

# 2022 Chesapeake Bay Oyster Restoration Update

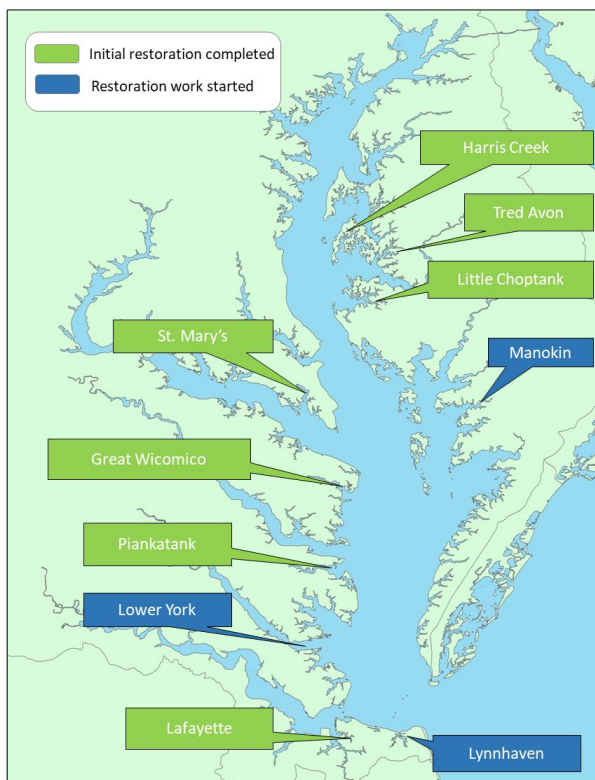
## Summary of Progress toward the Chesapeake Bay Watershed Agreement's 'Ten Tributaries by 2025' Oyster Outcome

*Numbers in this document are rounded.*

The [2014 Chesapeake Bay Watershed Agreement](#), which guides the work of the Chesapeake Bay Program, calls for state and federal partners to “restore native oyster habitat and populations in 10 Bay tributaries by 2025, and ensure their protection” (hereafter, “Ten Tributaries initiative”). Five tributaries are being restored in Maryland and five in Virginia. To achieve this outcome, the [Chesapeake Bay Program’s Sustainable Fisheries Goal Implementation Team](#) convened [working groups](#) in each state. With guidance from consulting scientists and the public, these groups set tributary-specific restoration goals and developed plans (hereafter, “[Restoration Blueprints](#)”) describing how the tributaries will be restored, consistent with success criteria described in the [Chesapeake Bay Oyster Metrics Report](#) (hereafter, “Oyster Metrics”). Detailed summaries of progress in Maryland and Virginia follow.

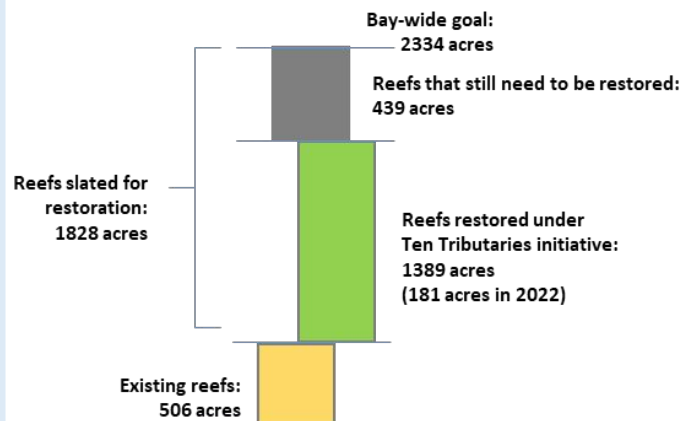
### Bay-wide Progress

#### Tributaries Complete: Seven of Ten Planned



#### Acres of Reef Restored: 1,389 of 1,828 planned

*That is more than two square miles—  
or 1,055 football fields—to date.*



#### Bay-wide Cost to Date: \$87.06 million (\$10.8 million in 2022)

This cost is Bay-wide, through the end of 2022, for reefs restored under the Ten Tributaries initiative. This includes reef construction only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef height and configuration, hydrologic factors, agency and stakeholder preferences, whether a reef requires seeding with juvenile oysters (as is typical in Maryland, due to lower natural oyster reproduction than Virginia rivers), and other factors.

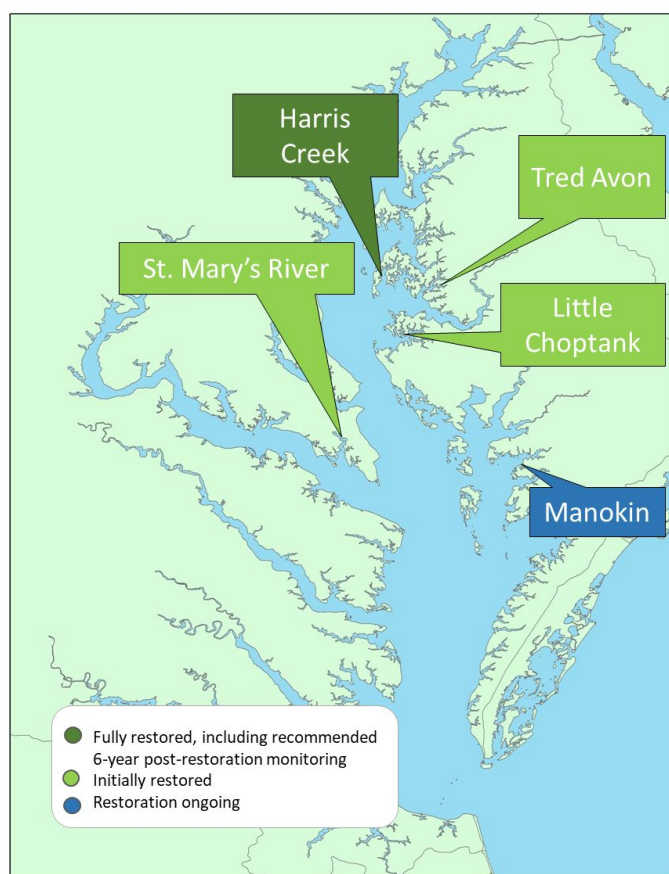
*See following sections for state-  
and tributary-specific information.*

# Maryland Summary

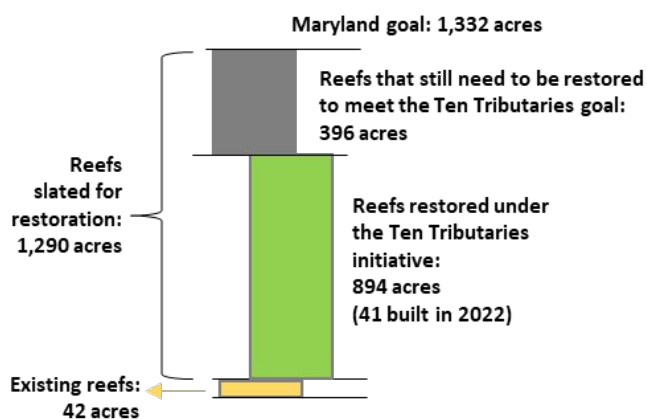
All five Maryland tributaries targeted for restoration under the Ten Tributaries initiative have been selected, and each now has a completed [Oyster Restoration Blueprint](#). Restoration work in four Maryland tributaries has now been completed (Harris Creek, Little Choptank River, Tred Avon River, and St. Mary's River). In-water restoration work in the last planned river, the Manokin, started in 2021 and continued in 2022. To date, partners have restored 894 acres of oyster reefs at a cost of approximately \$70.95 million. These reefs were constructed using one of two methods: by building a substrate base followed by planting with hatchery-produced oyster seed, or by placing only seed onto remnant reefs. [Monitoring results](#) show strong success relative to [preestablished success criteria](#), with 99% of 6-year-old restored reefs meeting at least the minimum threshold oyster density and biomass, and 83% meeting the higher target density and biomass.

## Progress in Maryland

### Tributaries Complete: Four of Five Planned



### Acres of Reefs Restored: 894 of 1,290 Planned



### Maryland Cost to Date: \$70.95 million (\$5.91 million in 2022)

This cost is through the end of 2022, for reefs restored under the Ten Tributaries initiative. This includes reef construction only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef configuration, hydrologic factors, agency and stakeholder preferences, and other factors.

### Seed Planted in Maryland under the Ten Tributaries Initiative: 5.93 billion (511.3 million planted in 2022)

All seed was spat-on-shell, produced primarily at the University of Maryland's Horn Point oyster hatchery. Some additional spat-on-shell was produced and planted by the Chesapeake Bay Foundation.

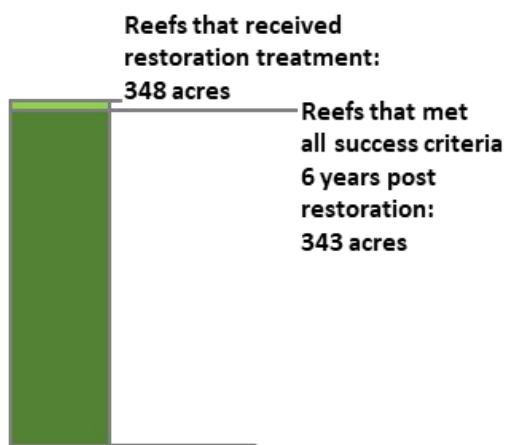
The Maryland portion of this report was compiled for the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team by the Maryland Oyster Restoration Interagency Workgroup (Stephanie Westby, chair; [stephanie.westby@noaa.gov](mailto:stephanie.westby@noaa.gov)).



Additional partners include the National Fish and Wildlife Foundation, The Nature Conservancy, University of Maryland, and the Chesapeake Bay Foundation.

Initial restoration work in Harris Creek was completed in 2015, followed by several years of planned second-year-class oyster plantings where needed. As of fall 2021, all 90 restored reefs (348 acres) in Harris Creek have been monitored as they matured to six years—the point where, per [Oyster Metrics](#), a reef can be considered successfully ‘restored’ if it meets all of the Oyster Metrics success criteria. Harris Creek is the first tributary, Bay-wide, where not only has restoration work (reef construction, seeding) been completed, but also where the recommended six-year post-restoration monitoring period has been completed. At six years of age, all but five acres of reefs (343 of the 348 acres that received restoration treatment) met the Oyster Metrics success criteria. Per the success criteria established in Oyster Metrics, and the [Harris Creek Restoration Blueprint](#), Harris Creek can now be considered fully, successfully restored. [Monitoring results](#) show strong success relative to [preestablished success criteria](#), with 98% of restored reefs meeting at least the minimum threshold oyster density and biomass, and 76% of reefs meeting the higher, target density and biomass.

## Acres Restored: 343 (restoration complete)

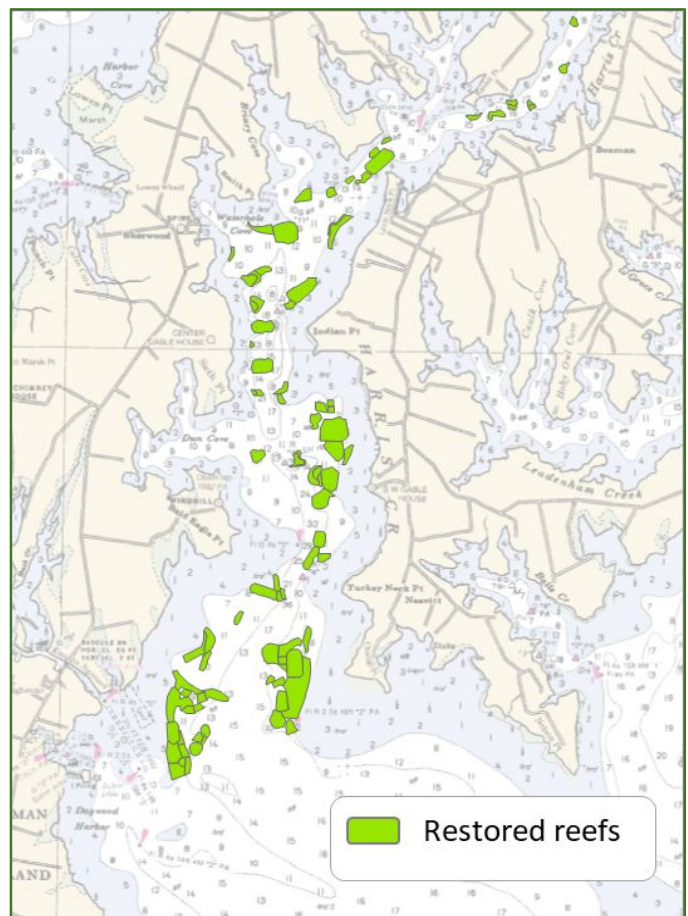


## Cost to Date: \$29.06 million (\$0 in 2022)

This cost is for reefs restored under the Ten Tributaries initiative. This includes reef construction and seeding only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef configuration, hydrologic factors, agency and stakeholder preferences, and other factors.

## Seed Planted: 2.49 billion (2011-2020)

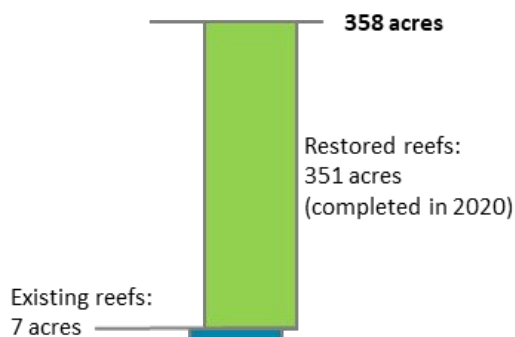
All seed was spat-on-shell, produced primarily at the University of Maryland’s Horn Point oyster hatchery. Some additional seed was produced and planted by the Chesapeake Bay Foundation.



# Little Choptank River

Initial restoration work was completed in the Little Choptank River in 2020 (see [video](#)). Since 2014, partners have restored 351 acres of reefs in the river. Work in 2022 focused on reef monitoring, and implementing the scheduled second-year-class oyster seedings called for in the [Little Choptank River Restoration Blueprint](#). On reefs where monitoring showed oysters densities and biomass higher than projected, the scheduled second seedings were not implemented. On reefs where densities and biomass were as projected, or lower, the scheduled second-year-class seedings were implemented. Reefs are also evaluated to determine if they meet other Oyster Metrics success criteria, including presence of multiple year classes and reef structural integrity. Monitoring to date shows that virtually all reefs are meeting the established success criteria. See the full [2021 Maryland Oyster Monitoring Report](#) for details. Results from past years were similar.

## Acres Restored: 351 (initial restoration complete)

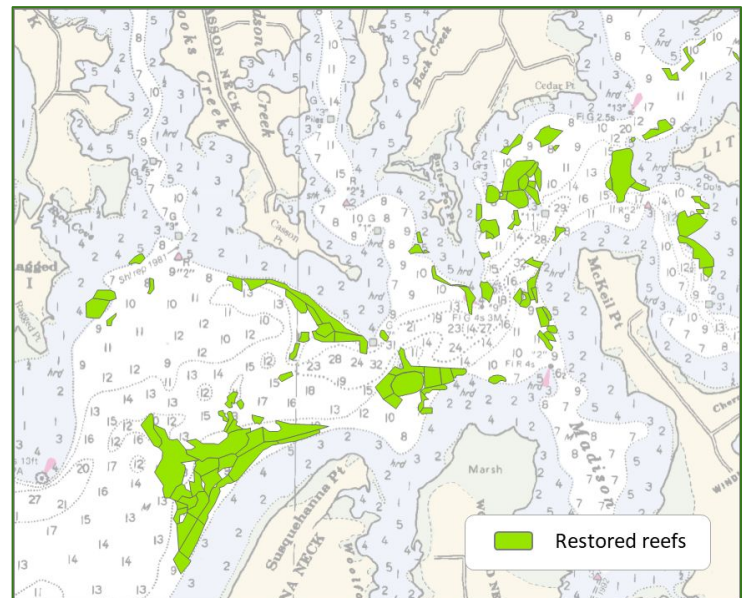


## Cost to Date: \$24.27 million (\$613,000 in 2022)

This cost is for reefs restored under the Ten Tributaries initiative. This includes reef construction and seeding only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef configuration, hydrologic factors, agency and stakeholder preferences, and other factors.

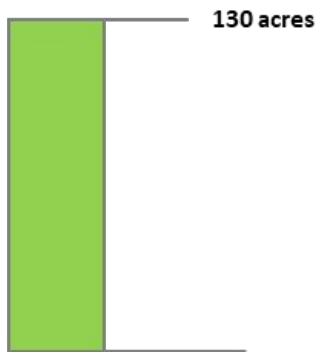
## Seed Planted: 1.98 billion (133.4 million in 2022)

All seed was spat-on-shell, produced primarily at the University of Maryland's Horn Point oyster hatchery. Some additional seed was produced and planted by the Chesapeake Bay Foundation.



Initial restoration work in the Tred Avon River started in 2015, and was completed in 2021. Work in 2022 focused on reef monitoring and on implementing the scheduled second-year-class oyster seedings called for in the [Tred Avon River Restoration Blueprint](#). On reefs where monitoring showed oysters densities and biomass higher than projected, the scheduled second seedings were not implemented. On reefs where densities and biomass were as projected, or lower, the scheduled second-year-class seedings were implemented. Reefs are also evaluated to determine if they meet other Oyster Metrics success criteria, including presence of multiple year classes and reef structural integrity. Monitoring to date shows that more than 85% of the restored reefs monitored are meeting at least the minimum threshold oyster density and biomass [success criteria](#). See the [2021 Maryland Oyster Monitoring Report](#) for details.

**Acres Restored: 130**  
*(initial restoration complete)*

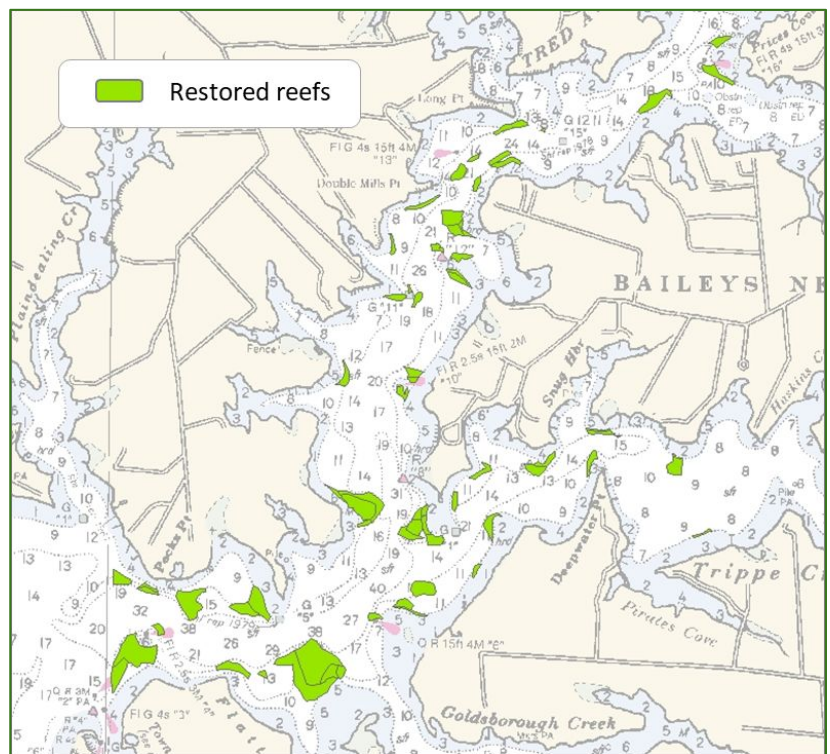


**Cost to Date: \$11.5 million**  
*(\$633,000 in 2022)*

This cost is for reefs restored under the Ten Tributaries initiative. This includes reef construction and seeding only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef configuration, hydrologic factors, agency and stakeholder preferences, and other factors.

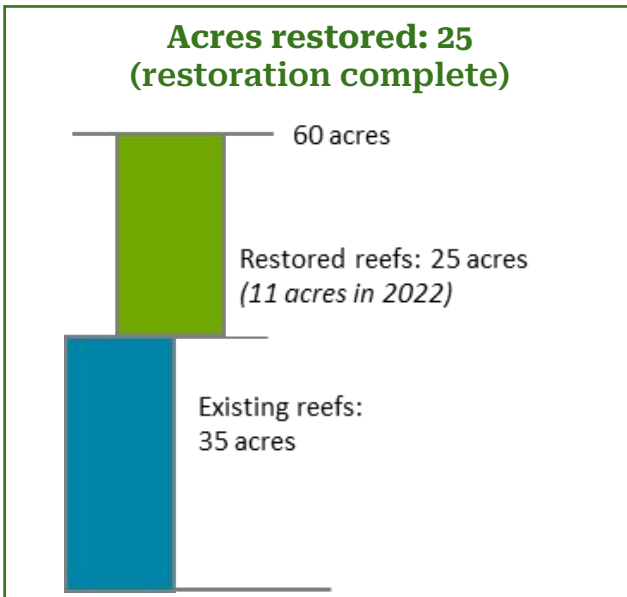
**Seed Planted: 1.06 billion**  
*(137.7 million in 2022)*

All seed was spat-on-shell, produced primarily at the University of Maryland's Horn Point oyster hatchery. Some additional seed was produced and planted by the Chesapeake Bay Foundation.



# Upper St. Mary's River

Initial restoration work in the St. Mary's River started in 2021, and was [completed in 2022](#). Partners have restored 25 acres of reefs (11 acres in 2022). Of the restored reefs, 9 acres were constructed from stone (2–4 inches in diameter, sourced from Vulcan Materials in Havre de Grace, Maryland), followed by seeding with hatchery-produced juvenile oysters. The other 16 acres of reefs were seeded only with hatchery-produced juvenile oysters. These restored reefs, in addition to the existing 35 acres of healthy reefs, bring the total to 60 acres, as called for in the [St. Mary's River Restoration Blueprint](#). The Maryland Department of Natural Resources funded the stone reef construction; oyster seeding was funded by the Maryland Department of Natural Resources and NOAA. Future work will focus on second-year-class seedings, as needed, per the St. Mary's River Restoration Blueprint, and on monitoring reefs per the Oyster Metrics success criteria. Other partners are interested in doing additional oyster restoration work in the St. Mary's River.

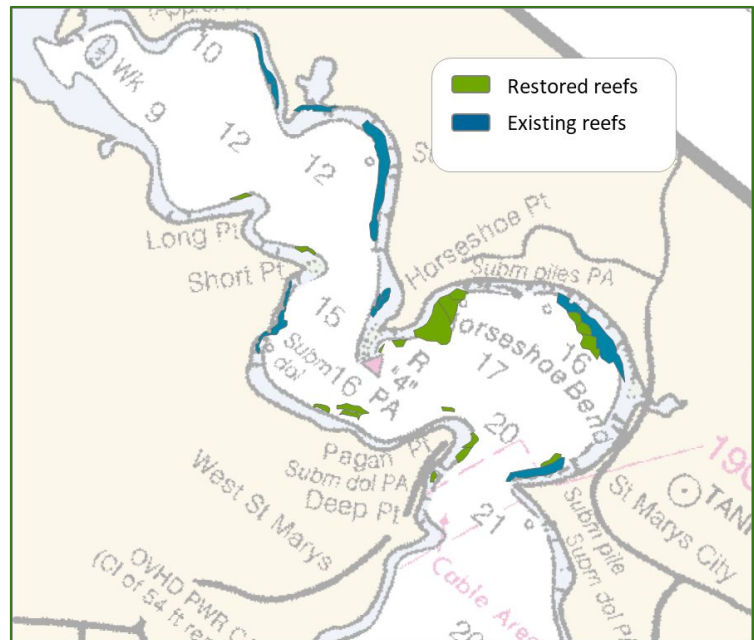


**Cost to Date: \$1.55 million  
(\$315,000 in 2022)**

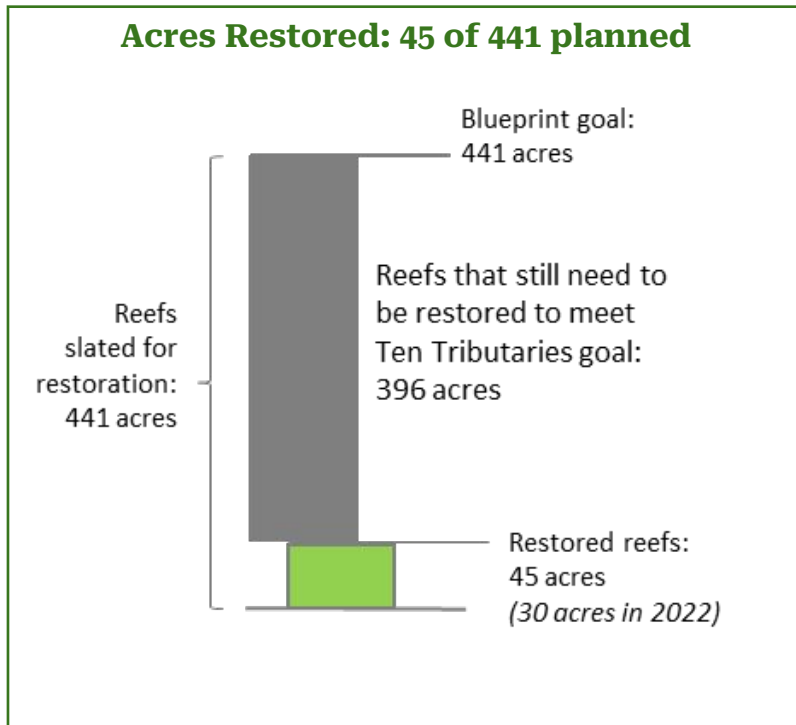
This cost is through the end of 2022, for reefs restored under the Ten Tributaries initiative. This includes reef construction and seeding only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef configuration, hydrologic factors, agency and stakeholder preferences, and other factors.

**Seed Planted: 151.1 million  
(68.5 million in 2022)**

All seed was spat-on-shell, produced primarily at the University of Maryland's Horn Point oyster hatchery.



The [Manokin River Restoration Blueprint](#) sets a goal of restoring 441 acres of reefs in the river. In-water restoration work started in 2021. All prerestoration groundtruthing surveys to determine restoration treatment per site are now completed. In 2022, partners restored 30 acres of reefs in the river. In addition, Murtech Inc., under contract from the Maryland Department of Natural Resources, constructed a 12-inch-high stone base on 32 acres in the river. The stone-base construction work is continuing into 2023; these reefs will be seeded with spat-on-shell over the next few years. This river requires the largest number of acres to be restored of any of the ten tributaries Bay-wide slated for restoration. Restoration work here will likely take until 2025.



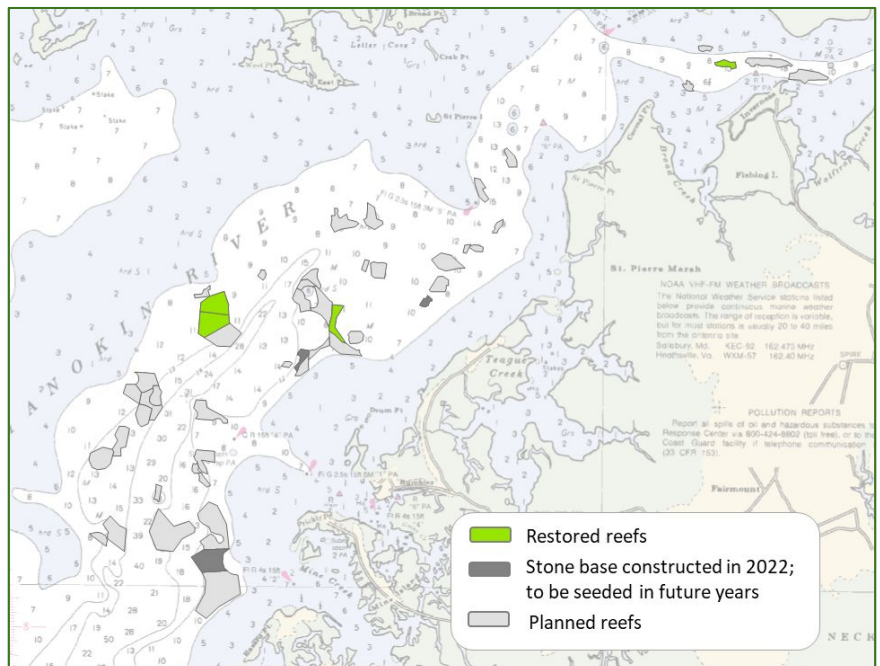
**Cost to Date: \$4.56 million (\$4.35 million in 2022\*)**

This cost is through the end of 2022, for reefs restored under the Ten Tributaries initiative. This includes reef construction and seeding only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef configuration, hydrologic factors, agency and stakeholder preferences, and other factors.

\*This cost includes the \$3.56 million the Maryland Department of Natural Resources spent in 2022 on reef-base construction in Manokin River. These reefs are not yet completed; they will receive oyster seedings in coming years.

**Seed Planted: 245.2 million (171.8 million in 2022)**

All seed was spat-on-shell, produced primarily at the University of Maryland's Horn Point oyster hatchery.



## Maryland 2022 Highlights and Challenges

### Highlights

- Partners completed initial restoration work in the St. Mary's River in 2022. This brings the number of restored tributaries in Maryland to four, out of the planned five.
- Partners were able to hold a [celebration event at St. Mary's College of Maryland](#). This honored not only the 2022 completion of the St. Mary's River, but also the 2021 completion of the Tred Avon River and the 2020 completion of the Little Choptank River. Those tributaries were completed during the height of the COVID-19 pandemic, and could not be celebrated at in-person events at the time of their completion.
- Harris Creek achieved fully successful restored status. All reefs reached six years of age, and all monitoring recommended per [Oyster Metrics](#) has been completed. 98% of reefs were determined to be successfully restored, providing for the first fully restored tributary under the Ten Tributaries initiative. (See Discussion Section of the [2021 Maryland Oyster Monitoring Report](#).)
- In Maryland's fifth tributary, the Manokin River, the Maryland Department of Natural Resources started construction of stone reefs. This is the largest planned river of the five selected in Maryland, and reef construction and seeding work here is expected to be the focus of the restoration efforts in 2023, 2024, and 2025.
- In 2020, 2021, and 2022, Maryland saw natural oyster spat sets levels above the 37-year average. This included particularly abundant spat sets in the St. Mary's River in 2022, and a high set in Tred Avon River, which has historically been a lower natural recruitment area than any of the other ten tributaries slated for restoration. These trends bode well for the longer-term success of the restored reefs.
- [Monitoring shows success](#) across the vast majority of three-year-old and six-year-old reefs.
- More than 511 million juvenile oysters (spat-on-shell) were produced and planted into the five selected tributaries in 2022. These juvenile oysters were produced by the University of Maryland's Horn Point Hatchery, with funding from NOAA and the Maryland Department of Natural Resources.
- In October, the Chesapeake Bay Foundation hosted the 2022 Maryland Rod and Reef Slam Fishing Tournament, designed to demonstrate the habitat value of restored oyster reefs. This year, 27 different species were caught during the tournament.

### Challenges

- Individuals in some user groups (e.g., boating public, adjacent private lease holders, waterfront property owners, watermen) have expressed opposition to some proposed projects in Maryland.
- The Manokin River is the largest tributary yet in terms of the number of acres of reefs that need to be restored.
- Oyster shell is in high demand and low supply across the oyster restoration, aquaculture, and wild harvest sectors in the Chesapeake region and nationally. Although reef base construction has largely switched to using alternative materials such as stone, oyster shell is still required for the hatchery to produce juvenile oysters (spat-on-shell). Partners across all sectors are exploring alternatives under an initiative led by the Oyster Recovery Partnership.
- Hatchery production of spat-on-shell is limited by shell availability, production facilities, and seasonality. Demand has increased due to oyster restoration and commercial harvest. Production was low in 2019 (due to high rainfall) and in 2020 (due to COVID-19). Combined, these factors present a challenge for acquiring the needed seed to complete Manokin restoration by 2025. Projections show that the planned Manokin restoration can be completed on time, but there is little room for error, delay, or uncertainty.

## Factors Influencing Success in Maryland

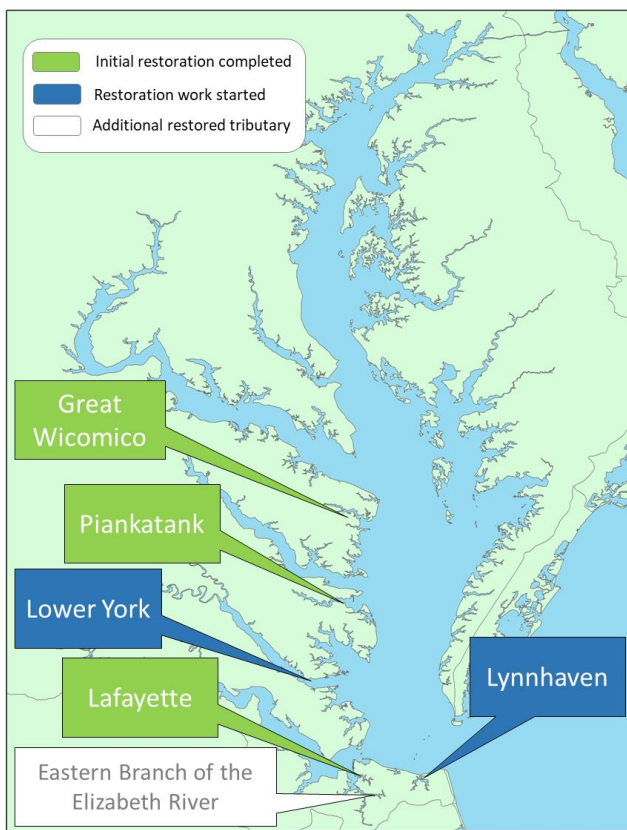
Many factors may influence the success of the Ten Tributaries outcome. These include water quality, oyster disease, fluctuations in natural oyster recruitment, fluctuations in hatchery production, and availability of suitable reef-building substrate. Despite these challenges, oyster restoration efforts in the Maryland waters of the Chesapeake Bay are already showing success with the completion of Harris Creek and the Little Choptank, Tred Avon, and St. Mary's rivers. Maryland is on track to meet its goal to restore five of the ten targeted tributaries Bay wide. These tributaries serve as evidence that oyster populations can prosper in Chesapeake Bay sanctuaries, either naturally or due to restoration efforts. If recent trends of low disease mortality rates continue, this may increase on-reef survival and sustainability of restoration efforts.



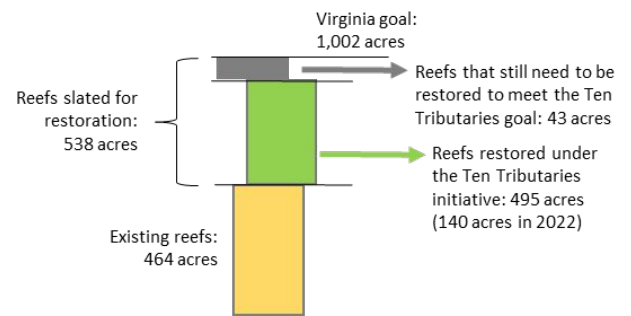
All five Virginia tributaries targeted for restoration under the Ten Tributaries initiative have been selected, and each now has a completed [Oyster Restoration Blueprint](#). Restoration work planned under the Ten Tributaries initiative in three Virginia tributaries has been completed (Lafayette, Piankatank, and Great Wicomico rivers). Additional restoration work, beyond the goals in the Ten Tributaries initiative, is also being done in some of these rivers. Planned in-water restoration work is nearly complete in the lower York River, and well under way in the Lynnhaven River. To date, partners have restored 495 acres of oyster reefs at a cost of approximately \$16.11 million. Above and beyond the ten tributaries planned for restoration Bay-wide, Virginia partners have also restored the Eastern Branch of the Elizabeth River to the same standards, making this an additional 'bonus' tributary.

## Progress in Virginia

### Tributaries Complete: Three of Five Planned (plus the Eastern Branch of the Elizabeth River)



### Acres of Reef Restored: 495 of 538 planned



### Virginia Cost to Date: \$16.11 million (\$4.17 million in 2022)

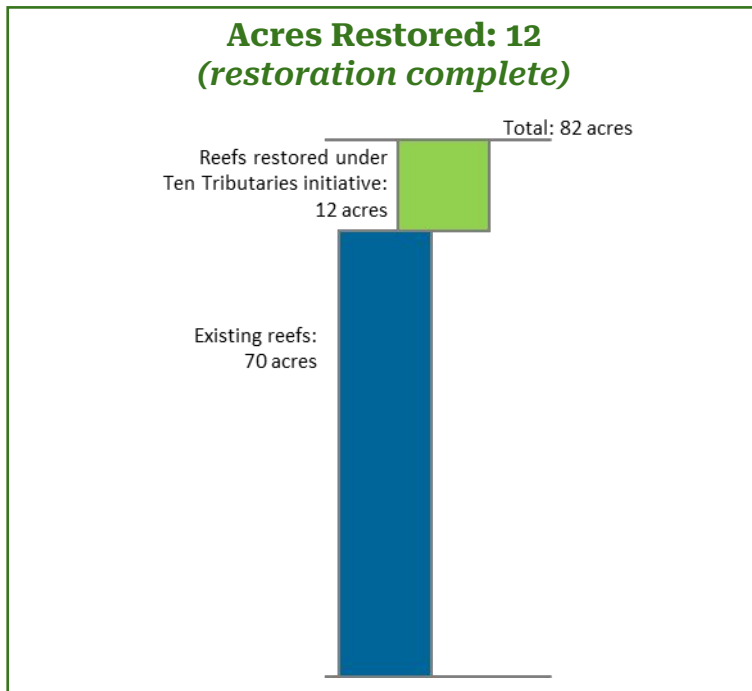
This cost is through the end of 2022, for reefs restored under the Ten Tributaries initiative. This includes reef construction only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef configuration, hydrologic factors, agency and stakeholder preferences, and other factors. This cost excludes the cost of restoring the Eastern Branch of the Elizabeth River, as that is considered above and beyond the Ten Tributaries initiative.

The Virginia portion of this report was compiled for the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team by the Virginia Oyster Restoration Workgroup (Stephanie Westby, chair, [stephanie.westby@noaa.gov](mailto:stephanie.westby@noaa.gov)).

Members include: Chesapeake Bay Foundation; Christopher Newport University; City of Norfolk; City of Virginia Beach; Elizabeth River Project; Lynnhaven River NOW; National Fish and Wildlife Foundation; National Oceanic and Atmospheric Administration; The Nature Conservancy; The Pew Charitable Trusts; Pleasure House Oysters/Ludford Brothers Oyster Company; U.S. Army Corps of Engineers; Virginia Commonwealth University; Virginia Institute of Marine Science; Virginia Marine Resources Commission.

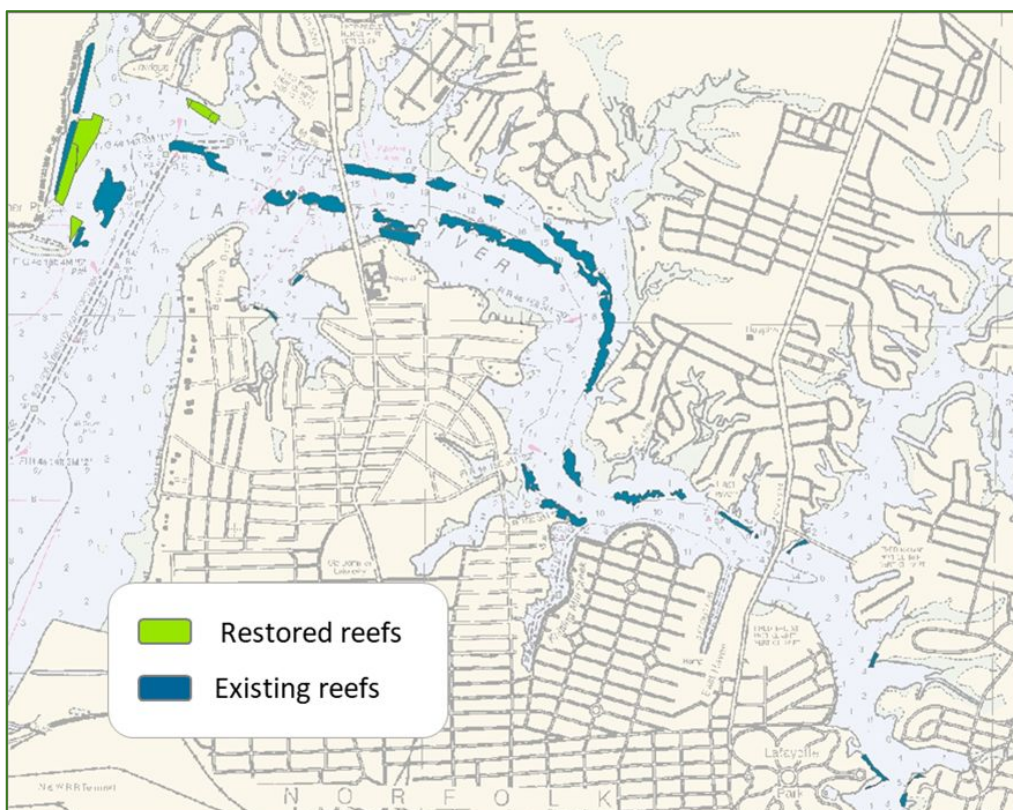
Planned oyster restoration work in the [Lafayette River Restoration Blueprint](#) was completed in 2018, making it the first river in Virginia to be considered complete under the Ten Tributaries initiative. The focus now is on monitoring the restored and existing reefs in the river. Earlier restoration projects show high densities of oysters representing numerous year classes, boding well for the newer Lafayette reefs. In 2022, VIMS conducted bathymetric and video surveys of three restored reefs in the river. Two of these reefs exceed the Oyster Metrics success targets for biomass and density; the third is still being analyzed.

Since 2018, the Elizabeth River Project has continued to coordinate the construction of shoreline oyster restoration projects through its partnership with the U.S. Navy's Lafayette Annex and waterfront residential property owners.



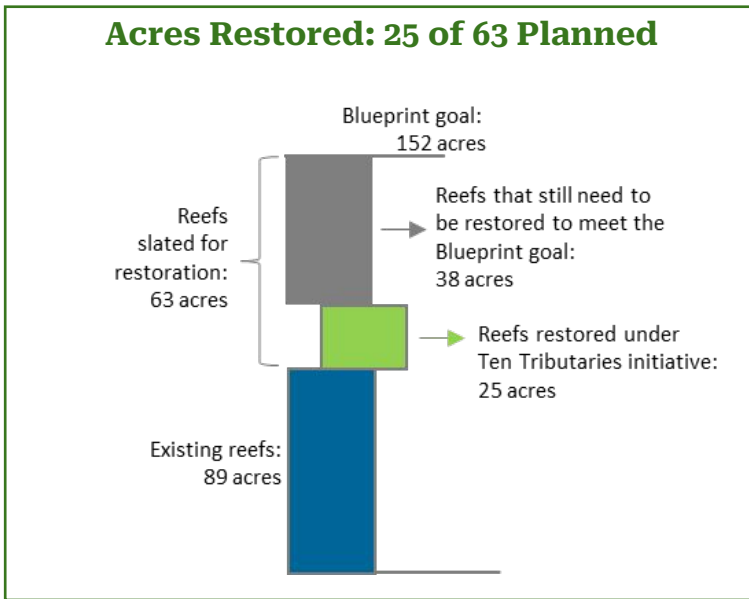
**Cost to Date: \$716,000**  
*(restoration completed in 2018)*

This cost is for reefs restored under the Ten Tributaries initiative. This includes reef construction only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef configuration, hydrologic factors, agency and stakeholder preferences, and other factors.



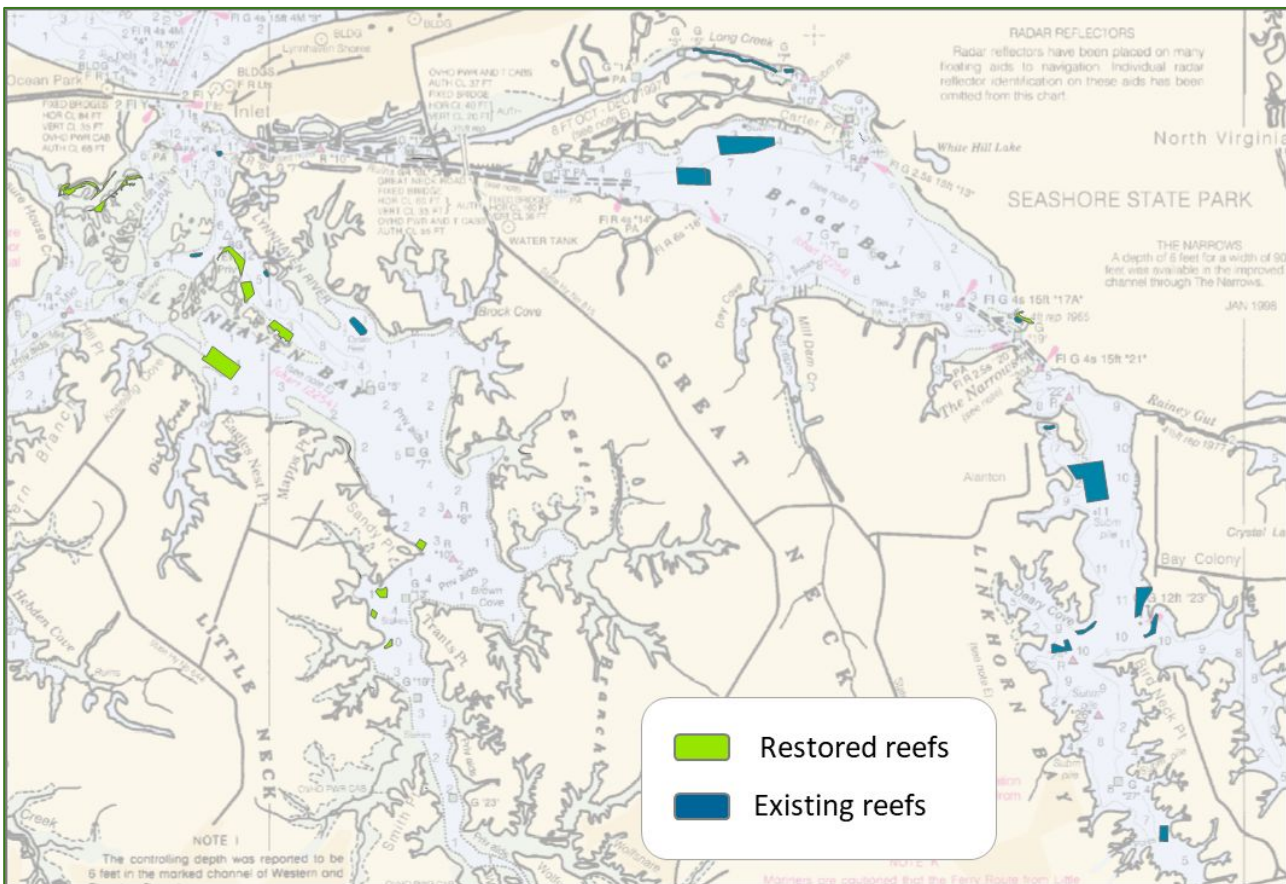
# Lynnhaven River

The [Lynnhaven River Restoration Blueprint](#) sets a goal of 152 acres of reefs in the river. In 2022, the Chesapeake Bay Foundation and Lynnhaven River Now constructed three reefs totaling 13 acres. Due to issues with the construction material and reef locations, these reefs are now under consideration for mitigation efforts in 2023, including possible removal. As of 2022, these reefs are not being counted toward the restored acreage in the Lynnhaven River. Under the Ten Tributaries initiative, 25 acres of reefs have been restored in the river (excluding the 13 acres now under consideration for mitigation), which is unchanged since the end of 2021. Pending permits, the U.S. Army Corps of Engineers' Norfolk District, with the City of Virginia Beach as its non-federal cost-share partner, plans to construct up to 25 acres of reefs in the Broad Bay area of the river as early as 2024.



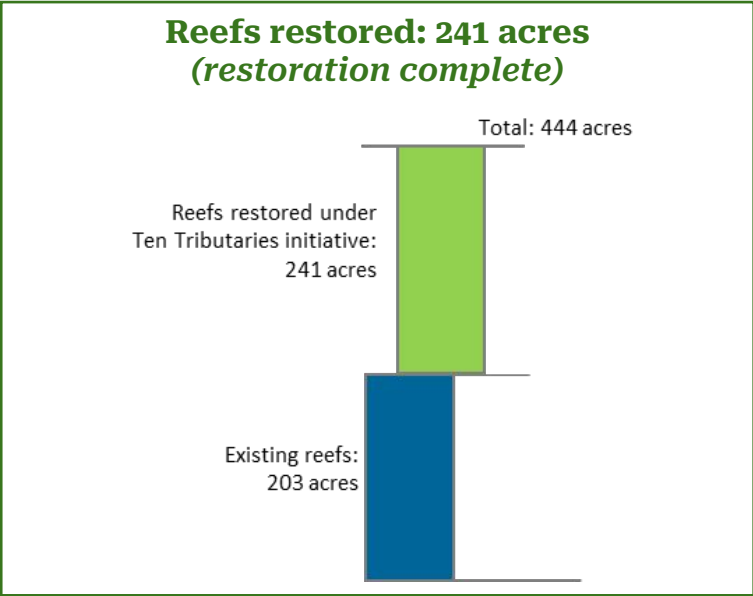
**Cost to Date: \$2.62 million**

This cost is through the end of 2022, for reefs restored under the Ten Tributaries initiative. This includes reef construction only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef configuration, hydrologic factors, agency and stakeholder preferences, and other factors.



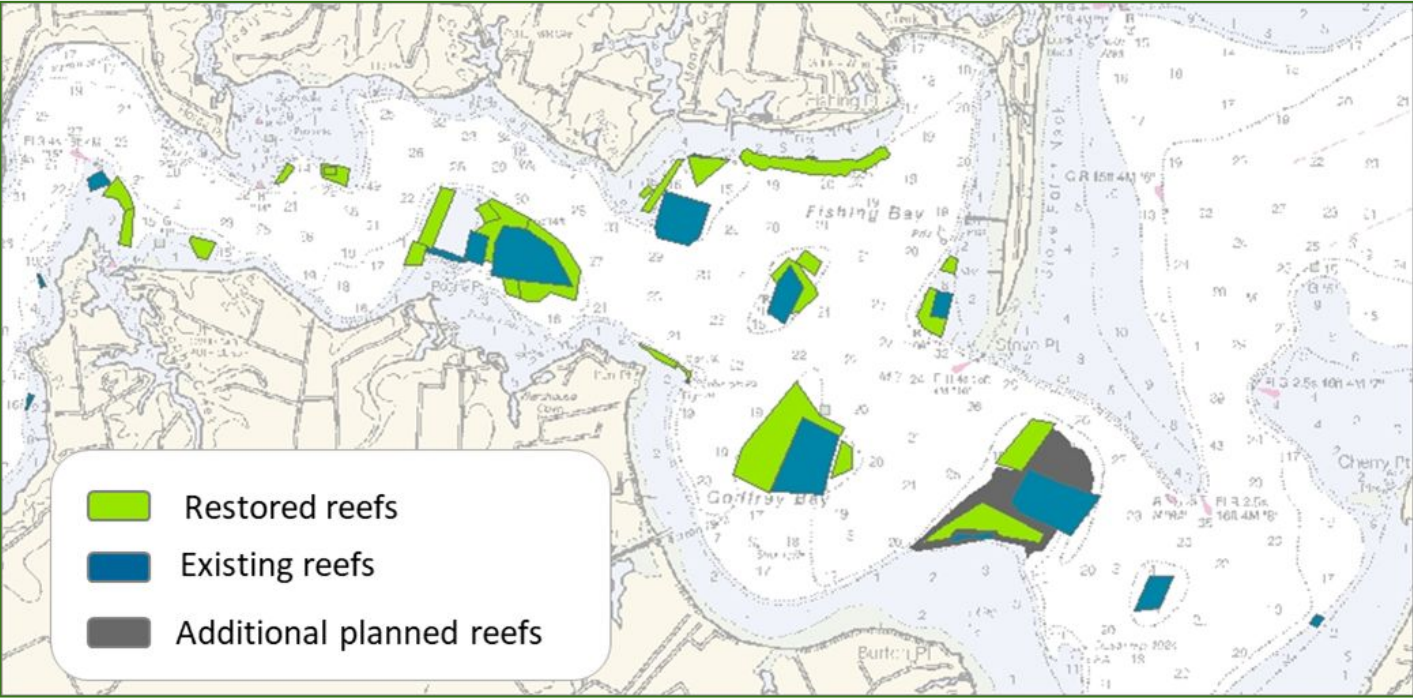
# Piankatank River

Oyster reef restoration work was completed in the Piankatank River in 2021, per the [Piankatank River Restoration Blueprint](#). Above and beyond completing the initial planned restoration, the U.S. Army Corps of Engineers' Norfolk District, with the Virginia Marine Resource Commission as its non-federal cost-share partner, will be constructing approximately 53 acres of reefs in the river in early 2023. A contract was awarded to Seaward Marine Corporation in September 2022 for this project. Class A-1 riprap will be used to create reefs approximately 12–18 inches high. Substrate will be placed in striations approximately 30 feet wide, spaced approximately 45 feet apart.



**Cost to Date: \$6.40 million**  
*(restoration completed in 2021)*

This cost is for reefs restored under the Ten Tributaries initiative. This includes reef construction only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef configuration, hydrologic factors, agency and stakeholder preferences, and other factors.



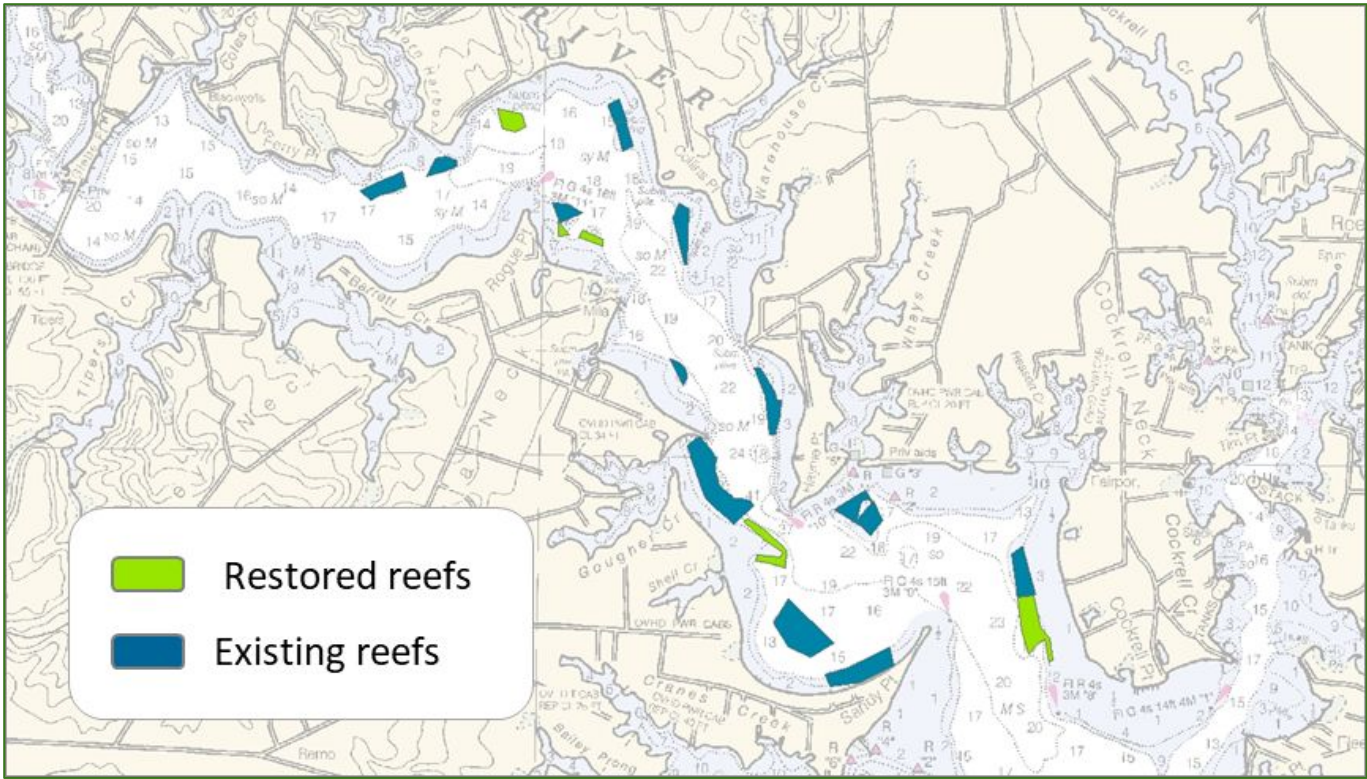
# Great Wicomico River

Oyster reef restoration work was completed in the Great Wicomico River in 2021, per the river's [Restoration Blueprint](#). The U.S. Army Corps of Engineers' Norfolk District, in partnership with the Virginia Marine Resources Commission, has begun planning efforts to perform adaptive management on existing reefs in the Great Wicomico River. Efforts include raising some of the 2004-constructed low-relief reefs to a higher elevation and placing habitat stones on areas prone to poaching. Exact scope and locations will be further refined in 2023, with construction estimated to begin in 2024.



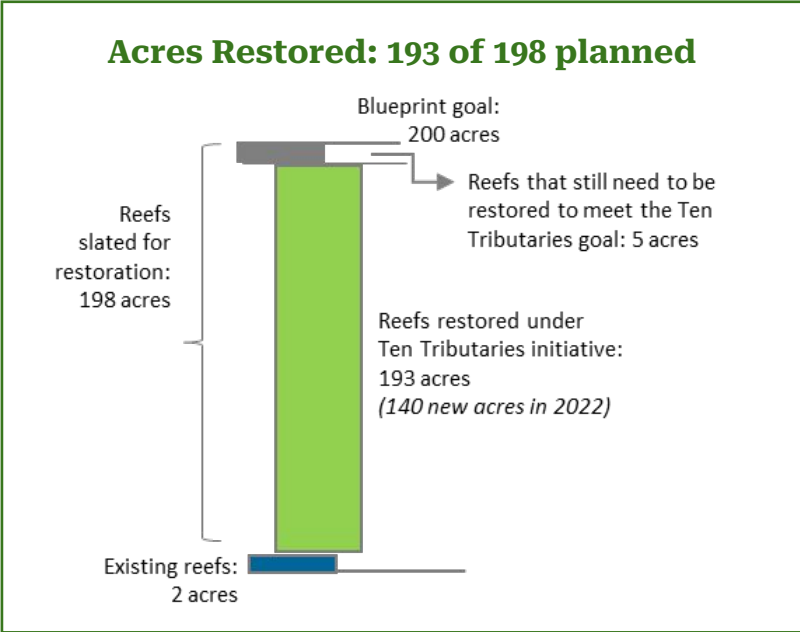
**Cost to Date: \$907,000**  
*(restoration completed in 2021)*

This cost is for reefs restored under the Ten Tributaries initiative. This includes reef construction only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef configuration, hydrologic factors, agency and stakeholder preferences, and other factors.



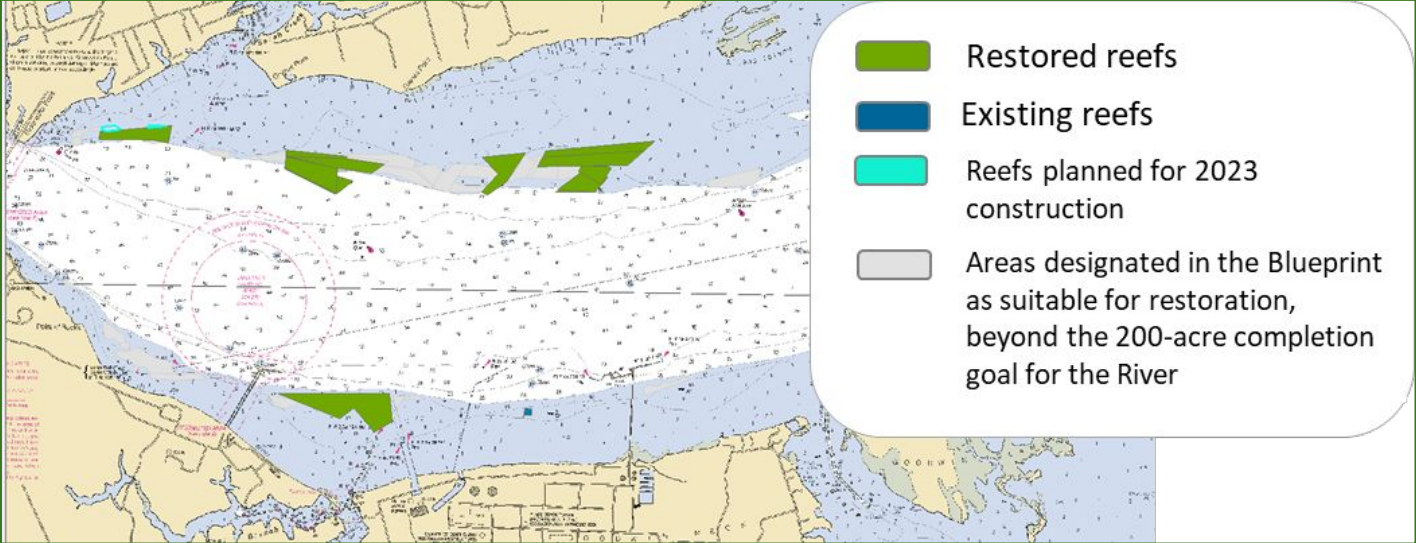
# Lower York River

The [Lower York River Restoration Blueprint](#) sets a goal of 200 acres of reefs in the river. In 2022, The Virginia Marine Resources Commission (VMRC) focused most of its construction work in the lower York River. VMRC spent approximately \$4.17 million on reef construction in the river, resulting in 140 acres of new reefs. This work brings the total restored reef acreage in the river to 193, just shy of the 200-acre goal. VMRC plans to continue reef construction in 2023, with the intention of reaching the goal early that year.



**Cost to Date: \$5.46 million**  
**(\$4.17 million in 2022)**

This cost is through the end of 2022, for reefs restored under the Ten Tributaries initiative. This includes reef construction only; costs such as benthic surveys, planning, permitting, and monitoring are not reflected. Restoration cost per acre varies due to factors including material type, reef configuration, hydrologic factors, agency and stakeholder preferences, and other factors.



## Virginia 2022 Highlights and Challenges

### Highlights

- Just under 30% of the reef acreage constructed in Virginia under the Ten Tributaries initiative was constructed in 2022. The previous year (2021) saw a similar level of reef construction, making this an impressive two-year run.
- Thanks to the Virginia Marine Resource Commission's 148 acres of reef construction in the lower York River in 2022, partners have now nearly completed planned work there. Only five more acres of reefs need to be constructed to reach the restoration goal for the lower York River. These reefs are slated for construction in early 2023.
- Virginia has experienced consistently high natural spat set since 2019. This has tended to boost shell volume and the number of larger oysters on restored reefs. This trend is consistent throughout Virginia, including on harvest reefs.

### Challenges

- Some individuals in user groups (e.g., boating public, adjacent private lease holders, waterfront property owners, watermen) have expressed opposition to some proposed projects in Virginia.
- As targets are almost reached, the last remaining acreage may become more difficult and/or expensive per acre of restoration on some tributaries.
- Due to issues with construction material and reef locations, 13 acres of reefs in the Lynnhaven River are now under consideration for mitigation efforts in 2023, including possible removal. This makes constructing the remaining planned reefs even more critical for completing restoration work in the river before the 2025 Chesapeake Bay Watershed Agreement deadline.

## Factors Influencing Success in Virginia

Many factors may influence the success of the Ten Tributaries outcome. These include restoration funding, poaching, water quality, oyster disease, acquisition of real estate rights, fluctuations in natural oyster recruitment, and availability of suitable reef-building substrate. That oyster restoration can succeed in the Virginia waters of the Chesapeake Bay has been validated by past successful oyster restoration efforts in the Lafayette, Piankatank, Great Wicomico, and Lynnhaven rivers and by the discovery of a relict, self-sustaining oyster population in the Lafayette River. These serve as evidence that oyster populations can prosper in the Chesapeake Bay, either naturally or due to restoration in sanctuaries. Virginia experiences consistent natural oyster recruitment rates, which minimizes the need for augmentation with hatchery-produced oysters. Recent declining trends in disease mortality rates have increased on-reef survival and sustainability of restoration efforts. Unpredictable environmental disturbances (e.g. freshets; sediment influx due to extreme weather events; temperature changes; hypoxia) may affect long-term reef success. These kinds of impacts may become more likely in the face of climate change.