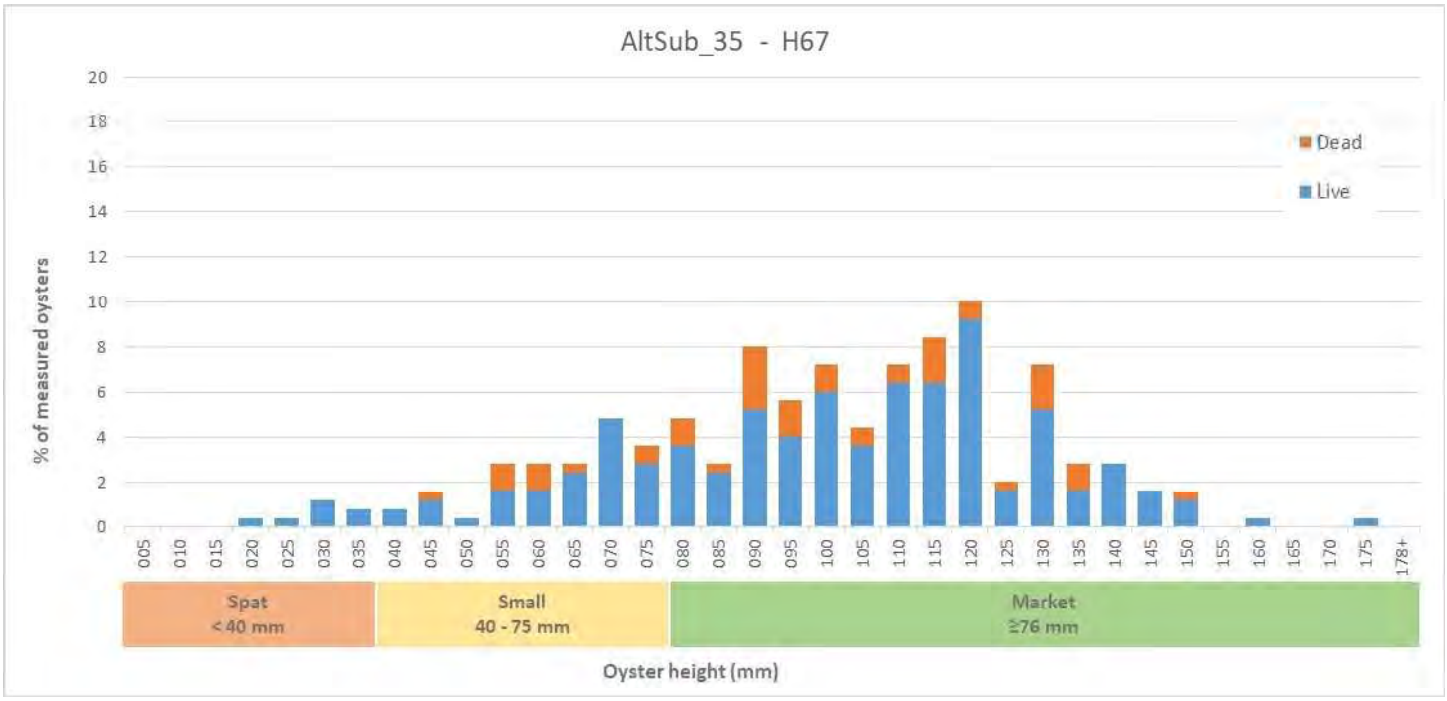
Reef Information	**Report reef ID**	**H67**
	Geodatabase Site_ID	AltSub_35
	Tributary	Harris Creek
	Reef area (acres)	1.45
Restoration Treatment	Restoration treatment	Substrate & Seed
	Substrate type added	Stone
	Average planned reef height*	12
	Year planted with spat (initial planting)	2015
	Second year class replanting	N/A
Monitoring Information	Monitoring type	3 Year Cohort
	Sample method	Diver
	Sample date	10/30/2018
	# samples taken	4
	# live oysters measured	200
	# live oysters counted	424
	# dead oysters counted	66
	% of oysters that were dead	13%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	212.00
	Standard error of live density (#/m^2)	37.32
	Number of samples meeting minimum threshold density (m^2)	4
	Percent of samples meeting minimum threshold density (%)	100%
	Number of samples meeting target density (m^2)	4
	Percent of samples meeting target density (%)	100%
	Average live density on stone (#/m^2)	193.50
	Standard error of live density on stone	37.61
	Average live density on shell--all shell types (#/m^2)	18.00
	Standard error of live density on shell-aall shell types	4.32
	Average live density on clam shell (#/m^2)	0.00
	Standard error of live density on clam shell	0.00
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	4
	Reef area meeting minimum threshold biomass (%)	100%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	4
	Reef area meeting target biomass (%)	100%
	Average live biomass across reef (g dry weight per m^2)	295.57
	Standard error of live biomass	59.10
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	TBD in 2021
	Average shell volume across entire reef (liters per m^2)	1.75
	Standard error of shell volume	0.25
	Average brown shell across all samples (%)	55%
	Total volume change (liters per m^2)	-
	% Change in total volume from 2015	-
	Surface shell volume change (liters per m^2)	-
	% change in surface shell volume change	-
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	TBD in 2021
Reef Height	Is reef height stable/increasing?	TBD in 2022
	3 years post restoration (cm)	
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H67 AltSub_35

Percent of Measured Oysters in the Market, Small, and Spat Categories



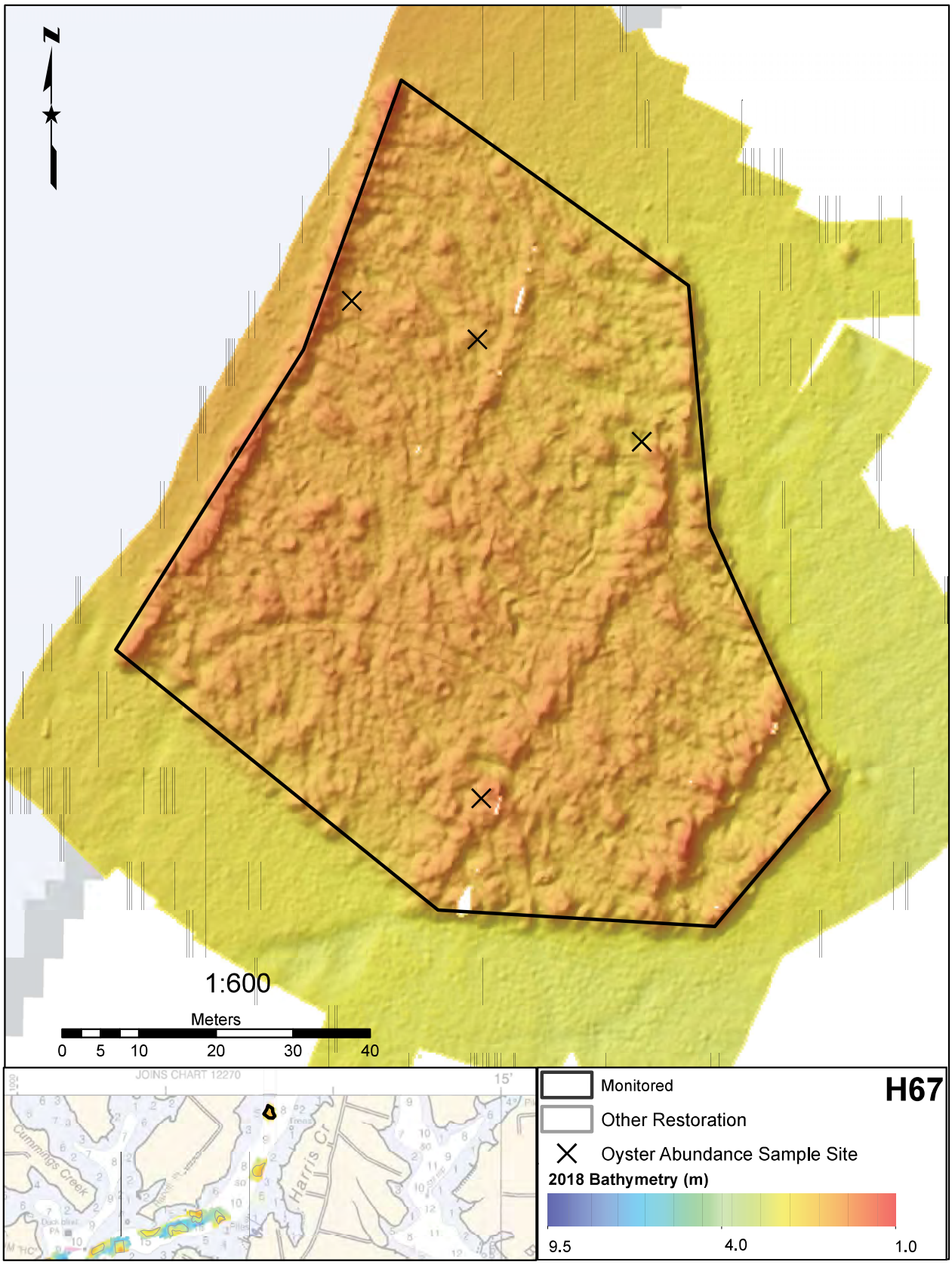
Shell Height of Oysters Measured on Reef



Reef H67 AltSub_35

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

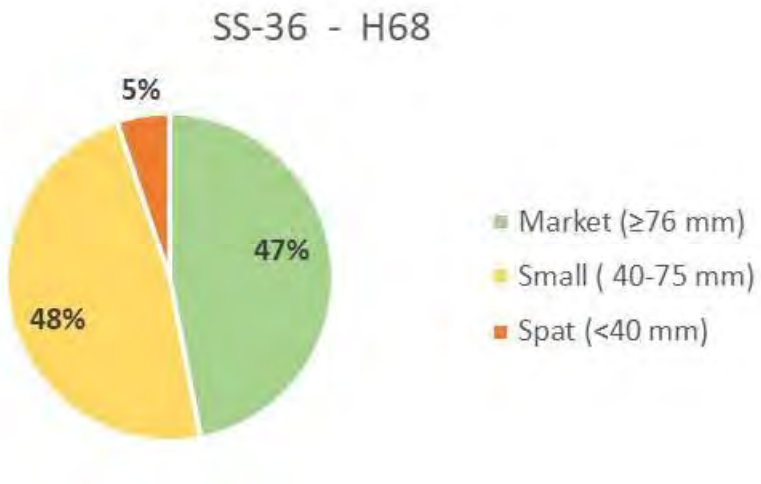


Reef H68 SS_36

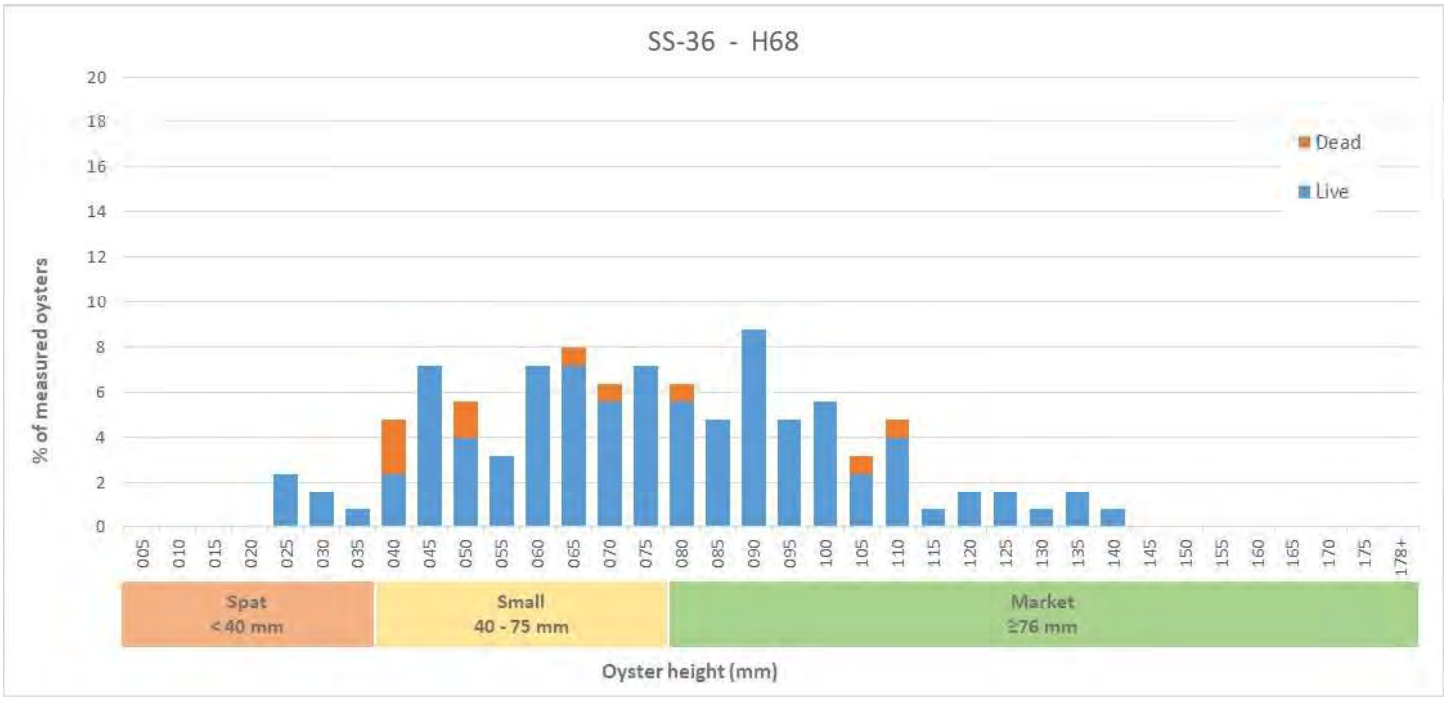
Reef Information	**Report reef ID**	**H68**
	Geodatabase Site_ID	SS_36
	Tributary	Harris Creek
	Reef area (acres)	2.02
Restoration Treatment	Restoration treatment	Substrate & Seed
	Substrate type added	Stone
	Average planned reef height*	12
	Year planted with spat (initial planting)	2015
	Second year class replanting	N/A
Monitoring Information	Monitoring type	3 Year Cohort
	Sample method	Diver
	Sample date	2/28/2019
	# samples taken	5
	# live oysters measured	115
	# live oysters counted	238
	# dead oysters counted	15
	% of oysters that were dead	6%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	95.20
	Standard error of live density (#/m^2)	14.68
	Number of samples meeting minimum threshold density (m^2)	5
	Percent of samples meeting minimum threshold density (%)	100%
	Number of samples meeting target density (m^2)	5
	Percent of samples meeting target density (%)	100%
	Average live density on stone (#/m^2)	58.00
	Standard error of live density on stone	8.58
	Average live density on shell--all shell types (#/m^2)	37.20
	Standard error of live density on shell-aall shell types	11.06
	Average live density on clam shell (#/m^2)	0.00
	Standard error of live density on clam shell	0.00
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	5
	Reef area meeting minimum threshold biomass (%)	100%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	4
	Reef area meeting target biomass (%)	80%
	Average live biomass across reef (g dry weight per m^2)	83.36
	Standard error of live biomass	13.31
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	TBD in 2021
	Average shell volume across entire reef (liters per m^2)	3.80
	Standard error of shell volume	1.83
	Average brown shell across all samples (%)	95%
	Total volume change (liters per m^2)	-
	% Change in total volume from 2015	-
	Surface shell volume change (liters per m^2)	-
	% change in surface shell volume change	-
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.048
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H68 SS_36

Percent of Measured Oysters in the Market, Small, and Spat Categories



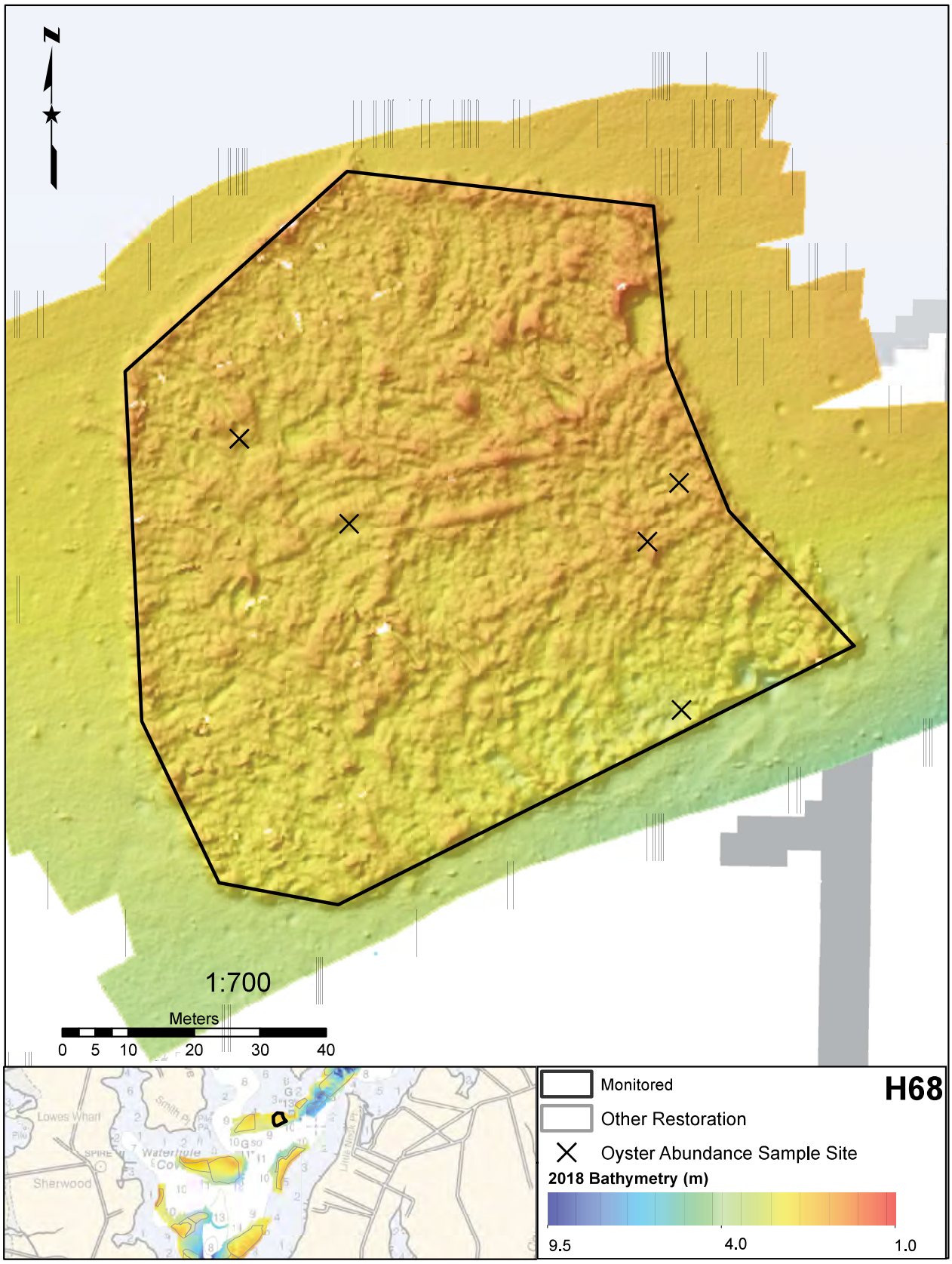
Shell Height of Oysters Measured on Reef



Reef H68 SS_36

Fall 2018 Hillshaded Bathymetry Surface Derived from Multibeam Sonar

For interpretations of features in sonar imagery, see Appendix A: Methods.

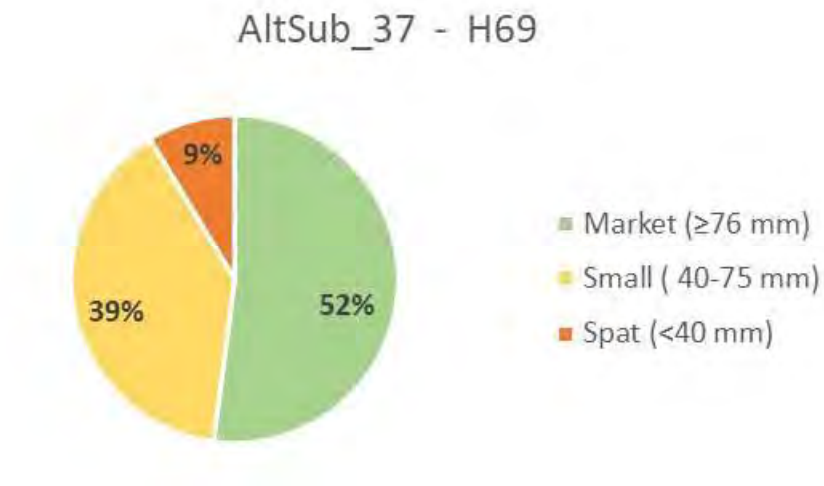


Reef H69 AltSub_37

Reef Information	**Report reef ID**	**H69**
	Geodatabase Site_ID	AltSub_37
	Tributary	Harris Creek
	Reef area (acres)	1.55
Restoration Treatment	Restoration treatment	Substrate & Seed
	Substrate type added	Stone
	Average planned reef height*	12
	Year planted with spat (initial planting)	2015
	Second year class replanting	N/A
Monitoring Information	Monitoring type	3 Year Cohort
	Sample method	Diver
	Sample date	10/22/2018
	# samples taken	5
	# live oysters measured	265
	# live oysters counted	868
	# dead oysters counted	61
	% of oysters that were dead	7%
Oyster Density	Fall 2018: Did reef meet minimum threshold density?	Yes
	Fall 2018: Did reef meet target density?	Yes
	Average live density across reef (#/m^2)	347.20
	Standard error of live density (#/m^2)	20.88
	Number of samples meeting minimum threshold density (m^2)	5
	Percent of samples meeting minimum threshold density (%)	100%
	Number of samples meeting target density (m^2)	5
	Percent of samples meeting target density (%)	100%
	Average live density on stone (#/m^2)	282.00
	Standard error of live density on stone	13.46
	Average live density on shell--all shell types (#/m^2)	60.80
	Standard error of live density on shell-aall shell types	12.63
	Average live density on clam shell (#/m^2)	0.00
	Standard error of live density on clam shell	0.00
	Average live density across reef at 3 years post restoration (for 6-year-old reefs only) (#/m^2)	N/A
Oyster Biomass	Fall 2018: Did reef meet minimum threshold oyster biomass?	Yes
	Number of samples meeting minimum threshold biomass	5
	Reef area meeting minimum threshold biomass (%)	100%
	Fall 2018: Did reef meet target oyster biomass?	Yes
	Number of samples meeting target biomass	5
	Reef area meeting target biomass (%)	100%
	Average live biomass across reef (g dry weight per m^2)	326.25
	Standard error of live biomass	21.83
	Average live biomass across reef at 3 years post restoration (for 6-year-old reefs only) (g dry weight per m^2)	N/A
Shell Volume	Is the shell budget stable/ increasing?	TBD in 2021
	Average shell volume across entire reef (liters per m^2)	1.20
	Standard error of shell volume	0.20
	Average brown shell across all samples (%)	90%
	Total volume change (liters per m^2)	-
	% Change in total volume from 2015	-
	Surface shell volume change (liters per m^2)	-
	% change in surface shell volume change	-
Multiple Year Classes	Are multiple year classes present?	Yes
Reef Footprint	Is reef footprint stable/increasing?	Yes
Reef Height	Is reef height stable/increasing?	Yes
	3 years post restoration (cm)	0.067
	*Average planned reef height: The amount of reef-building material placed into a reef was calculated by multiplying the desired average reef height (ex: 6"; 12") by the reef area. The actual height of the reef varied across the reef.	

Reef H69 AltSub_37

Percent of Measured Oysters in the Market, Small, and Spat Categories



Shell Height of Oysters Measured on Reef