2025 Maryland Oyster Reef Monitoring Report

Analysis of Data from the ‘10 Tributaries’ Sanctuary Oyster Restoration Initiative in Maryland

Data discussed in this report were collected in fall 2025. This report was produced by the NOAA Fisheries Office of Habitat Conservation's Restoration Center and NOAA Chesapeake Bay Office divisions, in partnership with the Maryland Oyster Restoration Interagency Workgroup of the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team.

This report, past monitoring reports, tributary-specific oyster restoration plans ('blueprints'), and other oyster restoration technical documents produced by the Maryland Oyster Restoration Interagency Workgroup of the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team are available at https://www.chesapeakebay.net/who/publications-archive/maryland_and_virginia_oyster_restoration_interagency_teams.

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Executive Summary

Context

The 2014 Chesapeake Bay Watershed Agreement[1] included a goal to restore oyster populations in 10 Chesapeake Bay tributaries by 2025 (hereafter, the ‘10 Tributaries Initiative’). This goal was achieved in 2025 as documented in the 2025 Chesapeake Bay Oyster Restoration Update and Completion Summary[2].

In Maryland, partners including the National Oceanic and Atmospheric Administration; U.S. Army Corps of Engineers, Baltimore District; Oyster Recovery Partnership; and the Maryland Department of Natural Resources worked to achieve this goal through the Maryland Interagency Oyster Restoration Workgroup (hereafter, ‘the Workgroup’). The Workgroup was convened under the Sustainable Fisheries Goal Implementation Team of the Chesapeake Bay Program and is chaired by Stephanie Reynolds Westby (NOAA).

A set of oyster restoration success criteria, commonly known as the Chesapeake Bay Oyster Metrics[3], was developed prior to implementing restoration work in the 10 Tributaries. These guidelines recommend monitoring restored reefs three years and again six years after restoration. Success is evaluated at the six-year mark, with the three-year monitoring serving as an interim assessment.

A subset of reefs in the Manokin, St. Mary’s, and Tred Avon rivers was due for either three-year or six-year monitoring in fall 2025, and the results are described in this report.

This report describes reef health relative to four reef-level success criteria set forth in the Oyster Metrics document: oyster density, oyster biomass, multiple year classes, and shell budget. See Discussion section for more information.

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

Fall sampling included counting and measuring healthy oysters. Photo: Oyster Recovery Partnership.

Key Monitoring Results

Key results from 2025:

Four 6-year-old reefs (totaling 5 acres) were monitored in 2025. Of these:

- 100% met both the minimum threshold and target oyster density success criteria.
- 100% met both the minimum threshold and target oyster biomass.
- 100% met the success criteria for shell budget and multiple year classes.

Key results from 2015 through 2025:

213 6-year-old reefs (totaling 771 acres) were monitored from 2015 through 2025. Of these:

- 99% met the threshold density and 84% met the target density.
- 99.5% met the threshold oyster biomass and 90% met the higher, target biomass.
- 100% met the success criteria for multiple year classes.
- 93% met the success criteria for shell budget.

Section 1: Background and Overview

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

The 2014 Chesapeake Bay Watershed Agreement[1] 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) was charged with working to achieve this goal. Driven by Executive Order 13508 (Chesapeake Bay Protection and Restoration) of 2009, some work toward tributary-scale oyster restoration was underway even before the 2014 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,"[2] (hereafter, 'Oyster Metrics') established Bay-wide, science-based, consensus success criteria for oyster restoration to be tracked three years, and again six years, following initial restoration (Table 1).

<table>
<tr><td rowspan="6">Reef-level success criteria</td><td rowspan="4">Biological Metrics</td><td>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.</td></tr>
<tr><td>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.</td></tr>
<tr><td>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 (40-75mm); spat (<40mm).</td></tr>
<tr><td>Shell Budget: Stable or increasing shell volume on the reef</td></tr>
<tr><td rowspan="2">Structural Metrics</td><td>Reef Footprint: Stable or increasing reef footprint compared to baseline.</td></tr>
<tr><td>Reef Height: Stable or increasing reef height compared to baseline</td></tr>
<tr><td>Tributary-level success criteria</td><td colspan="2">A minimum of 50% of currently restorable area within a given tributary, that constitutes at least 8% of historic oyster habitat, meets the reef-level success criteria.</td></tr>
</table>

Table 1: *Oyster Metrics reef-level and tributary-level success criteria. Success relative to the reef-level criteria are determined when each reef is monitored six years post restoration.*

Once these success criteria were adopted, the Fisheries GIT convened interagency workgroups in Maryland and Virginia to plan and coordinate restoration work in each state. In Maryland, 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 Workgroup developed oyster restoration tributary plans (also known as “blueprints”) for Harris Creek[4], Little Choptank River[5], Tred Avon River[6], upper St. Mary’s River[7], and Manokin River[8], in consultation with a group of consulting scientists and the public.

1.2: Overview of Report Content

Reefs are monitored at three and six years after restoration, per recommendations from the Oyster Metrics Workgroup and each river’s tributary plan. In 2025, a subset of restored reefs in the Manokin, St. Mary’s, and Tred Avon rivers had matured to three or six years; these reefs were monitored in the fall. Summarized monitoring results for these reefs are included (Table 2), as well as a summary of cumulative monitoring results from 2015 through 2025 (Table3). Additionally, sentinel reefs (restored sites that are monitored annually) in the Tred Avon River were monitored in fall 2025. Data on these reefs are in Appendix A.

This report describes success relative to four of the six reef-level Oyster Metrics criteria: oyster density, oyster biomass, multiple year classes, and shell budget. In the earlier years of monitoring under the 10 Tributaries Initiative, all six Oyster Metrics success criteria were measured (the previously listed four Metrics, plus reef height and reef footprint). However, over the course of nearly a decade of monitoring, all reefs (100%) passed the reef height and reef footprint metrics. This information, combined with a requisite halt in sonar work during the pandemic years and the resource-intensive nature of measuring these parameters using sonar equipment, led NOAA to adapt to measuring these two parameters only on reefs that, per the other, more sensitive Metrics, are showing signs of potential poor reef health. None of the fall 2025 cohort of monitored reefs were determined to be in poor health. This revised protocol is consistent with the adaptive management recommended in the original Oyster Metrics document. (See Discussion section for full description.)

Past monitoring reports are available from the Chesapeake Bay Program’s Maryland and Virginia Oyster Restoration Interagency Teams Publications page.

In addition to Oyster Metrics success criteria monitoring, oyster disease data is also collected by DNR, and is available in DNR’s annual Fall Survey Report. Water quality data is available at DNR’s Eyes on the Bay website and on the NOAA Chesapeake Bay Interpretive Buoy System website.

1.3: Funding and Acknowledgements

Monitoring data in this report were collected, managed, and analyzed by ORP and contracted commercial watermen, with assistance from Workgroup partners.

This was funded by a $99,700 NOAA contract to ORP, and a $53,310 USACE programmatic agreement to ORP.

This report was drafted by NOAA, with guidance from the Workgroup. Results of these analyses will be used to document the success or failure of restoration relative to the Oyster Metrics criteria, to guide adaptive management of these reefs, and to inform future oyster restoration efforts. Technical review of this report was provided by scientific experts and Workgroup members, per NOAA research communications guidelines.

Section 2: Overview of Monitoring

2.1: Monitoring Synopsis

In fall 2025, the following reefs were monitored (Figures 2, 3, and 4):

- 3-year-old reefs: 18 reefs (totalling 31 acres) in the St. Mary's River and 5 reefs (totalling 45 acres) in the Manokin River
- 6-year-old reefs: 4 reefs (totalling 5 acres) in the Tred Avon River

Data used to determine success relative to the four measured metrics (oyster density, oyster biomass, multiple year classes, and shell volume) were collected at the same time, using a stratified random survey design. Methods used to select sampling sites, analyze samples, and assess success relative to each metric were identical for all reefs. See Appendix B for full monitoring methods.

Large-scale restoration work under the 10 Tributaries Initiative also occurred in Harris Creek and the Little Choptank River. All Harris Creek restored reefs are now more than 6 years old, which is the monitoring time frame recommended in Oyster Metrics. No reefs were due for three- or six-year monitoring in the Little Choptank River in 2025. Results from Harris Creek and the Little Choptank River have been tallied as part of Table 3, where cumulative results are described.

2.2: Location of Monitored Reefs

All 3-year-old and 6-year-old reefs monitored in 2025 are represented on the maps that follow.

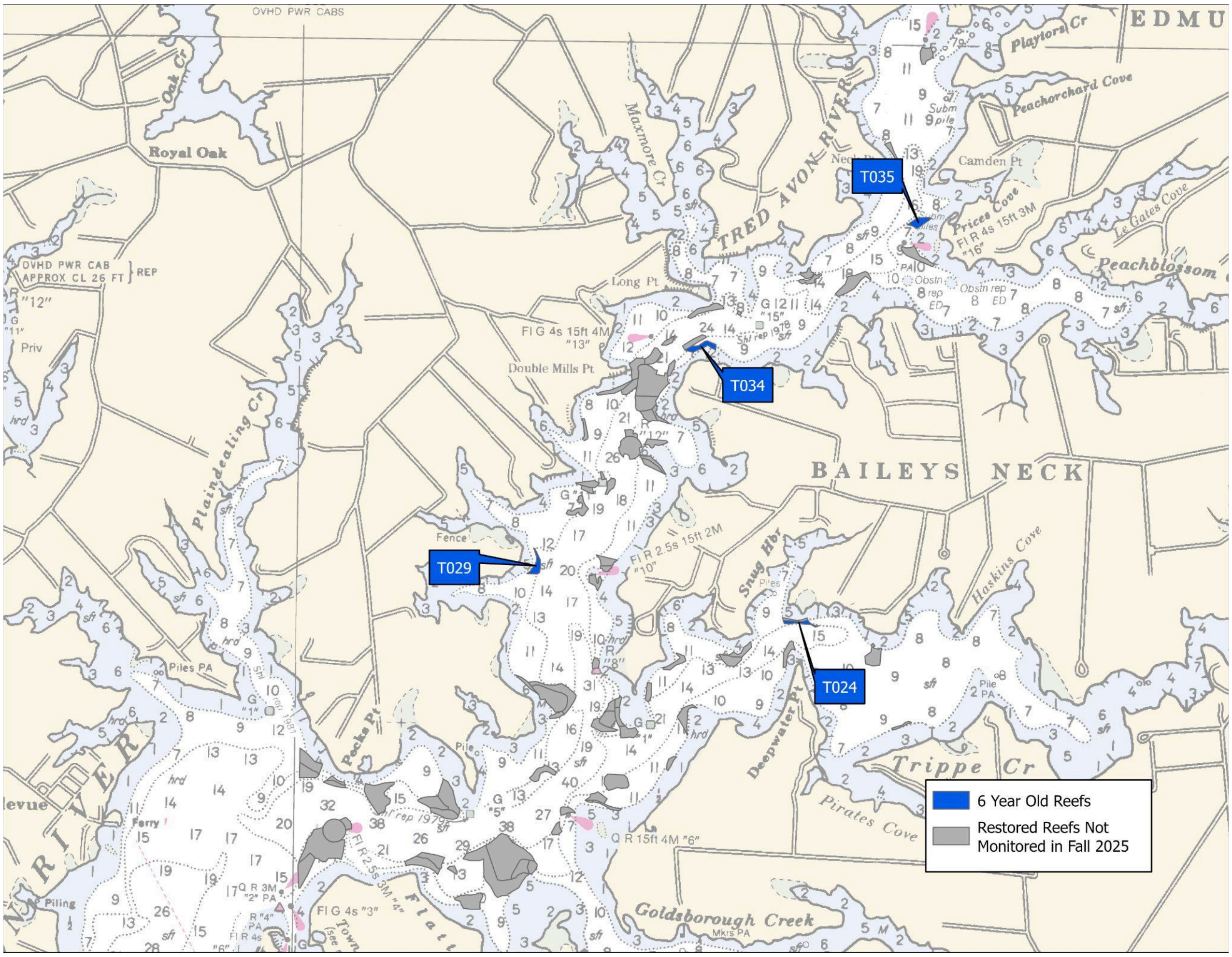

__Figure 2:__ Locations of Tred Avon River reefs monitored in fall 2025. Four 6-year-old reefs were monitored.

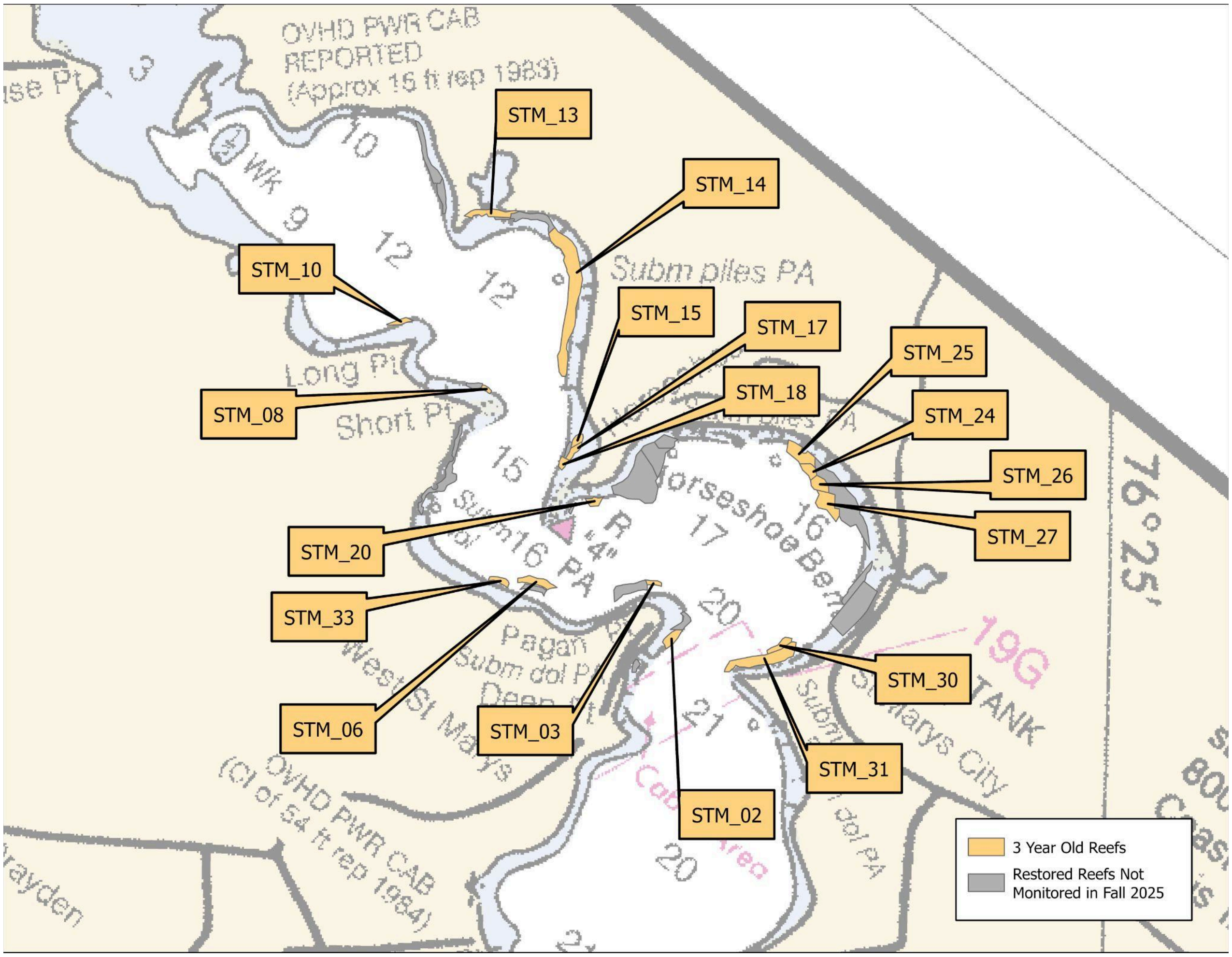

Figure 3: *Locations of St. Mary's River reefs monitored in fall 2025. 18 3-year-old reefs were monitored.*

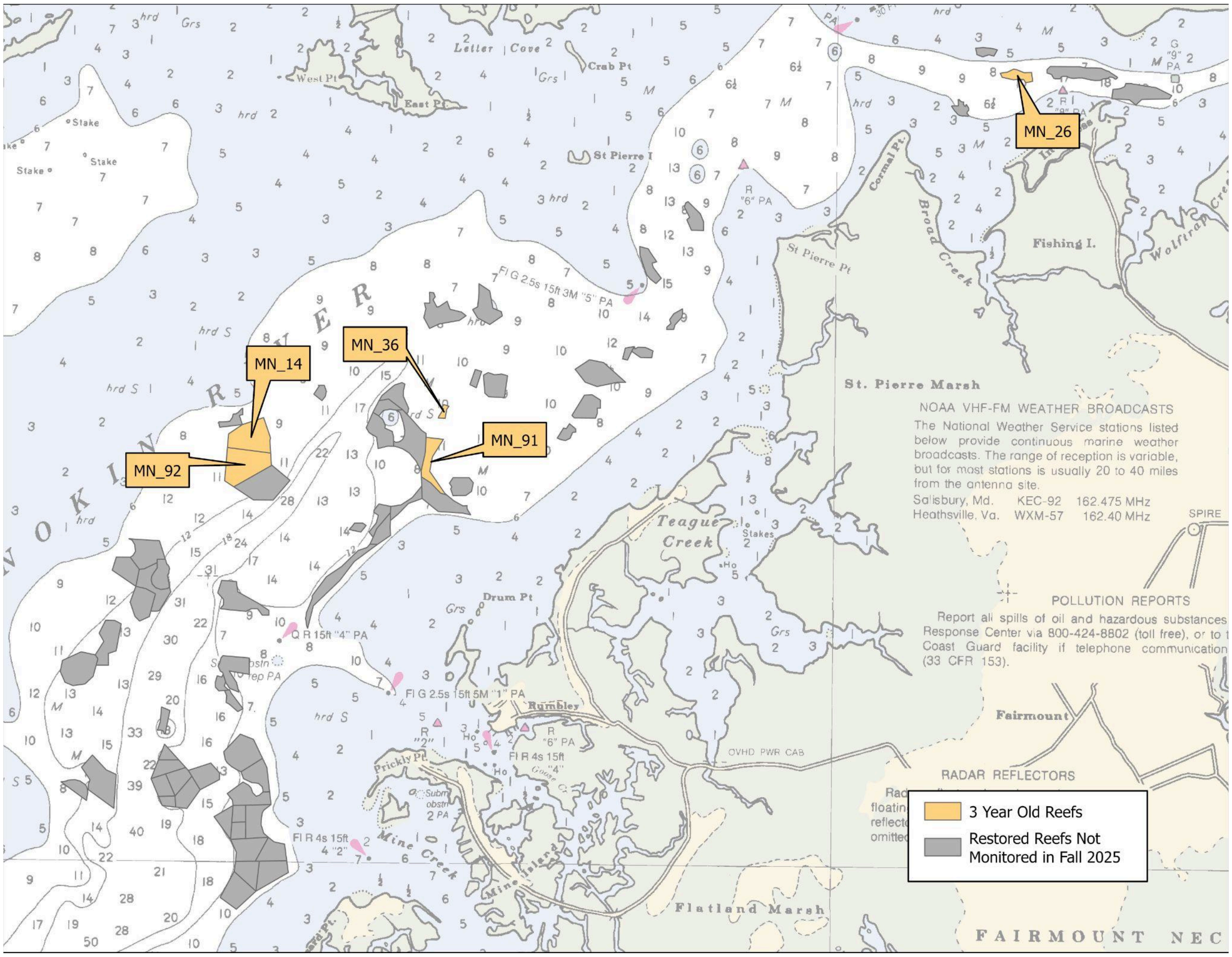

Figure 4: Locations of Manokin River reefs monitored in fall 2025. Five 3-year-old reefs were monitored.

Section 3: Results Summary

3.1: Summary of Fall 2025 Monitoring Results

Summarized results are depicted in Table 2. The table shows the percent of 3-year-old and 6-year-old reefs in each tributary, and across all tributaries, that met each Oyster Metrics success criteria.

			Oyster Density		Oyster Biomass		Multiple Year Classes	Shell Budget
Reef Type	**Tributary**	**# of reefs monitored in fall 2025**	**% of reefs meeting minimum threshold**	**% of reefs meeting target**	**% of reefs meeting minimum threshold**	**% of reefs meeting target**	**% with multiple year classes present**	**% with stable/ increasing shell budget**
3 Year Old	Manokin	5 (45 acres)	100%	40%	100%	20%	100%	TBD
	St. Mary’s	18 (31 acres)	100%	94%	100%	94%	100%	TBD
	Tred Avon	No 3-year-old reefs in Tred Avon in fall 2025						
	All Tribs Combined	**23 (76) acres**	**100%**	**83%**	**100%**	**78%**	**100%**	**TBD**
6 Year Old	Manokin	No 6-year-old reefs in Manokin in fall 2025						
	St. Mary’s	No 6-year-old reefs in St. Mary’s in fall 2025						
	Tred Avon	4 (5 acres)	100%	100%	100%	100%	100%	100%

Table 2: *Percentages of 3-year-old and 6-year-old reefs monitored in fall 2025 that met each Oyster Metrics success criterion. In 2025, only Manokin River and St. Mary’s River had 3-year-old reefs, and only Tred Avon had 6-year-old reefs. 3-year-old reefs have the designation ‘TBD’ for shell budget, as shell volume must be measured at least one more time to determine if there is a stable, increasing, or decreasing shell volume trend (shell budget).*

3.2: Summary of Cumulative Results, 2015–2025

Reef monitoring under the 10 Tributaries Initiative started in 2015. Summarized results from fall 2015 through fall of 2025 are depicted in Table 3. The table shows the percent of 3-year-old and 6-year-old reefs in each tributary, and across all tributaries combined, that met each oyster metric throughout the monitoring years. Figures 5 and 6 are graphic representations of the percent of reefs from 2015 through 2025 that met oyster density and biomass minimum threshold and target metrics.

			Oyster Density		Oyster Biomass		Multiple Year Classes	Shell Budget
Reef Type	Tributary	# of reefs monitored in fall 2015–2025	% of reefs meeting minimum threshold	% of reefs meeting target	% of reefs meeting minimum threshold	% of reefs target	% with multiple year classes present	% with stable/ increasing shell budget
3-year-old	Harris Creek	90 (348 acres)	98%	79%	98%	74%	100%	TBD
	Little Choptank	104 (358 acres)	98%	88%	98%	83%	100%	TBD
	Tred Avon	68 (131 acres)	93%	54%	96%	76%	100%	TBD
	St. Mary's	30 (60 acres)	97%	93%	97%	83%	100%	TBD
	Manokin	5 (45 acres)	100%	40%	100%	20%	100%	TBD
	All Tribs Combined	**297 (942 acres)**	**97%**	**77%**	**97%**	**78%**	**100%**	**TBD**
6-year-old	Harris Creek	90 (348 acres)	99%	79%	99%	81%	100%	98%
	Little Choptank	92 (339 acres)	100%	91%	100%	97%	100%	86%
	Tred Avon	27 (80 acres)	96%	74%	100%	93%	100%	96%
	All Tribs Combined	**213 (771 acres)**	**99%**	**84%**	**99%**	**90%**	**100%**	**93%**

Table 3: *Percents of 3-year-old and 6-year-old reefs monitored from 2015 through 2025 that met each Oyster Metrics success criterion. 3-year-old reefs have the designation 'TBD' for shell budget, as shell volume must be measured at least one more time to determine if there is a stable, increasing, or decreasing shell volume trend (shell budget). Some results may differ slightly from previous reports due to corrections made to previous minor calculation errors.*

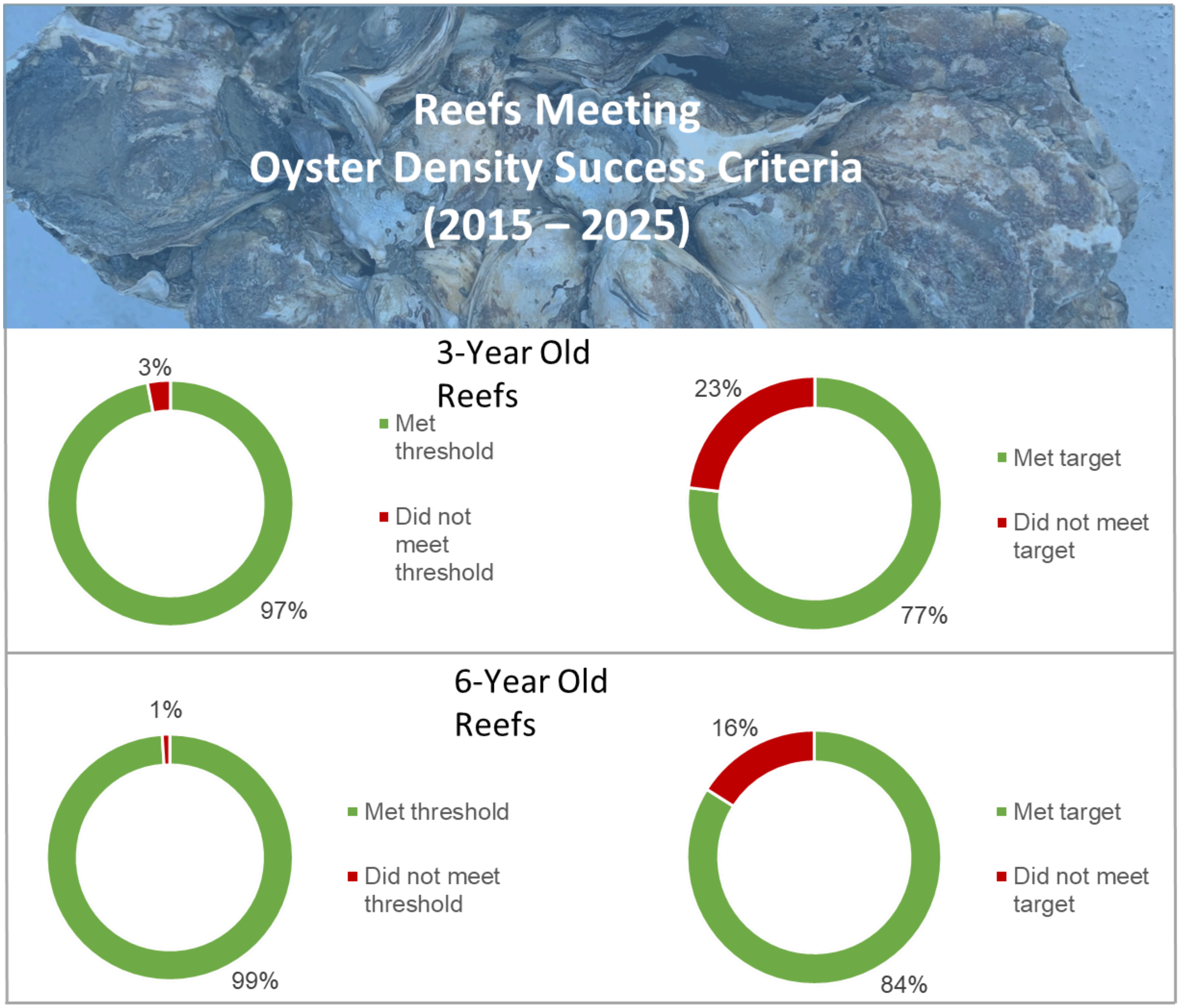

Figure 5: *Cumulative percentages of 3-year-old and 6-year-old reefs, across all tributaries, meeting the oyster density threshold and target success criteria 2015–2025.*

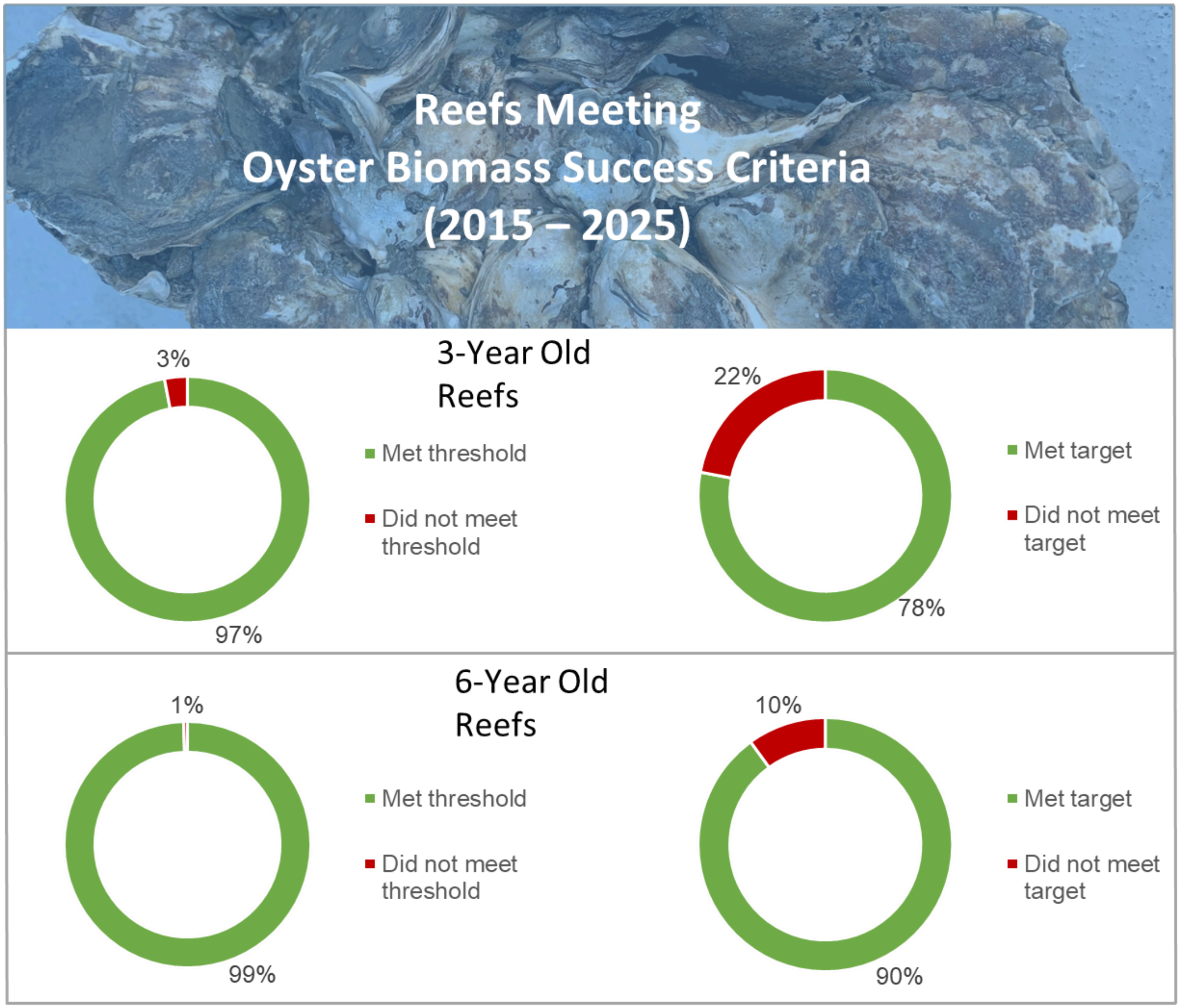

Figure 6: *Cumulative percentages of 3-year-old and 6-year-old reefs, across all tributaries, meeting the oyster biomass success criteria 2015–2025.*

Section 4: Discussion

4.1: Overall Trends

The trends observed in previous monitoring years generally continued in 2025, with a large majority of restored reefs meeting the Oyster Metrics success criteria measured.

Standout points include:

- Only four reefs in the 2025 monitoring cohort were 6 years old (the age at which, per Oyster Metrics, a reef can be considered successfully restored). All four of these reefs were in the Tred Avon River, and all four received substrate + seed restoration treatment. Of these, 100% met the targets for both oyster density and biomass, and had a stable or increasing shell budget.

- Among 6-year-old reefs monitored from 2015 through 2025, across all tributaries, 99% met the minimum threshold for oyster density, and 84% met the higher target level for oyster density.

- Among the five 3-year-old reefs monitored in the Manokin River in 2025, 100% met the minimum threshold for oyster density and biomass. However, notably, only 40% met the higher, target value for oyster density, and only 20% met the target biomass (see Table 2). These percentages are far lower than the 3-year-old reef averages across all tributaries throughout the 2015–2025 monitoring period (97% of 3-year-old reefs met the minimum threshold density and 77% met the target density. Biomass followed a similar trend. See Table 3). All five of these reefs received seed-only restoration treatment, which often results in lower oyster densities and biomass than substrate + seed treatment. Restoration partners will use this information to determine whether the planned second-year-class seedings are required, as laid out in the Manokin River Blueprint.

- Results from the St. Mary's River were much higher by comparison, with 100% of the reefs meeting minimum threshold for both oyster density and biomass and 94% meeting the higher target level for both density and biomass (see Table 2). This is true despite the high mortality observed at some sites within the St. Mary's Sanctuary (Appendix A). The St. Mary's River Watershed Association and the St. Mary's River Yacht Club recorded low dissolved oxygen levels (<5 mg/L) in the river in 2025. The elevated mortality on some sites may be related to low dissolved oxygen levels.

- 100% of the reefs monitored in 2025, across all tributaries, met the success criteria for multiple year classes. See Figure 7 for a visual representation of the relative proportion of large (market-size) oysters, small oysters, and spat on each reef monitored in 2025.

- Beyond monitoring the 3- and 6-year-old reefs in fall 2025, three sentinel reefs (8.5 acres total) were monitored in the Tred Avon River. These reefs are monitored annually, and were 9 years old in fall 2025. All three of these reefs met the minimum threshold and target for oyster biomass and density in fall 2025. Additional summarized data about these reefs is available in Appendix A.

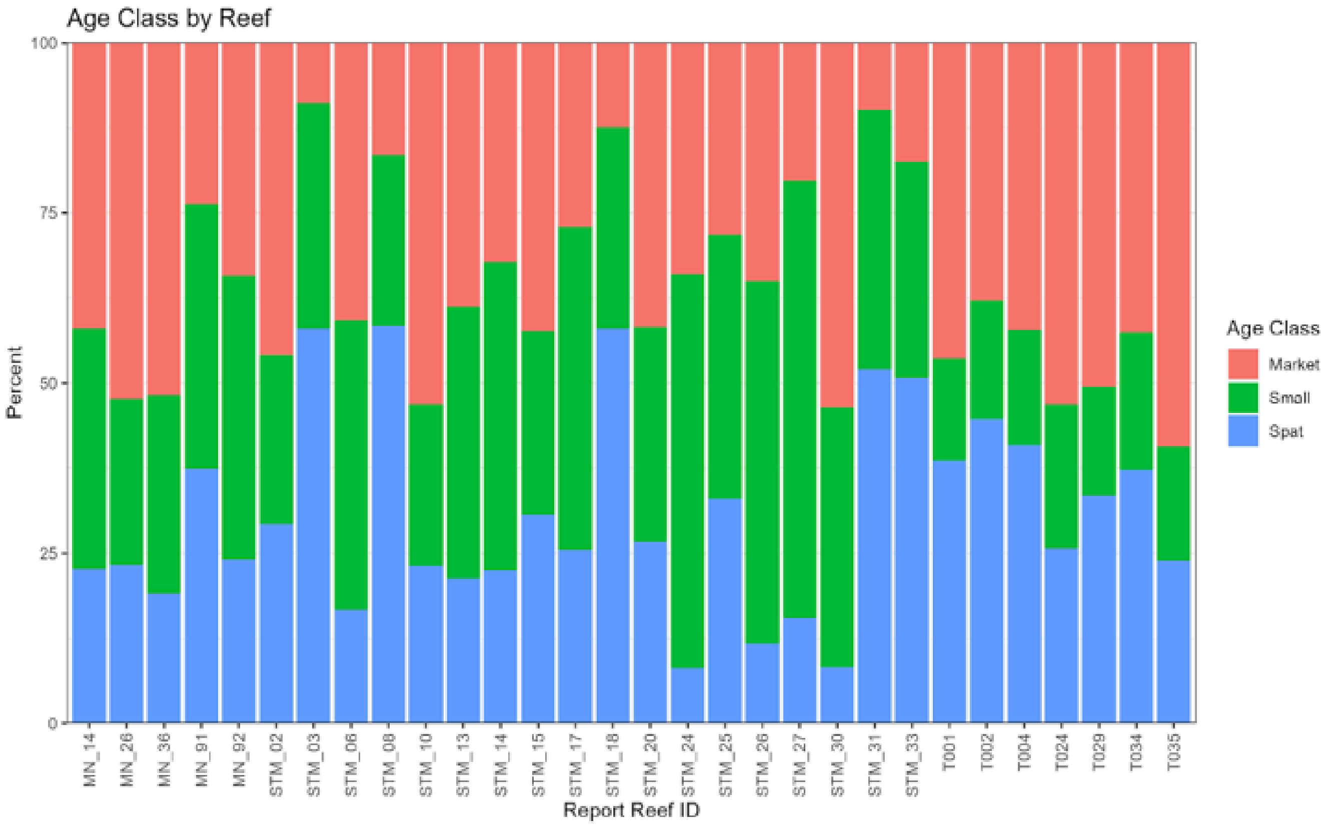

Figure 7: *Percentage of spat (< 40 mm), small (40 - 75 mm), and market (≥76 mm) oysters on each reef monitored in 2025. The Manokin reefs (those starting with 'MN' along the X axis) and St. Mary's ('STM') are 3 years old; Tred Avon ('T') reefs are 6 years old. More information about each reef can be found in Appendix A, referenced by reef number. Reef numbers appear along the X axis in this figure.*

4.2: Monitoring for Reef Height and Reef Footprint Success Criteria

This report describes restoration success relative to four of the six Oyster Metrics criteria (oyster density, oyster biomass, multiple year classes, and shell budget, collectively known as the 'biological metrics'). In the earlier years of monitoring under the 10 Tributaries Initiative, all six Oyster Metrics success criteria were measured (the four biological metrics, plus reef height and reef footprint). However, in more than a decade of measuring reef height and reef footprint, not a single reef has failed these criteria. NOAA has been the sole partner monitoring reef height and footprint, and has surveyed 134 reefs, comprising 511 acres, with multibeam sonar, at 0.25-meter resolution. Each of these reefs has been monitored at least twice since 2015, as required by Oyster Metrics. Through this work, NOAA has learned that 100% of the reefs monitored, including both restored and untreated reefs (control/reference reefs), met the reef height and footprint metrics. This information, combined with a requisite halt in sonar work during the pandemic years and the resource-intensive nature of measuring these parameters using sonar equipment, led the Maryland Oyster Restoration Interagency Workgroup under the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team to adapt to measuring these parameters only on reefs that failed to meet the biological metrics, indicating they could be experiencing structural challenges.

This revised protocol is consistent with the adaptive management approach recommended in the original Oyster Metrics document. Specifically, the Oyster Metrics document recognizes that "…future research will inform oyster restoration practices, and strongly encourages the use of sound adaptive management practices. We expect that, as the state of knowledge advances, targets and approaches outlined here will evolve." No reefs in the 2025 cohort failed to meet the biological metrics; therefore, per this revised protocol, no reefs were monitored for reef height or footprint.

4.3: Use of Multiple Gear Types

As in previous years, two different types of gear (hydraulic patent tongs and divers) were used to collect oyster samples, as each was more suited to different substrate types (See Appendix B, Table B1 for which reef types were monitored with which gear). This was done to maximize the efficiency of restoration monitoring. Earlier field comparisons[9] on harvested natural oyster reefs revealed no difference between oyster densities estimated using divers and those estimated using patent tongs. However, a 2020 study[10] in Harris Creek on restored reefs found that oyster densities estimated by divers were, on average, 3.35 times higher than those estimated using patent tongs, indicating that patent tongs resulted in statistically significantly fewer oysters. In 2025, new reinforced patent tongs were used (See Appendix B for full methods) that likely sampled more efficiently, and may reduce the difference between patent tong and dive sampling. However, because different gear types were used for sampling, and research[9,10] results varied, it may not be appropriate to use data in this report to compare the efficacy of different reef treatment types. For clarity and consistency, results in this report are given without the diver-based correction factor on reefs monitored using patent tongs. However, the authors recognize that results derived from patent-tong sampling may be conservative.

4.4: Elevated Natural Spat Sets in Maryland in Recent Years

In 2020–2025, Maryland saw natural oyster spat sets above the long-term, statewide average. In 2025 specifically, DNR surveys showed statewide spat concentrations nearly six times higher than the long-term average, marking the second-highest spat set recorded in 41 years. Regionally, the Choptank Complex, where two of the large-scale restoration tributaries are located, saw the highest spat set, followed by the St. Mary's region, where a third restoration tributary is located. Harris Creek and St. Mary's sanctuaries both had sites sampled with spat counts over 1,000 per bushel. These trends likely contributed to the success of the restored reefs, and bode well for their long-term health.

4.5: Factors Influencing Future Reef Health

Although the information in this report looks promising for the long-term sustainability of reefs in Tred Avon, St. Mary's, and Manokin rivers, several factors could affect continued success. These include future water-quality issues (e.g., low salinity, low dissolved oxygen levels), oyster disease, funding for future monitoring and adaptive management, and poaching (illegal oyster harvesting). Data and analyses in this report can be used to understand the success or failure of restored reefs within a six-year time frame, and to inform future restoration and adaptive management. The monitoring undertaken three years post restoration is considered an adaptive management checkpoint. Information from this interval is used by restoration partners to determine whether a reef requires the second seed planting called for in each river's tributary plan, and if unsuccessful reefs should receive other management actions.

Definitions

Some words defined here are used only in appendices, not in the report itself.

Biological metrics: Four of the six Oyster Metrics success criteria, including oyster density, oyster biomass, multiple year classes, and shell budget.

Fall 2025 monitoring: Monitoring undertaken on restored reefs that turned 3 or 6 years old in fall 2025. Monitoring was also done annually on sentinel reefs in the Tred Avon River. The sentinel reefs were not tallied as part of the 2025 summary results, as these reefs were not part of the 6-year-old reef cohort.

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.

Mixed shell: A mixture of scallop, whelk, and clam shell from seafood processing plants. The shell is double-cracked before being imported into Maryland to ensure a clean product. This process results in the shell being largely fragmented.

Oyster gardening reef: A reef planted with oysters from various community-based oyster programs, where volunteers grow oysters in cages hanging from docks.

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."[3] See Table 1 for description of the six reef-level criteria.

Premet reefs: 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, and therefore did not initially receive further restoration treatment. 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. These reefs are monitored every three years, as are other reefs, to determine appropriate adaptive management needs.

Reef restoration treatment: The particular method used to restore a reef. See Appendix B, Table B1 for description of reef treatment types.

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 an Oyster Metrics criteria. It can also help ensure that reefs meet the oyster density and biomass 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 5 oysters per m^2 or greater, but fewer than 50 oysters per m^2 (see Harris Creek Tributary Plan[3], Little Choptank Tributary Plan[4], and Tred Avon Tributary Plan[5] for detailed description of how the Workgroup determined treatment type for each reef). See Appendix B, Table B1 for additional reef treatment type information.

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). The sentinel reefs were not tallied as part of the 2025 summary results, as these reefs were not part of the 6-year-old reef cohort. See Appendix A.

Six-year-old reef: Reef that received restoration treatment six years previously, and—per Oyster Metrics and tributary plans—was monitored three years post restoration and again six years post restoration.

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 6-inch mesh screen. These reefs were then seeded with spat-on-shell. See Appendix B, Table B1 for additional reef treatment type information.

Stone reefs topped with mixed shell: Reefs constructed from a stone base, then capped with mixed shell and seeded with spat-on-shell. See Appendix B, Table B1 for additional reef treatment type information.

Stone reefs topped with fossil shell: Reefs constructed from a stone base, then capped with fossil shell and seeded with spat-on-shell. See Appendix B, Table B1 for additional reef treatment type information.

Substrate + seed reefs: Reefs treated with reef-building substrate, generally to a height of 6 inches to 1 foot above the surrounding soft bottom. Substrate was either mixed shell, fossil shell, stone, or a combination. Substrate placement was followed by planting with hatchery-produced spat-on-shell. Substrate + seed treatment type was typically used where pre restoration oyster populations were below 5 oysters per m^2, or where sonar surveys found no evidence of shell. See Appendix B, Table B1 for additional reef treatment type information.

Three-year-old reef: Reef that received restoration treatment three years previously, and—per Oyster Metrics and tributary plans—were monitored three years post restoration.

References

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Appendix A: Downloadable Table of Summary Data by Reef and Length-Frequency Histogram for Each Reef

2025 data is broken into three tables:

- Table A1: 2025 Summary data by reef
- Table A2: 2025 Length-frequency histograms for reefs monitored using divers
- Table A3: 2025 Length-frequency histograms for reefs monitored using patent tongs

To access Appendix A, click on this link to download an Excel file: https://www.chesapeakebay.net/what/publications/2025-appendix-a-table-of-summary-data-by-reef-final

Appendix B: Monitoring Methods

This section describes methods for determining success relative to biological Oyster Metrics criteria (oyster density, oyster biomass, multiple year classes, shell budget).

Survey Design

A stratified random sampling survey is used to collect biological data on restored reefs within a given tributary. Each reef is its own stratum, and a random number of sample points are assigned based on reef size, reducing relative error among samples. The number of samples collected at each reef is optimized for data precision and accuracy for each gear type used[1]. For reefs sampled using patent tongs, the number of samples increased with reef size and averaged 2.5 samples per acre. For reefs sampled using divers, 5 samples were collected per reef, averaging 1.5 samples per acre. ArcGIS Pro is used to generate sampling points for each reef. All reefs that are due for monitoring are compiled into a shapefile, and sampling locations are generated within the area of the reef that was planted with spat on shell. This ensures that sample points are created within the area that received oysters.

Field Collection

Data to determine success relative to the four biological metrics (oyster density, oyster biomass, multiple year classes, and shell volume) were collected at the same time. Data collection occurred from October through December of 2025. Sampling is conducted during daylight hours. Navigation to sampling locations and sample coordinate documentation is done using ArcGIS Field Maps (version 25.3.0) via a mobile device. The vessel navigates as closely as possible to the designated random points, and a waypoint (virtual GPS marker) is created at the location of each sample.

As in previous years, two different types of gear were used to collect samples, depending on reef substrate type (Table B1). Divers were used to collect samples from reefs with substrate materials that were not amenable to patent tong sampling (stone and fossil shell substrate reefs; see definitions in Section 5 of the report). Patent tongs were used to collect samples from all other reef types (seed only, mixed-shell base, and premet reefs; see definitions in Section 5 of the report).

Because two different gear types were used for sampling, and the relative sampling efficiencies of those gears can vary[2,3], oyster density and biomass data may not be directly comparable between reef treatment types. For both diver and patent tong data, oyster density and oyster biomass information were standardized based on area sampled.

Treatment Type	Reef-building substrate added?	Substrate Material	Cap Material	Seed oysters planted onto reef?	Gear type used to collect biological metrics data
Seed only	No	None	None	Yes (spat-on-shell)	Patent tongs
Mixed shell	Yes	Mixed shell (clam, conch, whelk)	None	Yes (spat-on-shell)	Patent tongs
Fossil shell	Yes	Fossil shell	None	Yes (spat-on-shell)	Divers
Oyster gardening reef	No	None	None	Yes (spat-on-shell)	Patent tongs
Stone	Yes	Amphibolite (stone)	None	Yes (spat-on-shell)	Divers
Stone topped with mixed shell	Yes	Amphibolite (stone)	Mixed shell (clam, conch, whelk)	Yes (spat-on-shell)	Divers
Stone topped with fossil shell	Yes	Amphibolite (stone)	Fossil shell	Yes (spat-on-shell)	Divers

Table B1: *Description of treatments used to restore reefs under the '10 Tributaries' initiative. Only some of these treatment types were used on reefs that were part of the fall 2025 monitoring cohort. Also listed is the gear type used to monitor each reef treatment type for the biological metrics (oyster density, oyster biomass, multiple year classes, and shell volume). See Section 5 in the report for full definitions.*

Hydraulic patent tongs are a specialized commercial fishing gear used to harvest oysters in the Chesapeake Bay. The patent tong design functions much like a benthic grab, collecting oysters and underlying substrate from a known fixed area of the bottom. The tongs used in 2025 were reinforced by welding heavy-gauge steel teeth onto the frame. These sampled an area equal to 1 m^2 of the seafloor. The patent tongs were suspended from a boom over one side of the vessel and deployed to the bottom at each sampling location. A DGPS antenna was positioned adjacent to the location where the patent tongs were deployed, and a waypoint with the geographic coordinates of each sample location was documented.

Dive sampling is conducted by navigating the vessel to each sampling location and deploying buoys with anchors to mark each sample location. Divers descend to the bottom at each buoy with a 0.71 m x 0.71 m (0.5041 m^2) quadrat and sample collection crates. The quadrat is placed up current of the buoy anchor. Before disturbing the reef surface, the diver makes observations on the percent cover of reef substrate within the quadrat. Any material contained within the quadrat, including loose oysters, loose shell, and any reef substrate, are excavated to ~6 inch depth and transported to the vessel for processing. The diver reports the depth of the excavation if bare sediment is reached shallower than 6 inches.

Sample Processing

In each sample, all oysters are counted and identified as live or dead, and a minimum of 30 live oysters are measured from each sample. Oyster clumps, the number of oysters associated with a clump, and the substrate type that oysters are attached to are documented. The shell height and total count of dead (old box) and recently dead (gapers) oysters are documented from each sample. The percent of the sample covered by fouling organisms (tunicates, mussels, barnacles, and/or sponge) and the percent of the sample that is black (anoxic shell) is documented for each sample. Additionally, field crews measure live oyster, dead oyster, and shell volume to the nearest half liter using graduated buckets.

Surface and bottom water temperature, dissolved oxygen, pH, and salinity are collected during each sampling event using a YSI Pro-Quatro water quality sonde (YSI Corporation, Yellow Springs, Ohio). Other environmental and station-specific variables collected at each site include sample number, date and time, weather information, Yates Bar name, vessel name, and staff conducting the monitoring.

Data Entry and Analysis

All data were entered into a Microsoft Access database. QA/QC protocols were used to review data for nonsensical values and typos. Oyster lengths and counts were used to derive density and biomass estimates for each reef.

Graphs were made to visually display size class information and proportion of live to dead oysters at the reef level. Additionally, all sample locations were plotted in ArcGIS to ensure that samples were collected on the reef footprint. Methods for analyzing data per each Oyster Metrics success criterion follow.

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. 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. To meet the Oyster Metrics threshold or target, at least 30% of the samples collected must meet the specified densities.

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 regression[4]: W=((10^((log10(L)*2.06)-3.76))), where W = dry tissue weight in g and L = shell height in mm. Biomass was then summed for the entire sample and standardized to a square meter. The biomass value was scaled based on the number of oysters measured out of the total number of oysters counted. The same approach as oyster density (above) was employed, in which at least 30% of samples collected had to meet the threshold or target to demonstrate restoration success.

Multiple Year Classes

- Oyster Metrics success criterion: Presence of two or more year classes of live oysters.
- Method: Year-class presence was approximated by examining length frequency data of all oyster heights measured at each reef. 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: <40mm) were present. There was no differentiation between hatchery-produced oysters and natural oysters.

Shell Budget

- Oyster Metrics success criterion: Neutral or positive shell budget on the reef.
- Method: The volumes of sampled shell and oysters were measured with graduated buckets and standardized to square meter based on the area sampled by patent tong or diver quadrat. Field measurements of shell resources included total shell volume, total live oyster volume, and the percent of black (buried) shell in a sample. Surface shell estimates were calculated as the percent of the total sampled shell volume that was not considered black shell, as shown below:

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

For patent tong sampled reefs, changes to the shell budget at individual reefs were analyzed by comparing surface shell volume data from three-year monitoring to surface shell volume from six-year monitoring. For diver sampled reefs, calculating shell volume was conducted similarly but using oyster volume instead of surface shell volume. The Workgroup found that previous volume estimates for stone sites did not involve excavating the entire dive quadrat. Therefore, members of the Workgroup concluded that oyster volume would be a truer representation of volume. To determine if the shell budget was increasing or stable, two-way t-tests were conducted for each reef (three-year vs six-year volume, significance $P<0.05$). Sites that did not have significant differences between measurements at three-year monitoring and measurements at six-year monitoring were concluded to have a stable shell budget. Sites with significant increases in shell budget were also concluded to have met the metric.

Appendix B References

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