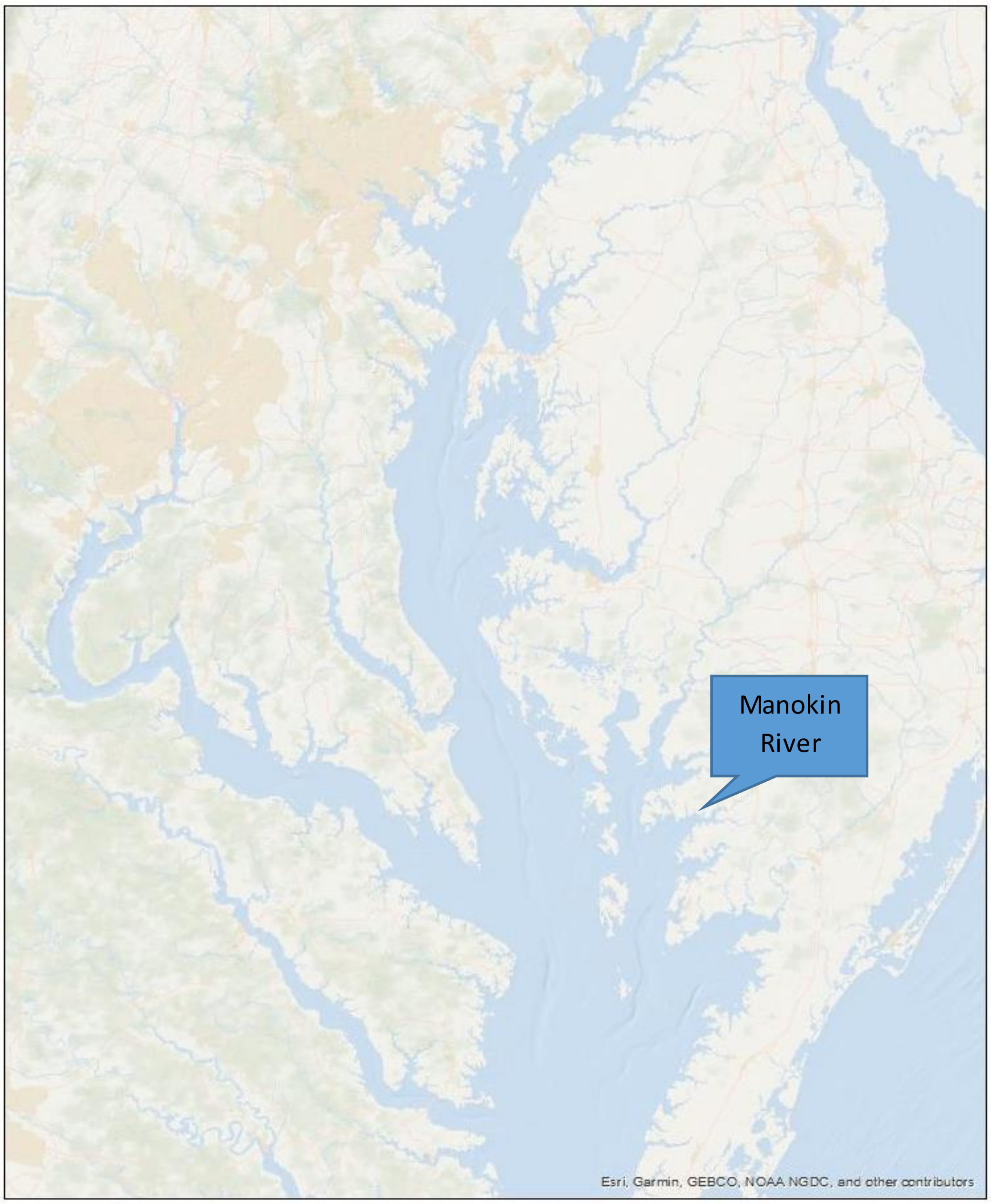
DRAFT Manokin River Oyster Restoration Tributary Plan:

A Blueprint for Restoring Oyster Populations in the Manokin River per the Chesapeake Bay Watershed Agreement

July 2020

Drafted by the Maryland Interagency Oyster Restoration Workgroup of the Sustainable Fisheries Goal Implementation Team



Maryland Interagency Oyster Restoration Workgroup:

National Oceanic and Atmospheric Administration: Stephanie Reynolds Westby (chair), David Bruce
Maryland Department of Natural Resources: Jodi Baxter, Laurinda Serafin
U.S. Army Corps of Engineers, Baltimore District: Angela Sowers
Oyster Recovery Partnership: Ward Slacum, Sara Coleman

Consultants:
Roger Dize, Somerset County Watermen's Association
Philip Harrington, III, current leaseholder
Daniel Webster, Somerset County Oyster Committee
Denise Breitberg, Smithsonian Environmental Research Center
Allison Colden, Chesapeake Bay Foundation
Matt Gray, University of Maryland Center for Environmental Science
Chris Guy, U.S. Fish and Wildlife Service
Tom Ihde, Morgan State University
Lisa Kellogg, Virginia Institute of Marine Science
Andy Lacatell, The Nature Conservancy
Jay Lazar, National Oceanic and Atmospheric Administration Chesapeake Bay Office
Elizabeth North, University of Maryland Center for Environmental Science
Kennedy Paynter, University of Maryland
David Schulte, U.S. Army Corps of Engineers, Norfolk District
Cecily Steppe, U.S. Naval Academy
Mike Wilberg, University of Maryland

The Manokin River Oyster Restoration Tributary Plan (Plan) is meant to be an adaptive, living document. The expectation is that there will be many lessons learned, and that the Plan will be adapted to reflect changing conditions and new information as restoration and monitoring progress. Continued dialogue with the consulting scientists, interested stakeholders, and the public is critical to this adaptive process. Acreage suitable for the different restoration types may be updated after annual groundtruthing bottom surveys.

Comments on this document are encouraged at any time, and can be directed to Stephanie Westby, Stephanie.westby@noaa.gov.

Appendices

Appendix A – Manokin River Restorable Bottom Assessment

Appendix B - Bottom Groundtruth Survey: Systematic Patent Tong Data Methods and Analysis

Key terms

CROH – Currently restorable oyster habitat – generated from Restorable Bottom Assessment (Appendix A). Identifies the restorable acres within a tributary using only spat on shell plantings. The bottom of this acreage has some level of biogenic shell characteristic. Does not include acreage that could be restored using alternate substrate. Utilized in the Tributary Plan as the first of two components to set the restoration goal.

HOH – historical oyster habitat, original Yates Bars within sanctuary boundaries. Utilized in the Tributary Plan as the second component to set the restoration goal.

Restoration goal – Number of acres meeting oyster success metrics at the end of the project. A site can meet success metrics by either exhibiting (and maintaining) those characteristics prior to restoration (premet), being restored by the use of spat on shell only (seed-only), or by being restored with alternate substrate followed by spat-on-shell (substrate + seed).

Suitable habitat – The acreage within a tributary that is biologically and physically suitable for oyster restoration minus excluded acreage for oyster water-way uses (navigation, piers, aquaculture, etc.) and valued resources (submerged aquatic vegetation). The suitable acreage is adopted as the restoration goal under the condition that it is 50 – 100% of CROH and 8 – 16% of HOH.

Executive Summary

The 2014 Chesapeake Bay Watershed Agreement, which guides the work of the Chesapeake Bay Program (CBP), calls for state and federal partners to “Continually increase finfish and shellfish habitat and water quality benefits from restored oyster populations. Restore native oyster habitat and populations in 10 tributaries by 2025 and ensure their protection.” (Chesapeake Executive Council 2014). Responsibility for achieving this goal rests with CBP’s Sustainable Fisheries Goal Implementation Team (GIT). For Maryland, the Sustainable Fisheries GIT convened the Maryland Interagency Workgroup (Workgroup) to plan, implement, and track progress toward this goal. The Workgroup developed the Manokin River Oyster Restoration Tributary Plan to: (1) describe how the river’s restoration goal was established, and (2) describe plans to achieve it. It details the restoration site selection process, and the reef construction, seeding, and monitoring required to bring the Manokin River Oyster Sanctuary in line with the oyster metrics definition of a successfully-restored tributary. It includes a map of restorable areas for restoration as well as an analysis of substrate and seed for restoration, and a cost analysis for substrate, seed and monitoring.

Substantial data collection and analysis went into the development of this Plan, including: benthic sonar mapping to identify suitable bottom for restoration, water quality analysis, examination of historic oyster bars, and surveys to determine current oyster populations and guide which restoration techniques should be applied to each site. Scientific and public consultation were sought by the Workgroup, and incorporated into the Plan.

Consistent with the Chesapeake Bay Oyster Metrics success criteria, the Workgroup developed a restoration goal of 441 acres for the river. There are an estimated 20 acres of existing reefs in the river that may be premet, already meeting the target density and biomass goals for a restored reef. The acreage of premet reefs may change after bottom groundtruthing surveys. Thus, an additional 421 acres of restoration work are needed in the river to meet the restoration goal (Table 1).

The cost estimate for completing the remaining 421 acres is $29,664,000. The estimated cost for year 3 and year 6 monitoring is $1,508,800.

This document is intended as a living document, and may be modified as needed in the future.

Table 1. Summary of Manokin River Restoration Goal, existing area that meet the target density and biomass metrics, area to be fully restored and the cost estimate.

Restoration Goal	441 acres
Estimated Premet Reefs*	20 acres
Estimated Area to be Restored	421 acres
Cost Estimate	$29,664,000

*Premet Reefs meet density and biomass targets prior to restoration work in the river. This may change after the results of the annual bottom groundtruthing surveys.

Note: The overall currently restorable restoration acreage for the river is 585.7 acres. These costs are for in-water reef construction and seeding only. Associated costs such as benthic surveys, oyster population surveys, planning, permitting, and monitoring are not reflected.

Sec. 1: Context and Scope

The 2014 Chesapeake Bay Agreement calls for state and federal partners to "Continually increase finfish and shellfish habitat and water quality benefits from restored oyster populations. Restore native oyster habitat and populations in 10 tributaries by 2025 and ensure their protection." Responsibility for achieving this goal rests with CBP's Sustainable Fisheries GIT.

In support of this goal, the Fisheries GIT convened the Oyster Metrics Workgroup to develop a science-based, common definition of a successfully restored tributary for the purpose of tracking progress toward the goal (related to Executive Order 13508 in 2009, and Federal Leadership Committee for the Chesapeake Bay in 2010). The Oyster Metrics Workgroup was composed of representatives from the state and federal agencies involved in Chesapeake Bay oyster restoration, as well as oyster scientists from academic institutions. The workgroup produced a report detailing these success metrics (Oyster Metrics Workgroup 2011). These metrics serve as the basis for the Manokin River tributary plan. The following criteria were among those set forth in the metrics report:

- A successfully restored reef should have:
    - A 'minimum threshold' of 15 oysters and 15 grams dry weight per square meter (m^2) covering at least 30% of the target restoration area at six years post restoration;
    - Ideally, a higher, 'target' of 50 oysters and 50 grams dry weight per square meter (m^2) covering at least 30% of the target restoration area at six years post restoration;
    - Two or more oyster year classes present; and
    - Stable or increasing spatial extent, reef height, and shell budget.
- A successfully restored tributary is one where:

- 50 to 100% of the currently restorable oyster habitat (CROH) has oyster reefs that meet the reef-level metrics above. Restorable habitat is defined as area that, at a minimum, has appropriate bottom quality and water quality for oyster survival, and
- 8 to 16% of historic oyster habitat, and preferably more, has oyster reefs that meet the reef-level metrics above

Like all GITs under the CBP, the Sustainable Fisheries GIT has crafted management strategies that describe the steps necessary to achieve each goal in the Chesapeake Bay Agreement. The strategies provide broad, overarching direction and are further supported by two-year work plans summarizing the specific commitments, short-term actions, and resources required for success. The Oyster Restoration Outcome Management Strategy (CBP 2015) calls for state-specific workgroups to develop tributary-specific plans to restore oysters in each of the 10 target rivers, consistent with the Oyster Metrics success criteria.

In 2012, the Sustainable Fisheries GIT established the Maryland Interagency Workgroup consisting of representatives from the National Oceanic and Atmospheric Administration (NOAA), U.S. Army Corps of Engineers (USACE) Baltimore District, Oyster Recovery Partnership (ORP) and the Maryland Department of Natural Resources (DNR) (Figure 1). The purpose of this Workgroup is to facilitate oyster restoration by coordinating efforts among the state and federal agencies, in consultation with the scientific, academic and oyster restoration communities. The Workgroup utilized the USACE Native Oyster Restoration Master Plan (USACE 2012) and the Maryland Oyster Restoration Plan and Aquaculture Development Plan (DNR 2009) to inform its work.

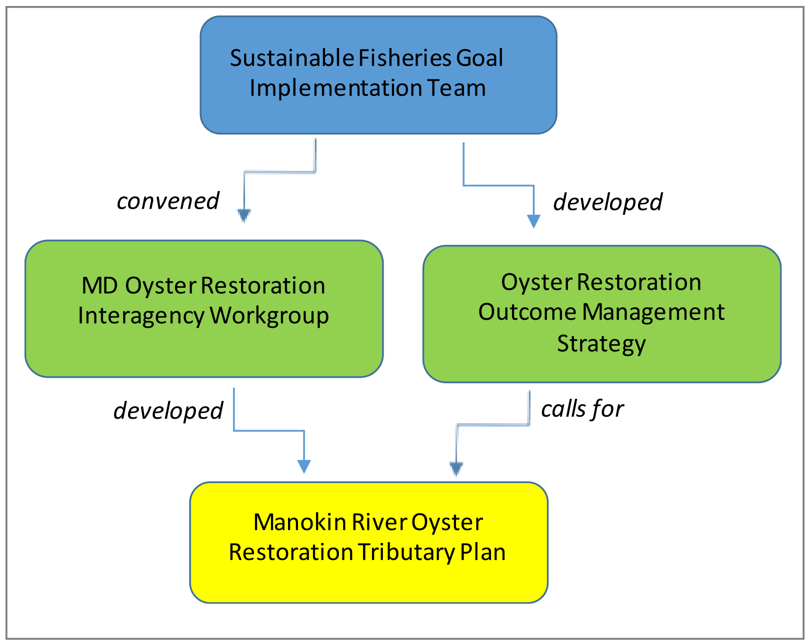


Figure 1: Organizational framework for large-scale oyster restoration in the Manokin River under the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team. Similar workgroups exist in Virginia.

Sec. 2: Selection of Manokin River as a Target Tributary

Several factors led to the designation of the Manokin River as a target tributary for large-scale oyster restoration under the Chesapeake Bay Watershed Agreement.

- The 2012 USACE Native Oyster Restoration Master Plan evaluated 63 tributaries of the Chesapeake Bay watershed. The document prioritized rivers based on historical, physical, and biological attributes to determine those tributaries with the potential to support large-scale oyster restoration. In this document, the Manokin River was designated as a Tier One tributary, indicating that it is suitable for oyster restoration.

- A portion of the river was designated as an oyster sanctuary and has been closed to wild commercial oyster harvest since 2010.
- The river has historically exhibited strong oyster recruitment.

In September 2018, DNR recommended the Manokin River as the fifth candidate for large-scale oyster restoration to the Sustainable Fisheries GIT. The selection was based on the Oyster Advisory Commission recommendation, findings of the USACE Master Plan, DNR's Fall Oyster Survey and patent tong survey data, the Maryland oyster sanctuary list, and bottom survey data from the Maryland Geological Survey (MGS) and NOAA. Criteria used in the tributary selection included water quality (salinity and dissolved oxygen appropriate for survival and reproduction), availability of restorable bottom (hard bottom capable of supporting oysters and substrate), historic spat set data, potential for larval retention, oyster sanctuary status, poaching enforceability, historic mortality, proximity to Public Shellfish Fishery Areas (PSFA), and tributary size.

In June 2019, the Sustainable Fisheries GIT formally approved the Manokin River oyster sanctuary as the fifth Maryland tributary for large-scale oyster restoration under the "10 tributaries" goal.

Sec. 3: Pre-restoration Status of the Manokin River Oyster Sanctuary

The Manokin River Sanctuary is located in the lower eastern portion of Maryland's Chesapeake Bay. It is a mesohaline region with a salinity typically above 14 ppt., but salinities beyond these levels can occur in a severe drought or freshet. The mouth of the river empties into the Tangier Sound. The sanctuary, created in 2010, encompasses 16,320 surface acres. During the 1906 to 1912 Yates Survey, 5,015 acres (7 bars) of historic oyster bottom was mapped within the sanctuary area (this area is called Yates Bars). After the Yates Survey, an additional 6,025 acres (12 bars) was added as a historic oyster bottom. Thus, in the Manokin River Sanctuary, there is a total of 11,040 acres of historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912, plus its amendments) within 19 historic oyster bars. The upper portion of the river is classified as a conditionally restricted shellfish harvest area by Maryland Department of the Environment (MDE) due to the potential for contamination of shellfish by fecal coliform and other bacteria (DNR 2016) (Figure 2).

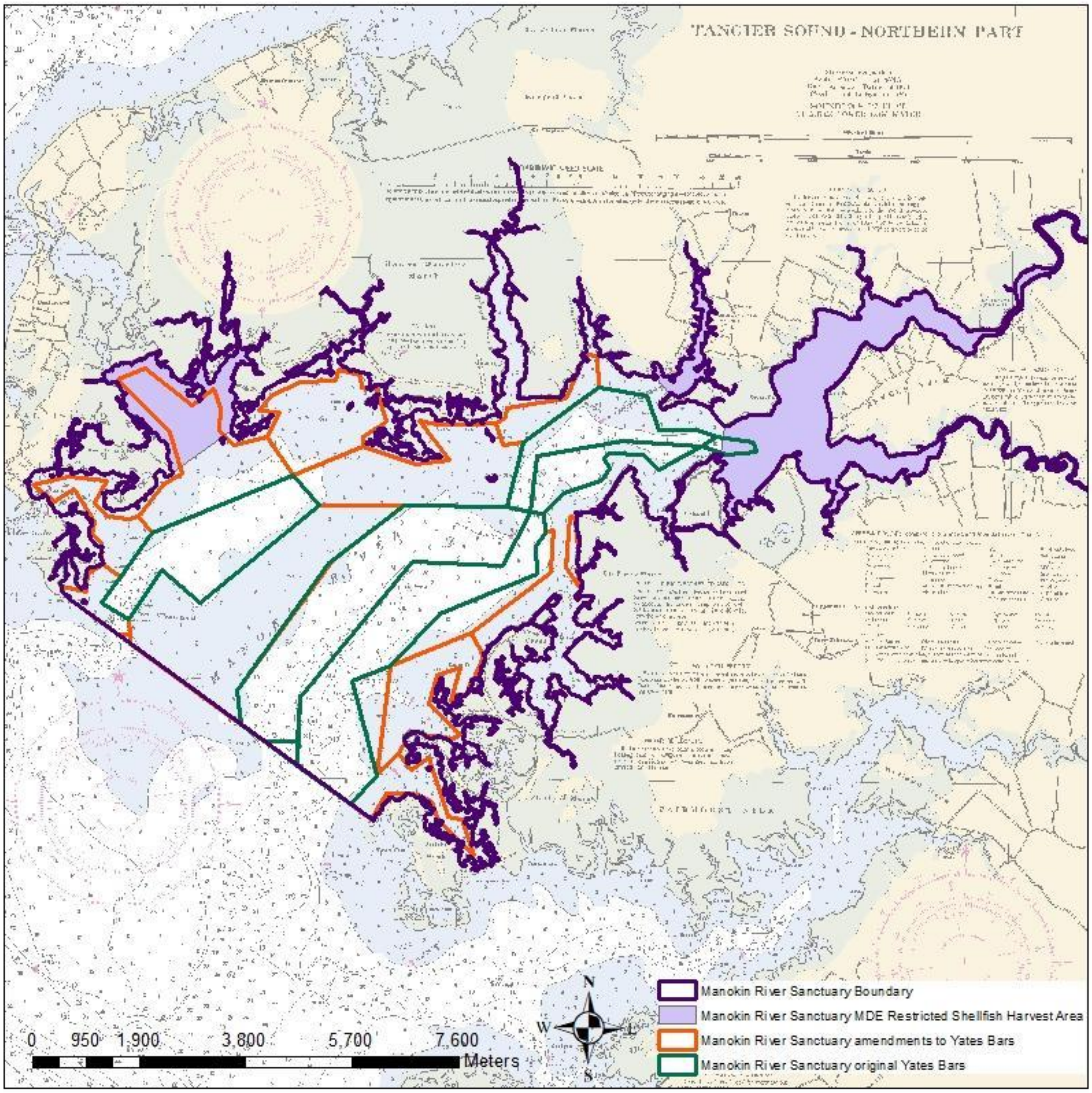


Figure 2. The Manokin River Oyster Sanctuary showing historic oyster bars (Yates bars plus the amendments) and areas closed to shellfish harvest by the MDE. Note: Cow Pen was originally part of Marshy Island original Yates bar.

The DNR Fall Oyster Survey has sampled five to eight bars annually within the area since 1990. The average number of live oysters per bushel was greater after the sanctuary was created, with the average number of small and market-size oysters increasing after the establishment of the sanctuary. This area, based on the annual Fall Oyster Survey data, exhibits a high annual spatfall relative to other areas of Maryland's portion of the Chesapeake Bay (Tarnowski 2019).

The Workgroup used data from DNR patent tong surveys conducted in 2012, 2015, 2017, and 2018 to determine the status of the oyster populations within the sanctuary. These patent tong surveys utilized a stratified random sampling design and were used to groundtruth the MGS sonar survey, determining the bottom suitable for restoration. Assisted by NOAA GIS analysis, this information was used to determine initial restoration construction areas and appropriate reef construction technique, including: reefs that already meet the metrics (premet, no construction needed), seed-only (spat on shell placed on hard bottom or to augment thin existing reefs), and substrate and seed (locations where reef substrate is used to build a foundation topped with spat on shell) (Appendix A).

Pre-restoration information estimated that, beyond the 20 acres that were determined to be premet (already meet density and biomass targets), an additional 617 acres are suitable for restoration (see Table 3). Seed-only restoration reefs were estimated to be 284 acres, and substrate and seed restoration reefs were estimated to be 333 acres. A systemic patent tong survey is conducted on these areas prior to restoration to groundtruth previous acoustic mapping and verify the areas are suitable for restoration and confirm the type of restoration (Appendix B). The systematic patent tong survey that is used for groundtruthing and to confirm restoration treatments will be done over multiple years, since the area to be surveyed is so great (up to 637 acres). The type of restoration suitable for each site is confirmed from the groundtruthing results, and this may change the estimated pre-restoration acreage for premet, seed-only, and substrate and seed. In 2019, seven sites were groundtruthed in preparation for restoration efforts.

Sec. 4: Oyster Restoration Goal

Sec. 4.1: Defining a successfully restored tributary per Oyster Metrics criteria:

The Oyster Metrics success criteria describe a two-pronged test to determine if a river is successfully restored (Figure 2). First, oyster reefs should cover 50 to 100% of a river's 'currently restorable oyster habitat'. To determine this, the Workgroup first had to define 'currently restorable bottom' in the river. By consensus among the Workgroup, the following were used to define CROH (This represents the revised CROH version accepted by the Sustainable Fisheries GIT; Lazar 2017):

- River extent: This was based on the area designated as a sanctuary in 2010. This river segment is 16,320 surface acres.
- Depth interval: The Baywide Bathymetry Grid developed by the CBP and a NOAA sonar survey from 1960 were interpolated to define restoration depths. Depths between 4 and 20 feet were considered restorable for the purposes of defining 'currently restorable oyster habitat.' The shallow depth limit of 4 feet was based on the practical limit of the vessels used for restoration activities, as well as the limits of acoustic surveys used to create the restorable bottom analysis. The 20-foot maximum depth cutoff was used due to concerns about potential hypoxia at greater depths. However, for substrate placement, a depth limit of 6 feet post-construction was used to allow for safe navigation over the substrate. A 2019 sonar survey conducted by NOAA was done to verify the bathymetry within the Manokin River.
- Benthic habitat (river bottom) type: Benthic habitat was classified using the Coastal and Marine Ecological Classification Standards (CMECS) using the 2010 MGS results updated with 2012, 2015, 2017, and 2018 patent tong data. The following types were

considered currently restorable: anthropogenic oyster rubble; sand and shell; biogenic oyster rubble; and muddy sand with shell. In general terms, anthropogenic oyster rubble is planted shell and biogenic oyster rubble is natural shell.

- Water quality: Water quality data are based on Maryland's Eyes on the Bay Program water quality station ET8.1, which has shown a stable salinity, with all values over 5 ppt, over a 25-year timeframe. The USACE Oyster Restoration Master Plan identifies tributary restorability absolute criteria for salinity as a mean of 5 ppt for bottom and surface for the interval of April to October 2001-2006. The absolute criteria for dissolved oxygen (DO) is a mean bottom value of 5 mg/l for the interval June to August. Recent observed DO levels (2009-2018) from ET8.1 sampling site within the sanctuary in May to September have average DO levels above the 5 mg/l threshold (Appendix A).

Using the above criteria, 585.7 acres were classified as 'CROH' (Appendix A). To meet the Oyster Metrics criteria of a restored tributary, the amount of restored area must (1) be at least 50% of the total CROH, and (2) be at least 8 to 16% of the historic oyster habitat. To meet the first part of the criteria for the Oyster Metrics definition of a restored tributary, between 292.8 (50%), and 585.7 (100%) acres will need to be restored. (Figure 3).

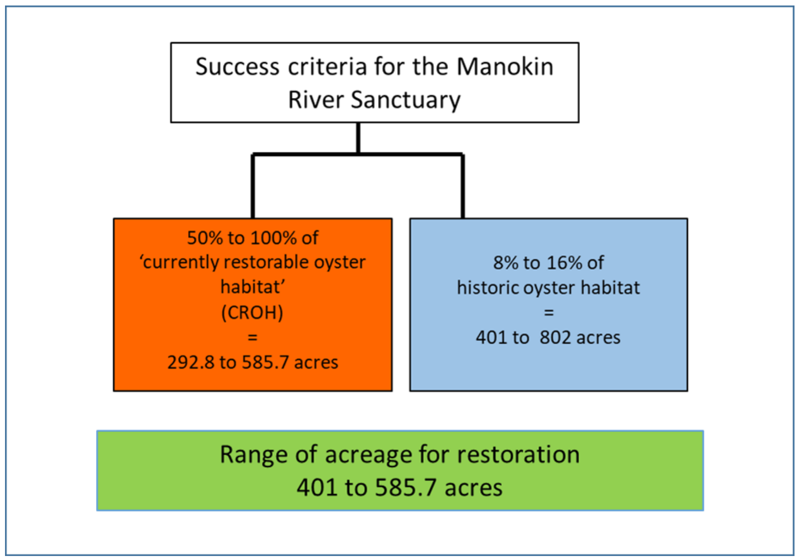


Figure 3: Oyster Metrics two-prong tributary-level success criteria, as applied to the Manokin River.

The second part of the criteria for the Oyster Metrics success criteria calls for at least 8 to 16% (401 to 802 acres) of the historic oyster habitat (original Yates bars, not including amendments) in the river to be restored (Figure 3). In the Manokin River sanctuary, per the USACE Native Oyster Restoration Master Plan, 8% of historic reef acreage is estimated at 401 acres. Therefore, at least 401 acres must be restored to meet the Oyster Metrics criteria of a restored tributary.

Sec. 4.2: Setting the oyster restoration target

Once the Workgroup determined the restoration target should be between 401 to 585.7 acres, a specific target of 441 acres was set within that range. The locations where restoration would actually occur was determined by identifying the areas within the sanctuary that were most "suitable" for oyster restoration and then eliminating areas that were not. This "suitable" area is not the same as CROH. CROH is only used to set the restoration area target and does NOT identify where restoration will occur. CROH is determined from locations where oysters could exist without substrate reef construction, and is defined by benthic habitats with some identified oyster shell component. Area "suitable" for oyster restoration includes bottom types that are 1) reasonably shell-free, where placement of substrate as a reef base will not cover existing shell resources, 2) existing functional oyster shell habitat that can be restored by only planting hatchery oysters, and 3) constraints of exclusionary parameters that include: buffers around docks, aids to navigation, and aquaculture leases; submerged aquatic vegetation (SAV) habitat, and more restrictive depth intervals that minimize navigation hazards. The target was set by determining the areas within the sanctuary that were most suitable for oyster restoration and then eliminating areas that aren't. The parameters eliminated were:

- SAV beds: There are historic and recent SAV beds in the Manokin River. The 2007-2016 SAV beds cover a total of 1,888 acres within the sanctuary. However, no area was removed from the potential restoration areas due to SAV. Restoration will not occur within SAV beds.
- Exclusion zones: No restoration work was planned underneath private docks or on private leases (no area removed). Areas within 750 feet of key bars (Georges and Drum Pt.) for the DNR Fall oyster survey were excluded, with a loss of 40.3 acres (Appendix A).
- Proximity buffers: Areas within 150 feet of aquaculture leases, within 250 feet of U.S. Coast Guard (USCG) navigational aids and within 50 feet of private docks for seed-only restoration or within 250 feet of private docks for substrate restoration, and 250 feet from pound net sites were not considered for oyster restoration work. An extended buffer zone of 300 feet on either side of the navigational channel for the entrance into Rumbley harbor was also removed (Appendix A).
- Post-construction depth: No restoration requiring substrate to be planted will occur in depths less than 7 feet, allowing for 6 feet clearance after restoration construction.
- A small area of CROH (18.6 acres) that was isolated in the northern portion of the river was removed from the restoration plan.

Considering the above parameters, the workgroup set a restoration target of 441 acres (401 minimum acreage + 10% buffer of 40 acres), or 75.5% of the CROH (Figure 4).

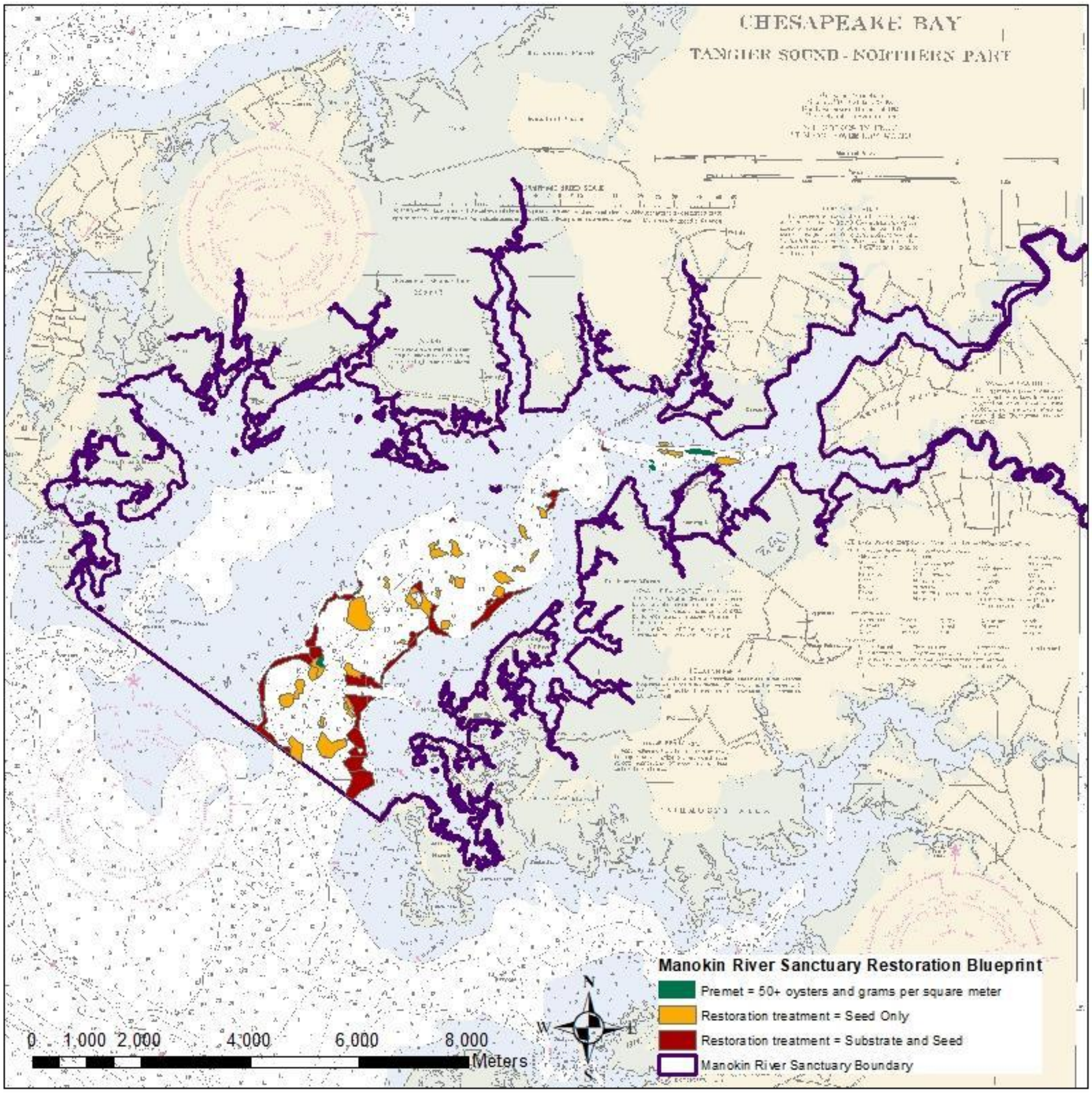


Figure 4. Manokin River sanctuary restoration blueprint map.

Sec. 5: Determining restoration treatment for planned reefs

Once the 637 acres suitable for restoration had been identified, the Workgroup made a determination as to which reefs should receive 'seed-only' restoration treatment (hatchery-produced spat-on-shell (SOS) to be added to existing remnant reefs), or 'substrate and seed' restoration treatment (adding reef-building substrate to the reef footprint, followed by planting with hatchery-produced SOS), while some do not require treatment because they are 'premet.' The parameters in Table 2 were used to delineate treatment type.

As stated above, some areas of CROH will not be restored: premet areas, SAV, docks, Fall Survey disease or key bars, and depth constraints. Based on the results of the groundtruth survey (Table 2), areas that already meet the Oyster Metrics target oyster density (50+ oysters per square meter) and oyster biomass (50+ grams per square meter) will be considered naturally restored, and will not receive restoration treatment. SAV beds were delineated using data from the Virginia Institute of Marine Science for the years 2007-2016 (Appendix A). These areas were not considered for oyster restoration to avoid interfering with this habitat type. Areas suitable for substrate and seed restoration and that have water depth of less than 7 foot will not be restored to avoid navigational conflicts. A buffer of 50 feet for seed-only restoration and a buffer of 250 feet for substrate and seed restoration reefs will be used around private docks to avoid navigational conflicts. The USCG restricts activity within and around navigational channels and buoys. All USCG navigational areas will have a 250 feet buffer to avoid navigational issues. The Workgroup also extended a buffer zone of 300 feet on either side of the navigational channel for the entrance into Rumbley harbor.

Georges and Drum Point oyster bars are key and disease bars for the DNR Fall Oyster Survey, therefore, a 750 ft. buffer around the Fall Survey sample location will not receive any treatment. They will serve as reference reefs during the 3 and 6 year monitoring surveys. The groundtruth survey will determine the type of restoration that would be suitable for these areas. Most likely these areas will be classified as seed-only sites based on the oyster density and biomass data from the patent tong surveys.

Table 2. Criteria used to determine treatment type for each targeted restoration area.

Criteria	**Restoration Treatment Type**	
	seed-only restoration treatment	**substrate and seed restoration treatment**
Water depth less than 4 feet or greater than 20 feet	no	no
Soft benthic habitat	no	no
Areas with hard bottom, and 50+ oysters per m^2	no	no
Areas with hard bottom, and 5-50 oysters per m^2	yes	no
Areas with hard bottom, no shell, and < 5 oysters per m^2	no	yes
Areas with hard bottom, < 5 oysters per m^2, AND with predominantly oxic shell, high quality shell, substantial surface shell, more oysters	yes	no
Areas with hard bottom, < 5 oysters per m^2, AND with predominantly anoxic shell, low quality shell, very little surface shell, few oysters, and in waters 6 to 20 feet deep	no	yes
Private dock buffer	50 ft.	250 ft.
Outside of SAV beds	yes	yes
Outside of exclusion zones	yes	yes

Table 3 shows the total area suitable for restoration, based on currently available data, relative to the CROH restoration metric. Suitable area is broken down by restoration type, providing estimates of the amount of bottom to be allocated for seed-only or substrate and seed implementation. Note that the total suitable area exceeds the CROH value; this discrepancy exists because CROH is based on the current area of oyster shell bottom whereas total suitable bottom includes area for constructing substrate reefs that intentionally avoids oyster shell.

Site classifications and associated acreages are subject to change based on a groundtruthing bottom survey. In areas that are slated for substrate and seed restoration, moving existing oysters will be considered before restoration to avoid burying live oysters.

Although the restorable bottom analysis determined that there are 637 acres available for restoration, time and resources are not available to restore all of the acreage by 2025. The Oyster Metrics outline that a successfully restored tributary is one in which at least 50% of currently restorable habitat (292.8 acres) as well as a minimum of 8% of historic oyster habitat (401 acres) is restored. Using this success metric as a guide, a minimum of 401 acres is required for restoration. The Workgroup used the minimum acreage of 401 (8% historic oyster habitat) acreage with a 10% buffer (40 acres) as the target for restoration acreage, totaling 441 acres.

Table 3. Manokin River sanctuary restoration acreage.

Restoration Treatment	**Estimated Acres Suitable for Restoration****	**Estimated Acres Planned for Restoration ****
Seed-Only	284	284
Substrate and Seed	333	137
Premet*	20	20
Restoration Area Totals (Suitable/Planned)	**637**	**441**
Currently Restorable Oyster Habitat (CROH)	**585.7**	
Target Restoration % CROH	**75.5%**	

*Premet Reefs meet density and biomass targets prior to restoration work in the river.

** Site classifications and associated acreages are subject to change based on a groundtruthing bottom survey.

To determine pre-restoration oyster density and to verify the type of restoration suitable for each site, a bottom groundtruth survey will occur (a systematic patent tong survey) (Table 4). Since the restorable bottom analysis determined that such a large area (637 acres) is available for restoration, the groundtruthing effort will need to be done in stages. About 75-100 acres are reasonable to survey semiannually. Yearly fall groundtruthing surveys will be conducted on bottom that is anticipated to need seed-only restoration. The results of the fall groundtruthing survey will verify the acreages to be seeded as seed-only in the spring of the following year. Yearly spring groundtruthing will occur on areas that are anticipated to need substrate and seed restoration. The results of the spring surveys will determine the acreages to be constructed in the fall or winter.

The first systematic patent tong survey was conducted in 2019 on 75 acres of habitat and the results determined the type of restoration construction that should occur on those acres (e.g., seed-only, substrate and seed, or premet) (Appendix B). Future patent tong groundtruth surveys will continue to occur to guide restoration.

Since the groundtruthing surveys will be done in stages, the area identified for construction of substrate and seed reefs will be determined each year. The construction effort will occur over the winter and is expected to span two years. In the spring, after the substrate reefs are constructed, a recruitment study will be implemented on the constructed reefs. Areas in deeper water will be prioritized for construction of substrate and seed reefs.

Since the Manokin is a high recruitment area, recruitment studies on areas that receive substrate construction will help to determine if initial seeding is necessary. Substrate site construction will occur in the winter and spat collectors will be placed on the constructed reef areas from May through July to monitor for a natural spat set. If a natural spatset is observed, then initial seeding will be postponed and reevaluated post three year monitoring.

Table 4. Systematic patent tong survey and restoration plan schedule.

Projected Timeline	Patent Tong Groundtruthing Survey (acres)		Restoration Treatment Schedule (acres)			
	Seed-Only	Substrate and Seed	Seeding Seed-Only Sites	Substrate Sites Construction	Recruitment Study (May-July)	Seeding Substrate Sites (August-September) *
Fall 2019	75	-	-	-	-	-
Spring 2020	-	100	50	-	-	-
Fall 2020	75	-	-	-	-	-
Winter 2020/21	-	-	-	75	-	-
Spring 2021	-	100	75	-	75	-
Summer 2021	-	-	-	-	-	75
Fall 2021	75	-	-	-	-	-
Winter 2021/22	-	-	-	75	-	-
Spring 2022	-	100	75	-	75	-
Summer 2022	-	-	-	-	-	75
Fall 2022	80	-	-	-	-	-
Spring 2023	-	-	80	-	-	-
*Seeding acreage will depend on recruitment study						

Sec. 6: Cost Estimate and Time Frame for Completion

The Workgroup developed a cost estimate of $29,664,000 (an estimated $14,594,000 for seeding and an estimated $15,070,000 for substrate) to complete the restoration. Costs are subject to change if groundtruthing surveys find more area requires substrate or if groundtruthing surveys find less areas need substrate and/or more areas are premet. These costs are for in-water reef construction and seeding only. Associated costs such as benthic surveys, oyster population surveys, planning, permitting, and monitoring are not reflected.

Sec. 6.1: Oyster Seed Needs and Cost Analysis

The estimated total maximum potential seed for restoration is 3.648 billion SOS at a total projected cost of $14,594,000 (Table 5).

Table 5. Manokin River Sanctuary Seed Requirements and Cost Estimates.

Reef Treatment	Acres to be Treated ***	Initial Seed per Acre	Initial Bushels of Spat-on-Shell per Acre	Total Initial Seed per Treatment (millions)	Seed Cost for Initial Treatment Type (at $4,000 per million seed)	Potentia l Second Seeding per Acre	Potentia l Second Seeding Bushel of Spat-on-Shell per Acre	Potential Seed required for Second Seeding (millions)	Potential Cost of Second Seeding
Seed-Only *	284	5.0 M	800	1,420	$5,680,000	3.5 M	560	994	$3,976,000
Substrate and Seed *	137	5.0 M	800	685	$2,740,000	3.5 M	560	479.5	$1,918,000
Seed-Only-Premet**	20	0 M	0	0	0	3.5 M	560	70	$280,000
Total	**441**			**2,105**	**$8,420,000**			**1,543.5**	**$6,174,000**

*While some of these seed-only sites had initial, pre-restoration density of more than 5 oysters per m^2, it was assumed for planning purposes that all sites showing between 5 and 50 oysters per m^2 had a starting density of 5 oysters per m^2. This assumes a planting of 5 million seed per acre, or 800 bushel of SOS for the initial planting and 3.5 million seed per acre, or 560 bushels of SOS for a second planting. The second seed planting density is for planning purposes, the actual density planted will be based on the year 3 monitoring data.

**Premet Reefs meet density and biomass targets prior to restoration work in the river but the sites may need a second year class seeding if the 3 year monitoring results determine the reef is not faring as projected.

*** Site classifications and associated acreages are subject to change based on a groundtruthing bottom survey.

The tributary plan calls for an initial large planting on most reefs, monitoring three years after restoration, a second-year-class seeding if needed, and monitoring six years after initial restoration (Table 5). If monitoring shows that reefs are faring as projected or lower in terms of oyster density and biomass, they will receive the planned second-year-class seeding. If monitoring shows that reefs are faring better than projected, they will not require the planned second-year-class seeding. This planned two-seeding structure ensures reefs will have a second year class of oysters (an Oyster Metrics success criterion) and allows for potential savings on the second year class seeding if reefs are faring better than projected. The Workgroup made a very conservative assumption that there would be no natural spat set over the course of implementation when calculating initial planting densities, however, Manokin tributary has a strong history of natural recruitment and will likely have natural spat set. For planning purposes, it is estimated that secondary plantings will be at a level of 3.5 million SOS per acre, but actual second plantings will be based on the year-3 monitoring densities. Natural spat set or high mortality rates may make a second seed planting unnecessary or may require a higher level of secondary seeding. Population monitoring will be critical to determining the need for the additional seeding. This will occur, at a minimum, on each reef three and six years post-restoration. See monitoring section 7.1.

Initial Planting:

Using monitoring data from the Harris Creek sanctuary, the Workgroup set assumed survival rates for the first year planted spat-on-shell at 8%. The Workgroup used the projected annual survival of 71% for out-year survival of both planted spat-on-shell and existing oysters (those on the reef prior to restoration), based on a 34-year average observed mortality rate on a bar (Georges) within the Manokin Sanctuary from the DNR Fall Oyster Survey (Tarnowski 2019).

Planted spat-on-shell: First year survival rate = 8%;

Out-year annual survival rate = 71%;

Existing oysters on reef: Annual survival rate = 71%.

SOS planting densities will be based on two variables: number of spat per acre, and amount of shell with spat set on it (bushels) per acre. The initial planting SOS density target is 5 million per acre. Assuming 500-600 shells per bushel, this equates to planting a minimum of 800 bushels of SOS per acre with 10-12.5 spat per shell (see explanation below). Logistical ability to plant at exact spat densities and exact shell densities is limited, so actual planting densities will vary and will be recorded.

The number of spat setting on one shell varies widely on hatchery-produced SOS. As a result, the amount of shell with spat set on it planted on a given restoration site varies tremendously, even assuming a constant planting density. Setting a minimum volume of shells with spat per acre as well as a minimum density of the spat per acre is aimed at standardizing plantings. The Workgroup recognizes that fully standardizing the set rate of larvae is not possible due to the unpredictability of larval behavior. To mitigate for the inevitable cases where very high spat-per-shell set rate occurs, which may increase the chance of crowding mortality (spat mortality due to a high number of spat that set on one shell), additional SOS may be planted if the set rate is too high. This should allow for a more consistent volume of spat to be planted after accounting for crowding mortality.

The shell threshold (800 bushels of shell per acre) is derived from the following:

One million spat per tank was the average HPL set rate in 2015 and 2016. Assuming 500-600 shells per bushel and 160 bushels of shell per Horn Point Laboratory (HPL) setting tank, a set of 1 million spat per tank equates to 10-12.5 spat per shell (1 M spat/tank x 1 tank/160 bu shell x 1 bu/500 shells). A reef requiring 5 million spat per acre, assuming one million spat per tank, would require five HPL tanks. This equates to 160 bushels per tank x 5 tanks, or 800 bushels of SOS per acre. If higher density seed is used (e.g., 1.5 million spat per tank), then additional SOS must be deployed to reach the 800 bushels of shell per acre threshold.

Secondary plantings:

The results of the year-3 monitoring will be used to assess if the sites need the planned second planting of SOS. This planned two-seeding structure ensures reefs will have a second year class of oysters (an Oyster Metrics success criterion) and allows for potential savings on the second year class seeding if reefs are faring better than projected. If monitoring shows that reefs are faring better than projected, they will not require the planned second-year-class seeding. If monitoring shows that reefs are faring as projected or lower in terms of oyster density and biomass, they will receive the planned second-year-class seeding. For planning purposes, it is estimated that secondary plantings will be at a level of 3.5 million per acre, but actual second plantings will be based on the year-3 monitoring densities.

Sec. 6.2: Substrate Needs and Cost Analysis

A projected 220,981 cubic yards of substrate are needed to implement the tributary plan. This projection assumes that substrate reefs in the Manokin River Sanctuary will be built at height of 12 inches, however, some reefs may be built at 6 inches to address areas of navigational concern. Constructing 12-inch-high reefs requires 1,613 cubic yards of substrate per acre.

The total projected cost for building reefs with substrate is $15,070,000 (Table 6). This includes pre construction sonar, substrate deployment, and post construction sonar where substrate is placed to ensure that there are no high spots during construction that would affect safe navigation. These sonar surveys are discrete from the sonar surveys that MGS and NOAA perform prior to and after restoration and are intended only to ensure proper substrate height on the constructed reefs.

Dredged shell had been used as a substrate in Maryland waters of the Chesapeake Bay for many decades, up until 2006; however, dredged shell is currently unavailable. Fresh shell is used as substrate for setting larvae; however, it is also a limited resource and is not available in the quantities necessary for building reefs. Substrate for the Manokin sanctuary may be any combination of oyster shell or alternative substrates such as clam shell, construction rubble, or rock. Clam shell or mixed shell (conch, clam, and whelk) is a by-product of Atlantic coastal fisheries. Fossilized shell (from Florida) is oyster shell cemented into a fossilized limestone. Amphibolite, non-calcium stone, is generated from local quarries. All of these materials have been used in prior restoration efforts in the Harris Creek, Little Choptank, and Tred Avon sanctuaries. Fossilized shell from Florida was used in the Harris Creek sanctuary and the Little Choptank sanctuary, however it will not be used as substrate for the Manokin restoration.

Table 6. Manokin River Sanctuary Estimated Substrate and Cost.

Reef Treatment	Acres to be Treated ***	Substrate Required per Acre (cubic yards)*	Substrate Cost ($110k per acre)
Seed-Only	284	0	0
Substrate and Seed	137	1,613	$15,070,000
Premet**	20	0	0
Total Target Restoration	**441**	**1,613**	**$15,070,000**

* Assumes a 12-inch reef height. Reefs heights may vary from 6 inches to 12 inches.

**Premet Reefs meet density and biomass targets prior to restoration work in the river.

*** Site classifications and associated acreages are subject to change based on a groundtruthing bottom survey.

Sec 7: Monitoring

Sec. 7.1: Monitoring for Oyster Metrics Criteria:

The main objective of monitoring efforts in the Manokin River Sanctuary is to determine if restored reefs can be considered successful per the Oyster Metrics standards. Table 7 outlines the proposed restoration and monitoring timeline. This timeline is dependent on funding and the issuance of a tidal wetlands permit for the placement of substrate for the reef base from the MDE and USACE. According to the Oyster Metrics report, several biological parameters (oyster density, oyster biomass, and presence of multiple year classes), and structural parameters (reef height, reef areal extent, shell budget), should be monitored to determine reef-level success. For each parameter, the Oyster Metrics report recommends the assessment protocols and monitoring intervals described in Table 8.

In keeping with the Oyster Metrics report, and assuming funding can be secured, these parameters will be monitored on Manokin River Sanctuary oyster reefs. Projected costs for reef monitoring are in Table 9. Results will be used to determine reef success and to implement adaptive management actions as necessary.

Table 7. Estimated timeline for reef seeding and monitoring.

Reef Treatment	Estimated first seeding*	Estimated 1st monitoring (3 year)	Estimated second year class seeding*	Estimated 2nd monitoring (6 year)
Seed-Only	2020-2023	2023-2026	2024-2027	2026-2029
Substrate and Seed	2021-2022	2024-2025	2025-2026	2027-2028
Premet**	N/A	2023-2026	2024-2027	2026-2029

*As reef construction and hatchery production allows.

**Premet Reefs meet density and biomass targets prior to restoration work in the river but the sites may need a second year class seeding if the 3 year monitoring results determine the reef is not faring as projected.

Table 8. Reef-level success criteria for oyster restoration projects (adapted from the Oyster Metrics report).

Goal	Success Metric	Assessment Protocol	Frequency
Significantly enhanced live oyster density and biomass	Target: An oyster population with a minimum mean density of 50 oysters and 50 grams dry wt/m^2 covering at least 30% of the target restoration area at 3 years post restoration activity. Evaluation at 6 years and beyond should be used to judge ongoing success and guide adaptive management. Minimum threshold: An oyster population with a mean density of 15 oysters and 15 grams dry wt biomass/m^2 covering at least 30% of the target restoration area at 3 years post restoration activity. Minimum threshold is defined as the lowest levels that indicate some degree of success and justify continued restoration efforts.	Patent tong or diver grabs	Minimum 3 and 6 years post restoration
Presence of multiple year classes of live oysters	Minimum of 2 year classes at 6 yrs post restoration.	Patent tong or diver grabs	Minimum 3 and 6 years post restoration
Positive shell budget	Neutral or positive shell budget.	Quantitative volume estimates shell (live and dead) per unit area	Minimum 3 and 6 years post restoration
Stable or increasing spatial extent and reef height	Neutral or positive change in reef spatial extent and reef height as compared to baseline measurements.	Multi-beam sonar, direct measurement, aerial photography	Within 6 -12 months post-restoration, and 3 and 6 years post restoration

Table 9. Estimated costs for reef monitoring.

Reef Treatment	Acreage ****	Assessment Protocol	Estimated cost for 1st monitoring	Estimated cost for 2nd monitoring	Total Estimated Cost
Seed-Only	284	Patent tong**	$397,600	$397,600	$795,200
Substrate – rock*	137	Diver*	$328,800	$328,800	$657,600
Premet***	20	Patent tong**	$28,000	$28,000	$56,000

*Diver survey costs estimated to be $2,400 per acre. **Patent tong survey costs estimated to be $1,400 per acre. ***Premet Reefs meet density and biomass targets prior to restoration work in the river; however, based on year 3 monitoring results these sites may need supplemental seeding. **** Site classifications and associated acreages are subject to change based on a groundtruthing bottom survey.

Sec. 8: Management

The Manokin River Oyster Restoration Tributary Plan is meant to be an adaptive, living document. The expectation is that the plan will be adapted to reflect changing conditions and new information. As the document is adapted, newer versions will be posted to ensure transparency. Continued dialogue with the consulting scientists, interested stakeholders, and the public is critical to this adaptive process. Comments on this document are encouraged at any time, and can be directed to Stephanie Westby, Stephanie.westby@noaa.gov.

The Workgroup will produce annual updates describing progress that has been made on restoring the oyster population in Manokin River Sanctuary.

References

Chesapeake Bay Program. 2015. Oyster Restoration Outcome Management Strategy 2015-2025, v. 2. https:// www.chesapeakebay.net/documents/22030/2020-2021_oyster_management_strategy.pdf

Chesapeake Executive Council. 2014. The Chesapeake Bay Watershed Agreement. https:// www.chesapeakebay.net/documents/FINAL_Ches_Bay_Watershed_Agreement.withsignatures-Hlres.pdf

Federal Leadership Committee for the Chesapeake Bay. May 2010. Executive Order 13508: Strategy for Protecting and Restoring the Chesapeake Bay Watershed.

Lazar, Jay. 2017. Adaptive Management: Oyster Restoration Framework Update. Chesapeake Bay Program Sustainable Fisheries GIT Meeting December 18, 2017. chesapeakebay.net/channel_files/25674/6_adaptive_management-oyster_restoration_framework_update_12-18-2017.pdf

Maryland Department of Natural Resources. 2016. Oyster Management Review 2010-2015. dnr.maryland.gov/fisheries/Documents/FiveYearOysterReport.pdf

Obama, Barack. May 12, 2009. “Chesapeake Bay Protection and Restoration.” Executive Order 13508.

Oyster Metrics Workgroup. 2011. Restoration Goals, Quantitative Metrics and Assessment Protocols for Evaluating Success on Restored Oyster Reef Sanctuaries. Report to the Sustainable Fisheries GIT of the Chesapeake Bay Program.

Tarnowski, Mitchell. 2019. Maryland Oyster Population Status Report 2018 Fall Survey. Maryland Department of Natural Resources Publ. No. 17-070819-154. Annapolis, MD. https://dnr.maryland.gov/fisheries/Documents/18ReptFinal.pdf

U.S. Army Corps of Engineers, Baltimore and Norfolk Districts. Chesapeake Bay Oyster Recovery: Native Oyster Restoration Master Plan, Maryland and Virginia, September 2012.

Volstad, J. H., J. Dew, and M. Tarnowski. 2008. Estimation of Annual Mortality Rates for Eastern Oysters (*Crassostrea virginica*) in Chesapeake Bay Based on Box Counts and Application of Those Rates to Projected Population Growth of *C. virginica* and *C. ariakensis*, Journal of Shellfish Research, 27(3):525-533.

Appendix A

DRAFT-Manokin River Restorable Bottom Assessment 02/20/2020

Background

This document identifies the potential area suitable for oyster restoration in the Manokin River Oyster Sanctuary based on existing spatial data. GIS layers were geo-processed using decision thresholds similar to those used for the other MD restoration projects. The final products in this draft are

1. inventory of available restoration-relevant spatial data,
2. an estimate of "evidence based" restoration target of Currently Restorable Oyster Habitat (CROH) based on sidescan sonar and patent tong survey data,
3. an estimate of Historic Oyster Habitat (HOH),
4. an estimate of the area that currently meets the restoration success density target (50 live oysters/m^2), and
5. identification of the area and general locations suitable for a) constructing substrate reefs (Substrate and Seed Restoration) and b) restoring existing shell bottom with hatchery SOS (Seed-Only Restoration). Not addressed in this document is the creation of a blueprint that identifies exact boundaries of restoration sites.

Summary 1: Targets and Restorable Bottom Estimates

Currently Restorable Oyster Habitat (CROH) (min. depth = 4.0 ft. MLLW)	**585.7 acres***
50% of CROH	**292.8 acres**
Historical Oyster Habitat (HOH)	**5015.1**
16% HOH	**802.4**
8% HOH	**401.2**
Estimated area meeting the restoration success density target (50 live oysters/m^2, min. depth = 4.0 ft. MLLW)[1]	**20.1 acres**
Estimated bottom suitable for Substrate and Seed restoration (7-20ft depth)	**332.9 acres[1]**
Estimated bottom suitable for Seed-Only restoration (4-20ft depth)	**283.8 acres[1]**
Sum area: Substrate and Seed + Seed-Only	**616.7 acres[2]**

Table above: The restoration target will fall between 50 and 100% of CROH or between 8 and 16% of HOH.

V1

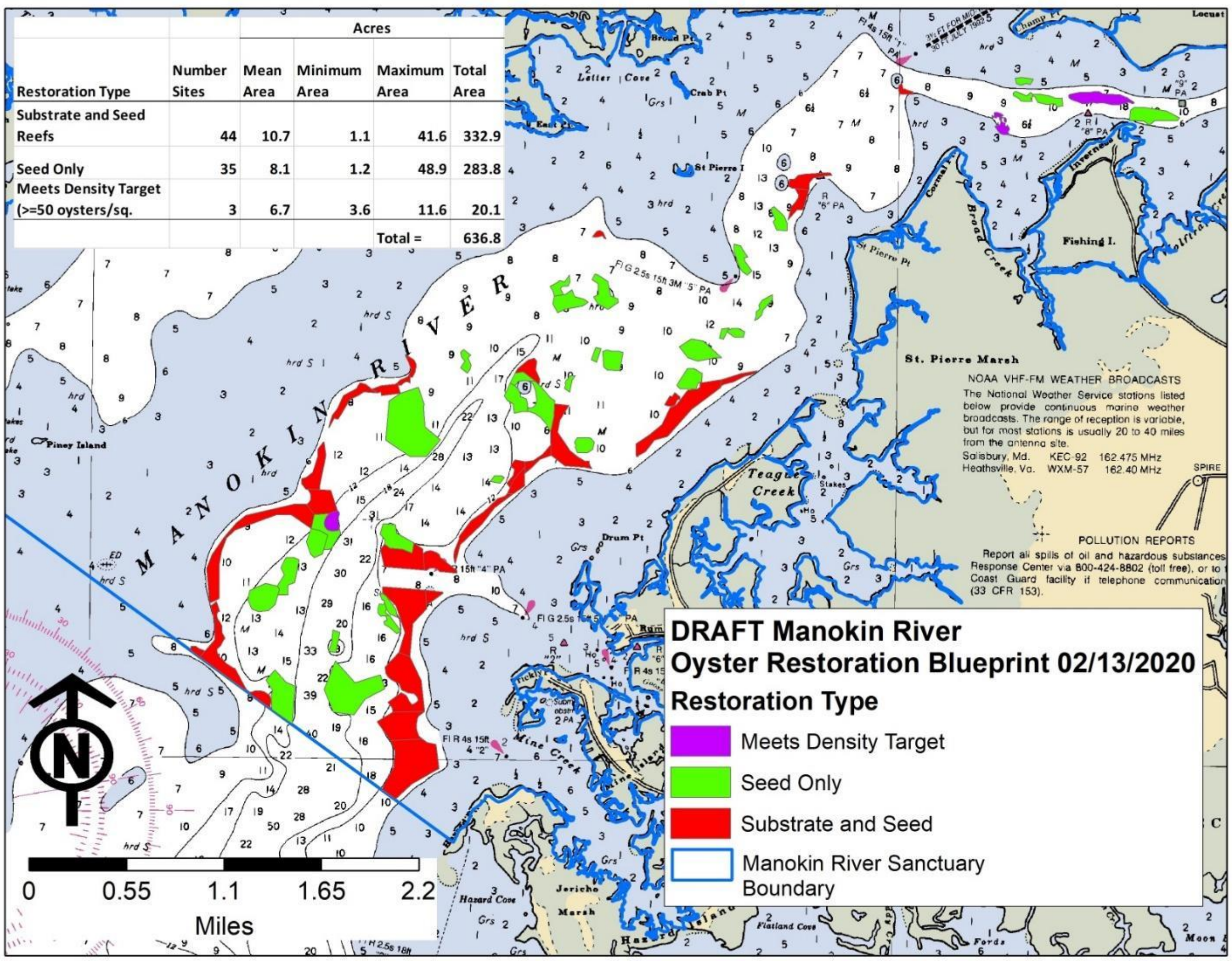
*NOTE: in a previous document (5/10/2019) the CROH value was 592 acres and erroneously did not account for removing areas with depths less than 4 feet.

[1]**NOTE:** These updated area values reflect changes made by:

- **a)** Removal of proposed sites in Northwest basin of sanctuary
- **b)** Modifications of site boundaries based on recent groundtruth and bathymetry surveys
- **c)** Removal of sites that intersect with new aquaculture leases
- **d)** Modifications to minimize navigation hazards at entrance to the Rumbley harbor channel

[2]**NOTE:** this value indicates there is ample area available for restoration (616.7 > 585.7 acre CROH).

Summary 2: Draft Restoration Blueprint 02/13/2020



Restoration Type	Number Sites	Acres: Mean Area	Acres: Minimum Area	Acres: Maximum Area	Acres: Total Area
Substrate and Seed Reefs	44	10.7	1.1	41.6	332.9
Seed Only	35	8.1	1.2	48.9	283.8
Meets Density Target (>=50 oysters/sq.	3	6.7	3.6	11.6	20.1
				Total =	636.8

Figure above shows the current (02/13/2020) draft of the oyster restoration blueprint. The blueprint identifies the area and location of Substrate-and-Seed and Seed-Only restoration sites. Details on geoprocessing steps used to determine these areas are on the following pages.

Spatial Data Inventory and Summary

Category	Number of features	Acres
Sanctuary Boundary	1	16,310.3
MDE Conditionally Approved Harvest Area	1	13,390.2
MDE Restricted Harvest Area	3	2,679.1
Benthic Habitat Characterization Footprint	268	5,819.9
NOBs in Sanctuary	6	4,447.5
Yates Bars in Sanctuary (original & additions)	6	11,028.9
Lease Applications in Sanctuary	8	163.4
Pound Nets in Sanctuary 250 ft. Buffer	7	113.4
Depth 4-7 ft.	6	3,371.8
Depth 7-20 ft.	3	3,631.8
Depth greater than 20 ft.	1	222.9
SAV Footprint 2007-2016	87	1,887.9
Marinas 250 ft. Buffer	2	9.0
Docks 2016 250 ft. Buffer	123	554.4
Maintained Navigation Channels in Sanctuary 150 ft. Buffer	3	108.1
ATONs in Sanctuary 250 ft. Buffer	14	63.1
MD Grows Oysters (MGO) Sites	0	0
MD DNR Fall Oyster Dredge Survey Sites 2018 750 ft. Buffer	2	81.1
MD DNR Patent Tong Survey 2012 Samples	161	N/A
MD DNR Patent Tong Survey 2015 Samples	147	N/A
MD DNR Patent Tong Survey 2017 Samples	163	N/A
MD DNR Patent Tong Survey 2018 Samples	140	N/A
CBP Water Quality Sampling Sites in Sanctuary	2	N/A
MDE Water Quality Sampling Sites in Sanctuary	9	N/A

Table above summarizes the different spatial datasets used in this assessment.

<u>Sanctuary Map</u>

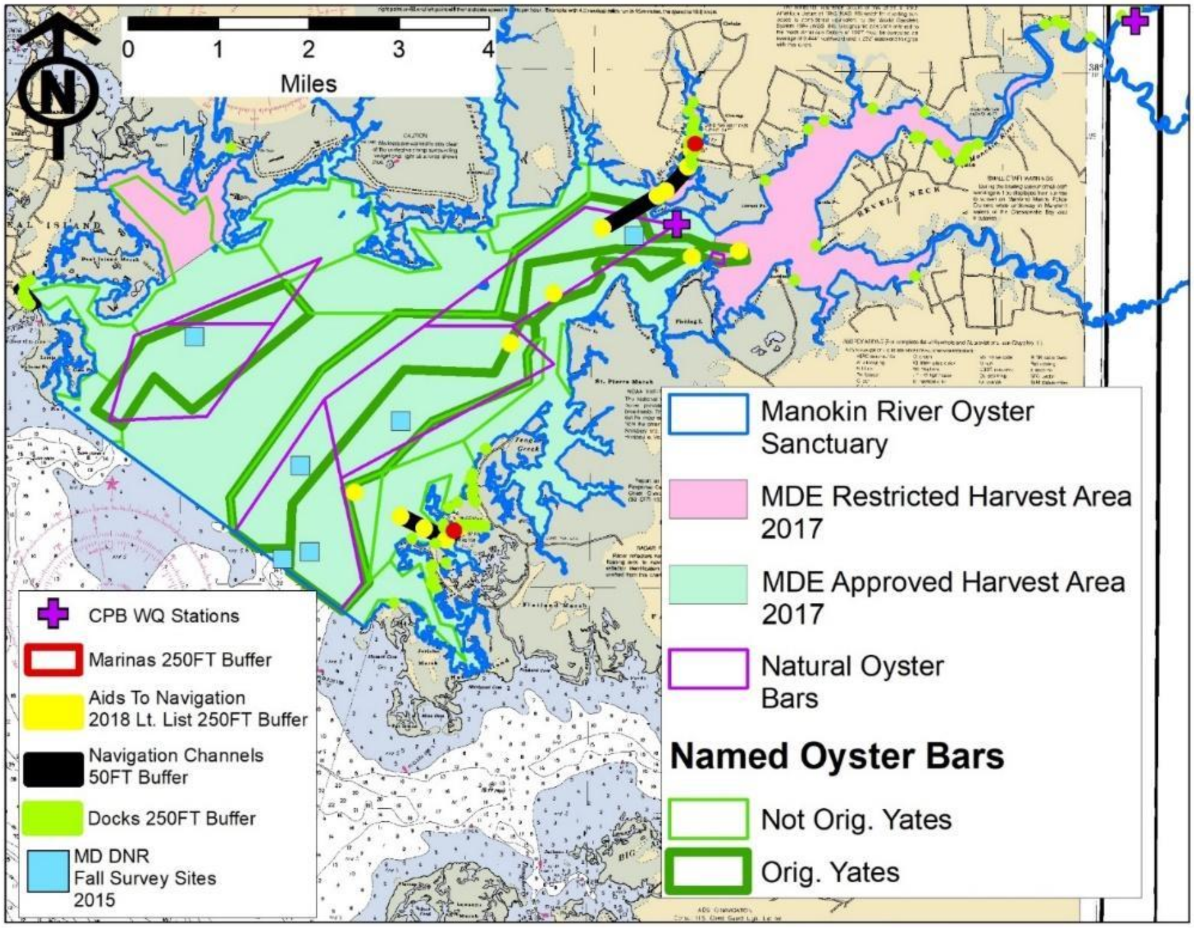


Figure above shows examples of selected spatial data within the Manokin River Oyster Sanctuary. Note: Cow Pen was originally part of Marshy Island Original Yates Bar.

Leases and Pound Nets

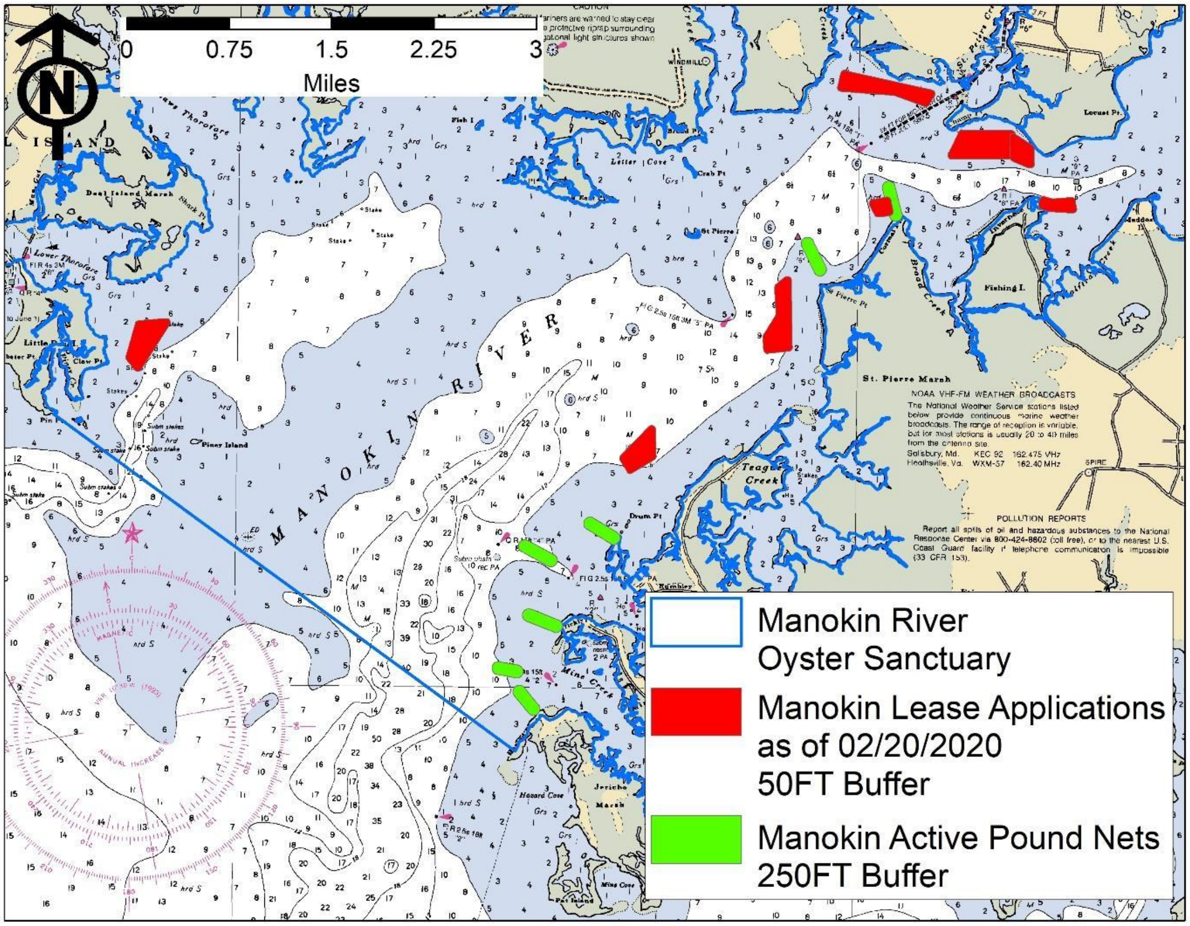


Figure above identifies the location of current aquaculture lease application sites and registered pond net locations. These data were used to restrict the area suitable for oyster restoration.

Interpolated Salinity and DO

USACE Master Plan Criteria

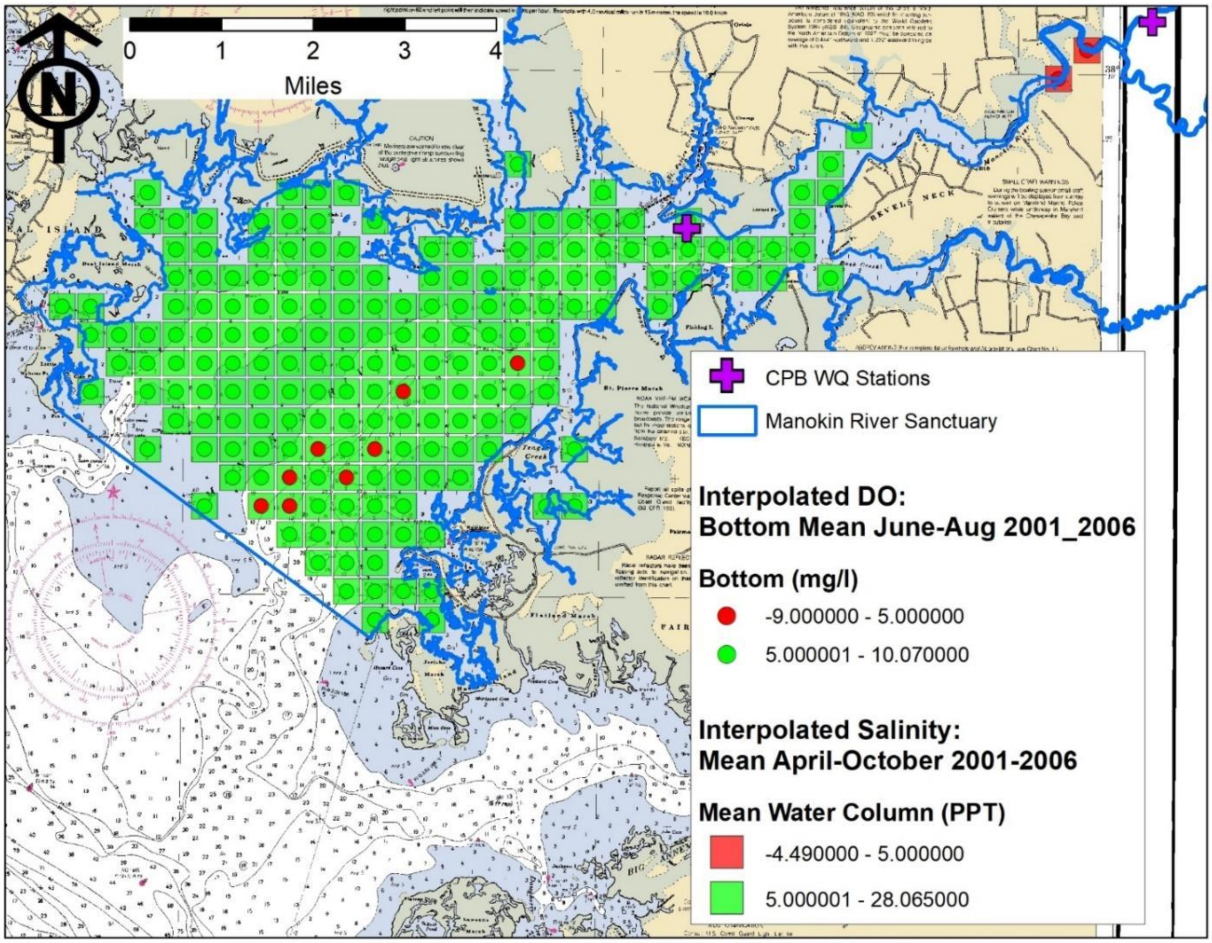
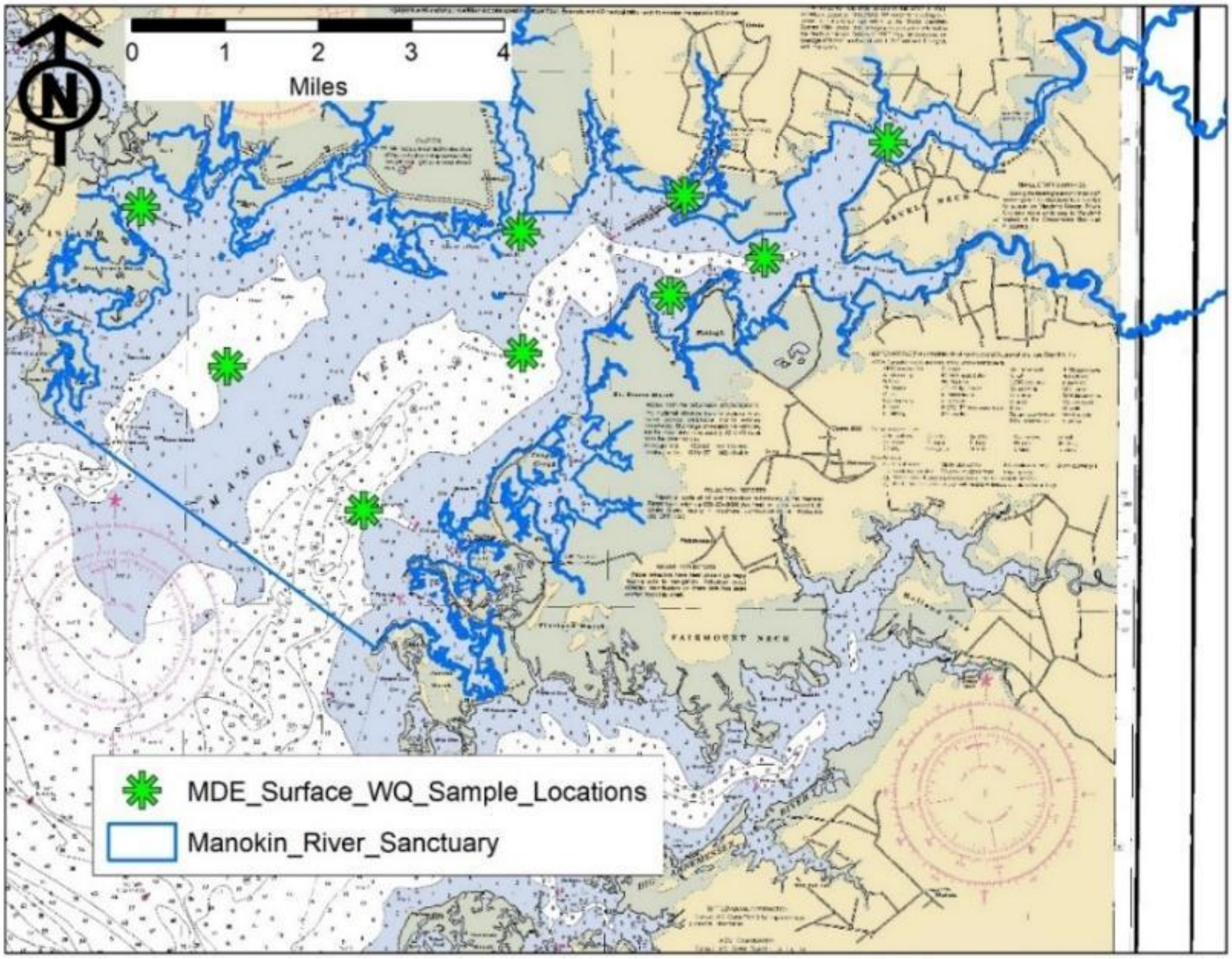


Figure above shows interpolated water quality data based on field samples collected at the CBP monitoring sites 2001-2006 and were derived with the Chesapeake Bay Interpolator.

The U.S. Army Corps Engineers Oyster Restoration Master Plan identifies tributary restorability absolute criteria for salinity as a mean of 5.0 ppt for bottom and surface for the interval of April to October 2001-2006. The absolute criteria for DO is a mean bottom value of 5.0 mg/l for the interval June-August 2001-2006.

Data presented here suggest that salinity levels are adequate relative to Master Plan (green squares) and that DO levels may be critical (red circles) in the deeper areas of the central river channel.

Recent Observed MDE Surface Salinity and DO



Station	Year	Months	Rainfall Year	Parameter	Mean	Std. Dev.	Q1	Median	Q3
All	2009	April-October	Dry	Salinity	15.69	1.19	15.30	15.80	16.20
All	2010	April-October	Wet	Salinity	15.17	2.24	13.00	15.90	17.00
All	2011	April-October	Wet	Salinity	12.97	1.06	12.35	12.80	13.20
All	2012	April-October	Average	Salinity	14.97	1.83	13.30	15.25	16.45
All	2013	April-October	Average	Salinity	14.98	1.44	14.10	15.20	16.20
All	2014	April-October	Average	Salinity	14.35	1.67	13.50	13.80	14.80
All	2015	April-October	Dry	Salinity	15.42	0.90	15.20	15.60	15.90
All	2016	April-October	Average	Salinity	15.53	2.20	14.15	15.20	17.15
All	2017	April-October	?	Salinity	15.45	1.74	14.40	15.40	16.30
All	2018	April-October	Wet	Salinity	15.28	2.58	12.65	15.10	18.05
	All				14.97	1.93	13.5	15.1	16.30

Station	Year	Months	Rainfall Year	Parameter	Mean	Std. Dev.	Q1	Median	Q3
All	2009	May-September	Dry	DO	6.99	0.80	6.50	6.85	7.60
All	2010	May-September	Wet	DO	7.11	0.50	6.70	7.00	7.60
All	2011	May-September	Wet	DO	6.71	0.99	5.60	6.95	7.30
All	2012	May-September	Average	DO	6.43	1.14	5.55	6.60	7.50
All	2013	May-September	Average	DO	7.69	0.59	7.30	7.60	8.20
All	2014	May-September	Average	DO	7.15	0.92	6.50	7.05	8.00
All	2015	May-September	Dry	DO	6.83	1.48	5.60	6.50	8.30
All	2016	May-September	Average	DO	6.98	0.49	6.60	7.10	7.40
All	2017	May-September	?	DO	8.01	0.61	7.45	7.95	8.50
All	2018	May-September	Wet	DO	6.94	0.49	6.55	7.00	7.30
	All				7.10	0.89	6.60	7.20	7.60

Table above summarizes surface water quality samples collected by MDE 2009-2018.

Manokin Depth Model

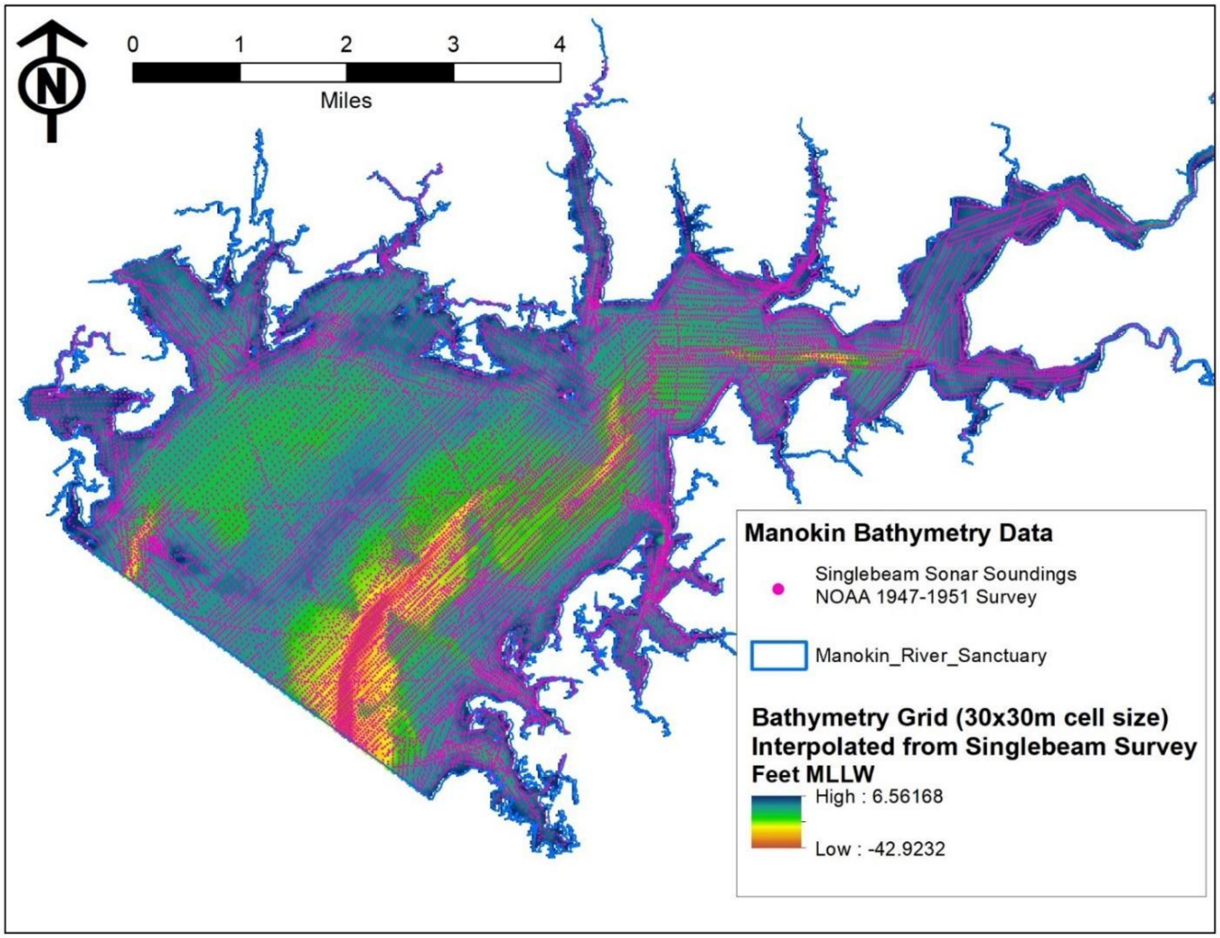
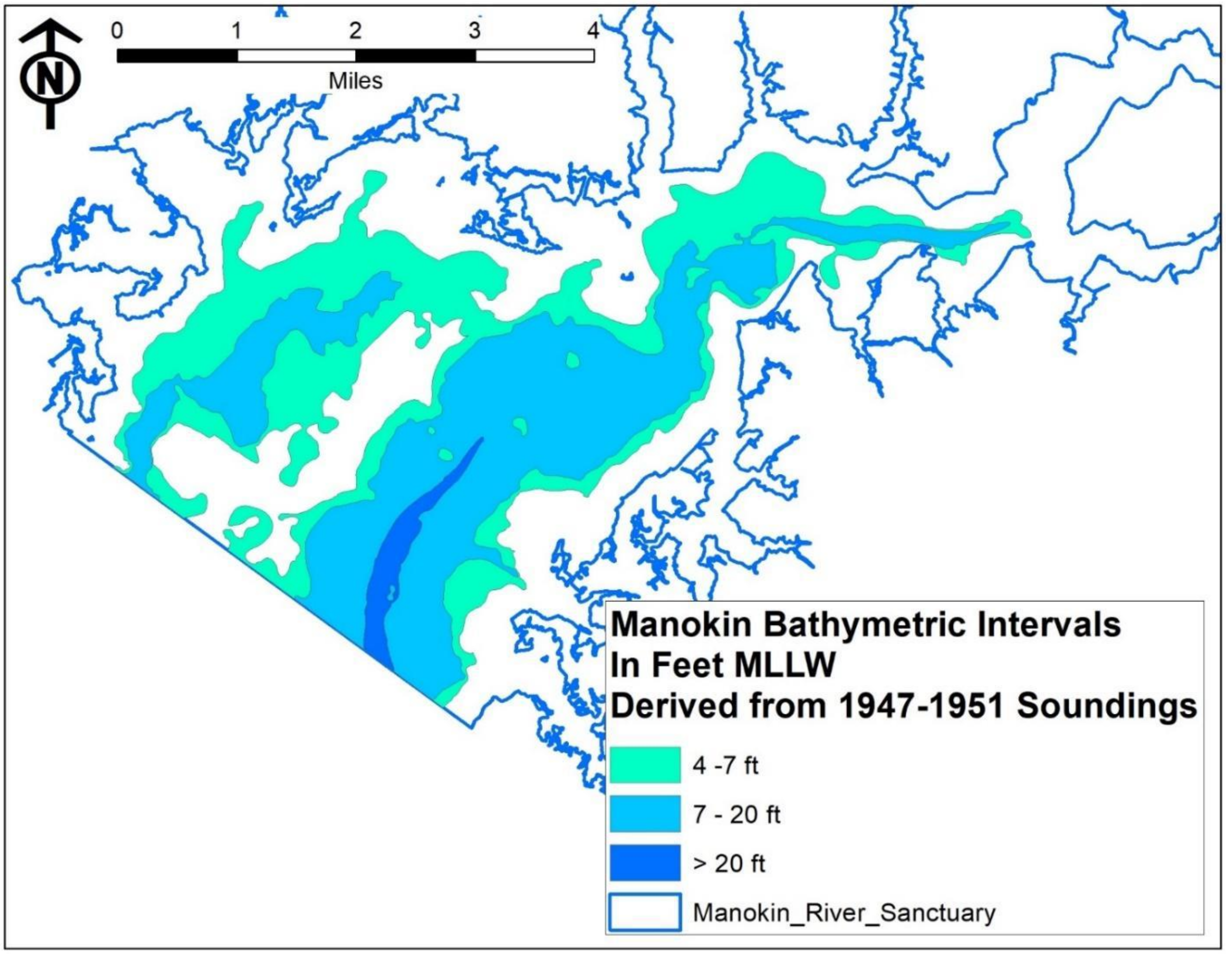


Figure above shows various bathymetry datasets available for restoration planning.

Planning of restoration projects in Harris Creek, Little Choptank, and Tred Avon used the Baywide Bathymetry Grid developed by the CBP. The CBP grid was derived from 1947-1951 survey soundings. For unknown reasons the ArcGIS Contour Tool was unable to correctly geolocate depth contours from the CBP bathymetry grid.

To remedy this problem, the CBP grid cells were classified into three intervals of 4-7 ft., 7-20 ft. and >20 ft. (MLLW). Polygons were hand digitized and then smoothed from the three intervals to define restoration depth limits (see next page).

<u>Restoration Depth Limits</u>



Above figure shows depth interval boundaries developed for Manokin Sanctuary from the CBP bathymetry grid.

Depth limits for each restoration method are:

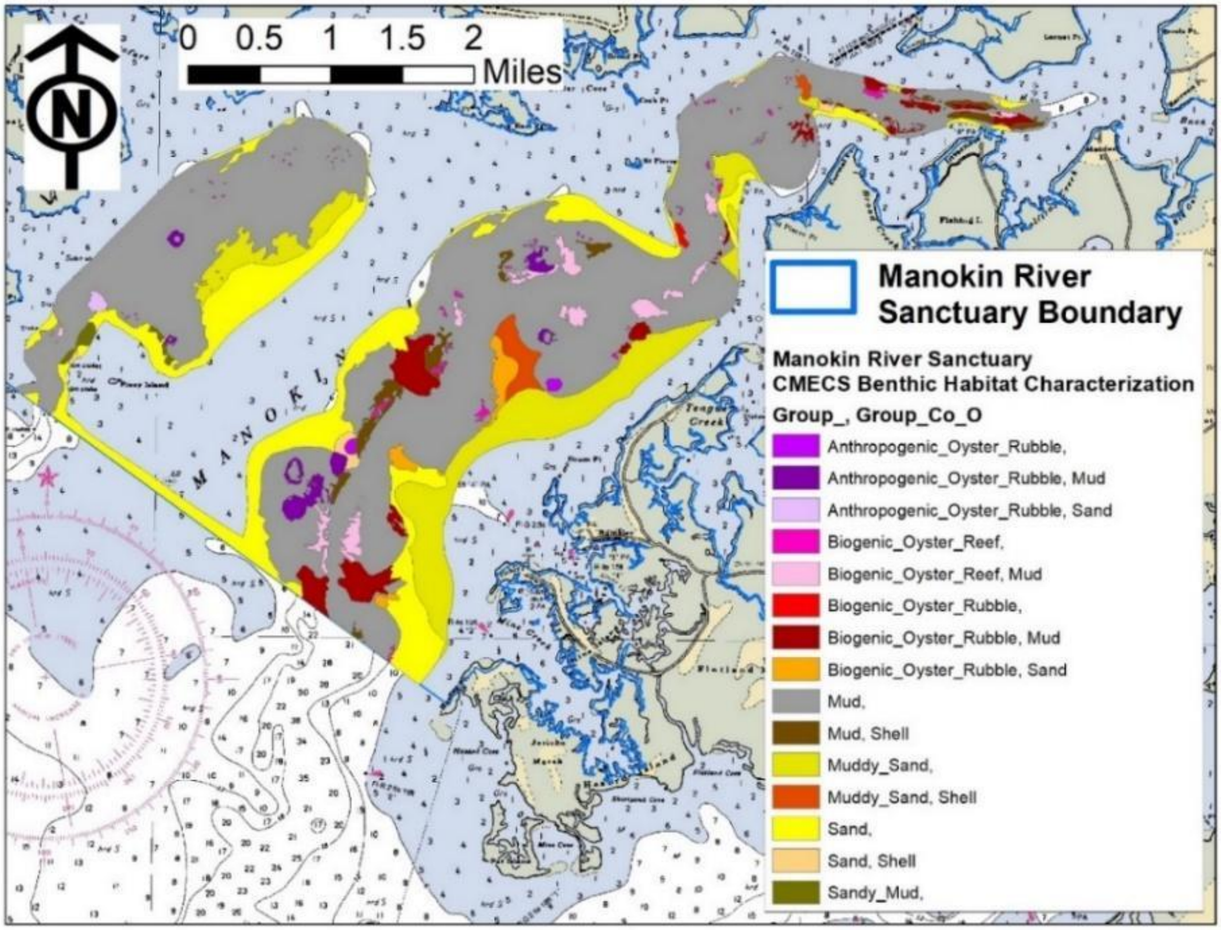
Seed-Only: 4-20 ft.

Constructed Substrate Reefs: 7-20 ft.

The USACE Master Plan absolute criteria for maximum depth is 20 feet MLLW.

As for restoration projects in Harris Creek, Little Choptank, Tred Avon and the St. Mary's rivers, draft substrate reef boundaries will be surveyed with multibeam sonar by the NOAA Chesapeake Bay Office to validate the site depths with more recent survey data.

<u>Bottom Type</u>

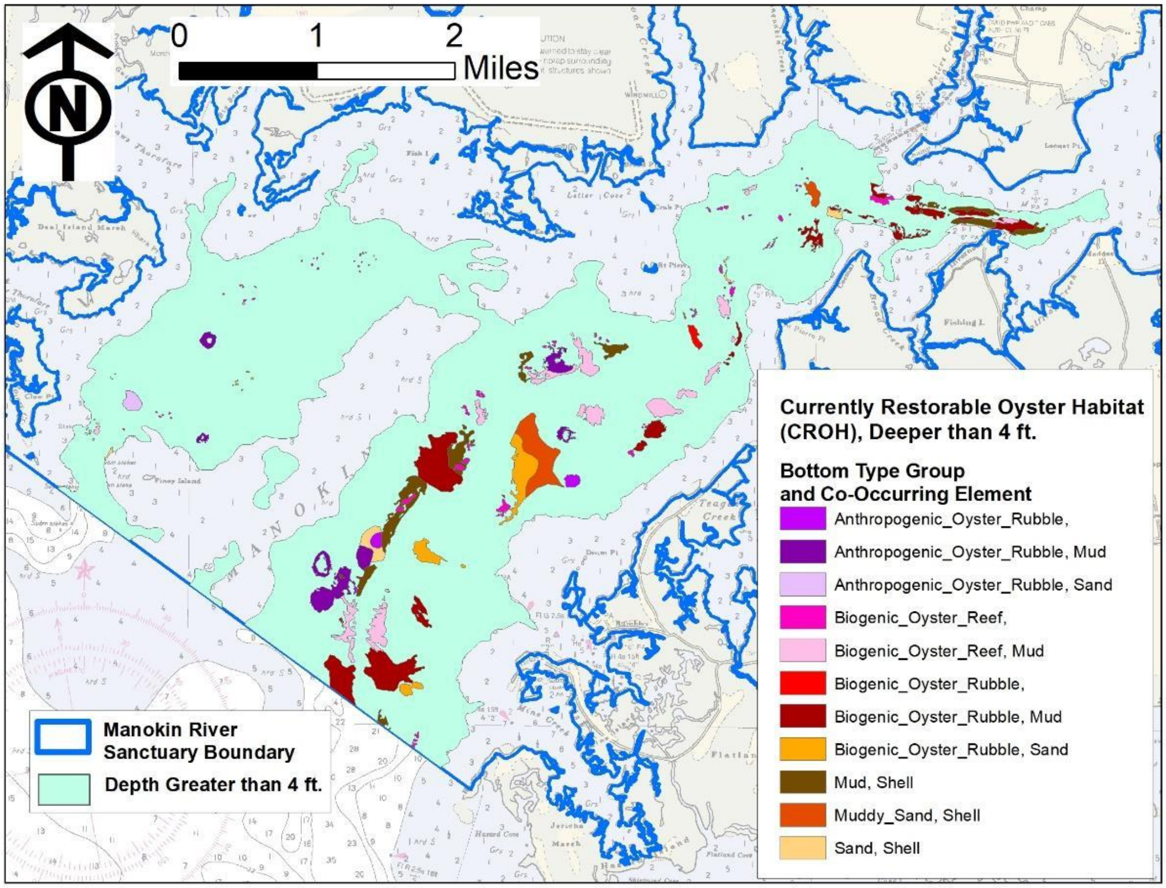


Area Summary: Existing Benthic Habitat Based on Survey Data					
Location	Bottom Type Group	Group Co-Occurring Element	Number of Polygons	Area (Acres)	Percent Area
Manokin	Biogenic_Oyster_Rubble		3	6.0	0.1
Manokin	Anthropogenic_Oyster_Rubble	Sand	1	9.3	0.2
Manokin	Anthropogenic_Oyster_Rubble		5	11.4	0.2
Manokin	Sandy_Mud		3	19.1	0.3
Manokin	Sand	Shell	6	22.0	0.4
Manokin	Biogenic_Oyster_Reef		77	30.1	0.5
Manokin	Biogenic_Oyster_Rubble	Sand	11	58.0	1.0
Manokin	Muddy_Sand	Shell	2	62.0	1.1
Manokin	Anthropogenic_Oyster_Rubble	Mud	7	69.2	1.2
Manokin	Mud	Shell	22	96.3	1.7
Manokin	Biogenic_Oyster_Reef	Mud	33	112.4	1.9
Manokin	Biogenic_Oyster_Rubble	Mud	40	211.6	3.6
Manokin	Muddy_Sand		7	631.8	10.9
Manokin	Sand		14	918.0	15.8
Manokin	Mud		22	3562.7	61.2
		Sum=	253	5819.9	100.0

Figure and table above show the results of seabed habitat characterization based on MGS acoustic mapping products that were groundtruthed with DNR patent tong samples. These data were used to set restoration target areas, identify where restoration may occur, and identify locations where oyster densities are sufficient enough that restoration is not warranted. Seabed habitat was classified with the Coastal and Marine Ecological Classification Standard (CMECS).

Restoration Target Estimation

Method 1: Currently Restorable Oyster Habitat (CROH) based on distribution of shell bottom from recent survey data with a minimum depth of 4 ft. MLLW. Actual restoration would range from 50-100% of CROH.



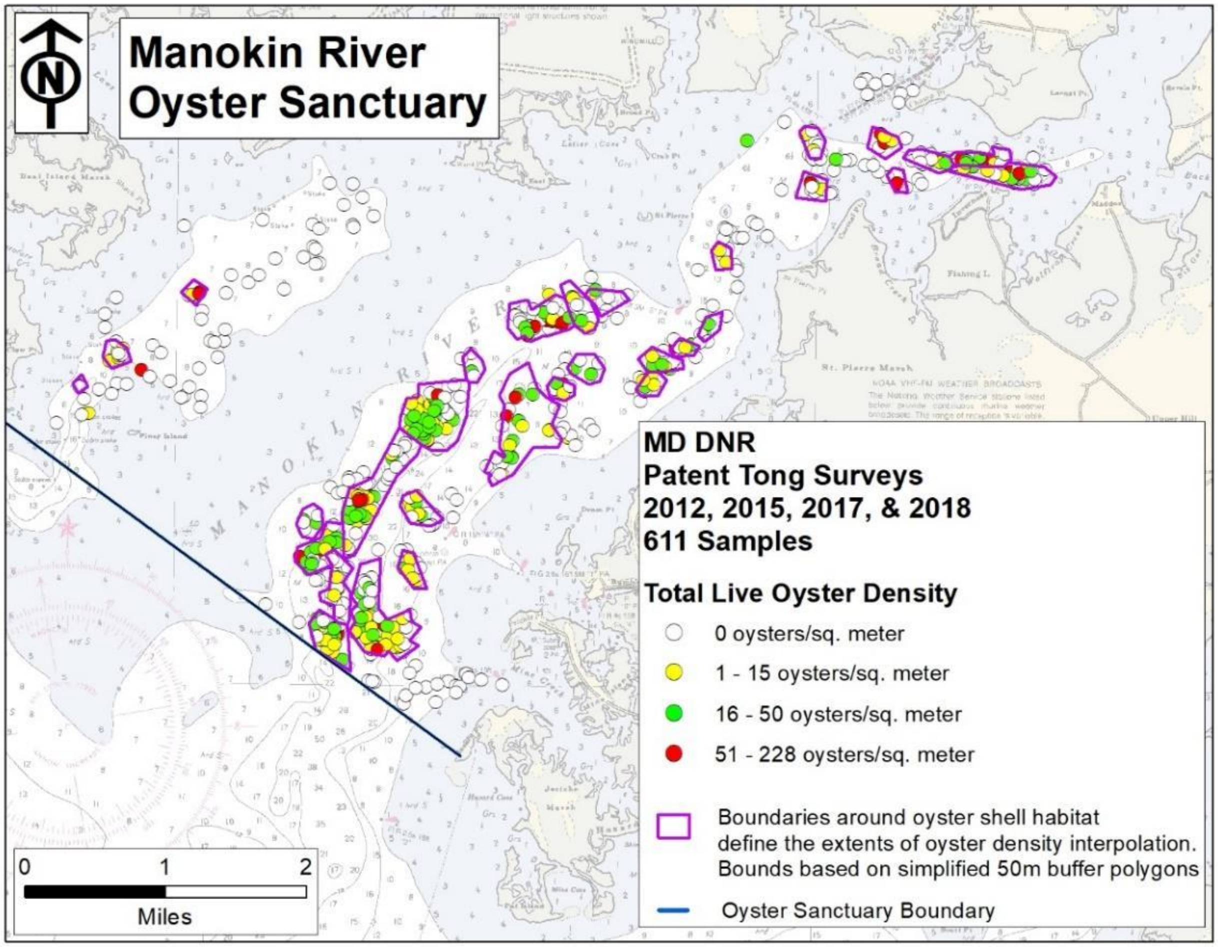
Area Summary: Setting the Evidence Based Restoration Target of Currently			
Location	Bottom Type Group	Co-Occurring	Area (acres)
Manokin	Biogenic_Oyster_Rubble	null	6.0
Manokin	Anthropogenic_Oyster_Rubble	Sand	9.3
Manokin	Anthropogenic_Oyster_Rubble	null	11.4
Manokin	Sand	Shell	19.8
Manokin	Biogenic_Oyster_Reef	null	30.0
Manokin	Biogenic_Oyster_Rubble	Sand	58.0
Manokin	Muddy_Sand	Shell	62.0
Manokin	Anthropogenic_Oyster_Rubble	Mud	69.2
Manokin	Biogenic_Oyster_Reef	Mud	112.4
Manokin	Biogenic_Oyster_Rubble	Mud	207.6
	Sum: 100% of CROH		585.7
	50% CROH		292.9

Restoration Target Estimation Continued

Method 2: Historic Oyster Habitat (HOH) based on Yates survey of 1911. Consistent with the US Army Corps of Engineers (USACE) Native Oyster Restoration Master Plan, the actual restoration target would range from 8-16% of HOH. Note: Cow Pen was originally part of Marshy Island, an original Yates bar.

REGION	BARNAME	YATESBARS	ACRES
MANOKIN RIVER	CORMAL	Orig. Yates	358.7
MANOKIN RIVER	COW PEN	Not Orig. Yates	31.3
MANOKIN RIVER	DRUM POINT	Orig. Yates	1403.4
MANOKIN RIVER	GEORGES	Orig. Yates	576.4
MANOKIN RIVER	MARSHY ISLAND	Orig. Yates	1650.5
MANOKIN RIVER	PINEY ISLAND SWASH	Orig. Yates	945.2
MANOKIN RIVER	SANDY POINT	Orig. Yates	49.6
		Sum Acres (HOH)=	5015.1
		16% HOH =	802.4
		8% HOH=	401.2

Live Oyster Density from 2012, 2015, 2017, & 2018 Patent Tong Surveys



Above figure shows the location of oyster abundance samples and total live density within each sample for recent patent tong surveys. Oyster densities of 15-50 /m^2 meet the established restoration success threshold, and densities greater than 50 meet the success target. Oyster shell habitat patches that have 30% or greater area meeting the target density do not need to be restored.

V1

Sanctuary	Year	Mean Density (no./sq. m)	St. Error	Min	Max.	n	Pct. Spat	Pct. Small	Pct. Market	Sum Oysters
Manokin	2012	16.91	2.37	0	156	161	0.7	90.35	8.95	2723
Manokin	2015	14.86	2.84	0	228	147	7.92	50.8	41.28	2185
Manokin	2017	5.62	1.46	0	133	163	38.65	48.25	13.1	916
Manokin	2018	14.42	1.94	0	179	140	12.28	65.03	22.68	2019
Sum =						611				7843

Table above indicates that aside from 2017, mean oyster density is reasonably similar for all survey years. Based on this information annual survey data were pooled to determine how much shell bottom area meets the restoration success target. In all survey years, small oysters (40-75mm) were the dominant size group.

Baseline Oyster Density

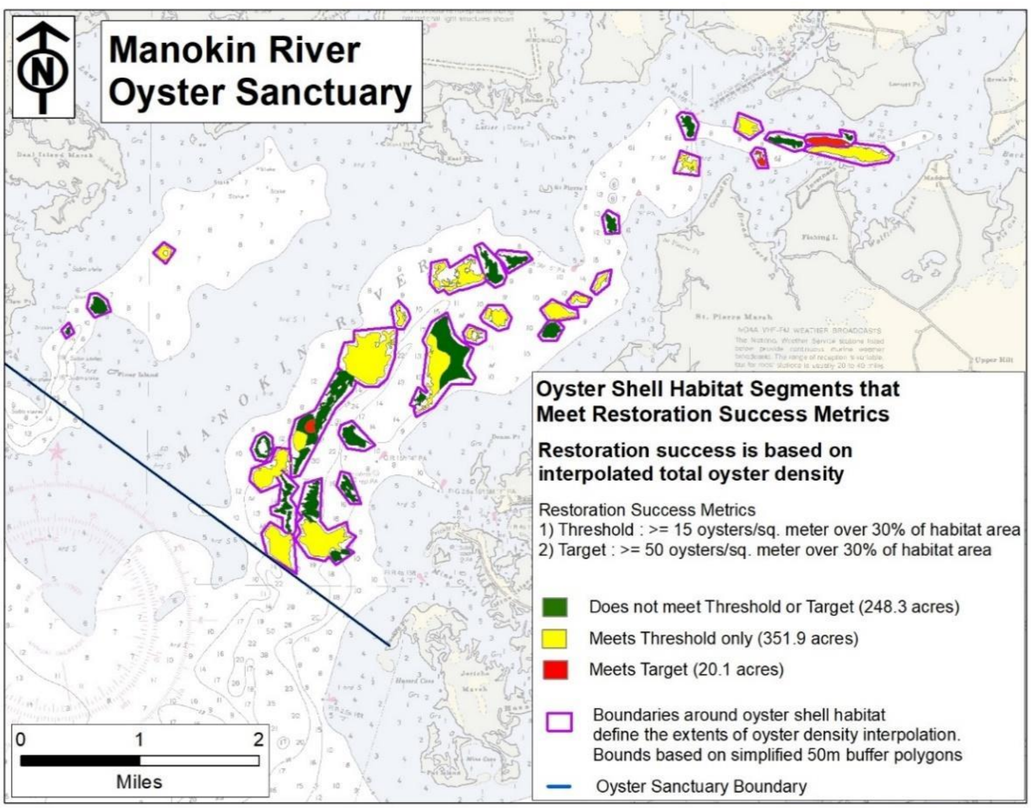


Figure above identifies the estimated area of oyster shell bottom that meets the restoration success metrics. Total oyster density values from patent tong samples falling within each of the purple boundaries were interpolated. Interpolated density data were extracted with the boundaries of the oyster shell habitat patches (green, yellow, and red polygons). Shell habitat patches that had 30% or greater interpolated grid cells (area) with densities greater or equal 50/m^2 were considered to meet the restoration success target and do not need to be restored.

Summary of Oyster Density Relative to Restoration Success Metrics									
		Total Patent Tong Samples			Patent Tong Samples Used in Interpolation			Interpolation Results: Shell Bottom Where 30% of Area Meets Metric	
Success Metric	Density Value (no/ sq. meter)	Number	Percent		Number	Percent		Acres	Percent
None	<15	422	69.1		259	58.3		248.3	40.0
Threshold	>=15	148	24.2		145	32.7		351.9	56.7
Target	>= 50	41	6.7		40	9.0		20.1	3.2
		611			444			620.3	

Table above summarizes the number of samples and interpolated areas meeting the restoration success metrics.

V1

Constructed Substrate Reefs with Hatchery Seed Restoration

Initial Steps and Criteria used to Determine the Location and Area Suitable for Restoration (07/15/2019)

	Layer	Area (acres)	Data Source
Initial	**Bottom Survey Extent**	5819.9	**MGS & DNR**
Step	**Geoprocessing Layer**	**Area Remaining After Geoprocessing**	
1	**Depth 7-20 ft. (inside)**	3580.8	**Manokin Depth Interval Polygons (from NOAA sounding points)**
2	**Mud and Shell Dominant Bottom (outside)**	566.4	**NCBO CMECS Habitat Characterization**
3	**Aquaculture Lease 150 ft. Buffer (outside)**	566.4	**DNR Aquaculture Tool**
4	**Navigation Aid Buffers 250 ft. (outside)**	560.5	**2016 USCG Light List**
5	**Private Dock 250 ft. Buffers (outside)**	560.5	**2003 Orthophoto**
6	**SAV 2007-2016 Boundary (outside)**	560.5	**VIMS**
7	**Navigation Channel Buffers 150 ft. (outside)**	560.5	**USACE**
8	**DNR Fall Survey 750 ft. Buffer (outside)**	548.9	DNR
9	**Marina 250 ft. Buffer**	548.9	**VIMS**
10	**Pound Net Trap 250 ft. Buffer**	542.8	DNR
11	**Interpolated Oyster Density >= 5 animals/sq. meter (outside)**	519.2	DNR
12	**Merge contiguous polygons and delete polygons < 0.5 acres**	516.1	
	Final Substrate Reef Area (23 polygons, 0.52 – 208.1 acres)	516.1	
	Modifications based on recent groundtruthing and bathymetry data, additional aquaculture leases, and removal of reef area approaching the Rumbley harbor channel entrance	332.9	**2/20/2020**

1) Table above shows the geoprocessing steps and spatial data layers used to determine the initial area (07/15/2019-516.1 acres) and location of bottom suitable for construction of substrate reefs.

2) The current blueprint reef area (02/20/2020 – 332.9 acres) reflects modifications to above based on recently available groundtruthing and bathymetry data, additional aquaculture leases, and removal of reef area to increase unobstructed access to the Rumbley harbor channel entrance.

V1

Hatchery Seed-Only Restoration

Initial Steps and Criteria used to Determine the Location and Area Suitable for Restoration (07/15/2019)

	Starting Layers	Area (acres)	Data Source
Initial	Bottom Survey Extent	5819.9	MGS & DNR
Step	Geoprocessing Layer	Area Remaining After Geoprocessing	
1	Depth 4-20 ft. (inside)	5391.2	Manokin Depth Interval Polygons (from NOAA sounding points)
2	Shell Dominant Bottom (inside)	469.2	NCBO CMECS Habitat Characterization
3	Aquaculture Lease 150 ft. Buffer (outside)	469.2	DNR Aquaculture Tool
4	Navigation Aid 250 ft. Buffer (outside)	468.6	2016 USCG Light List
5	SAV 2007-2016 Boundary (outside)	468.6	VIMS
6	Private Dock 250 ft. Buffer (outside)	468.6	2003 Orthophoto
7	Navigation Channel Buffers 150 ft. (outside)	468.6	USACE
8	DNR Fall Survey 750 ft. Buffer	439.9	DNR
9	Marina 250 ft. Buffer	439.9	VIMS
10	Pound Net Trap 250 ft. Buffer	439.9	
11	Interpolated Oyster Density >= 50 animals/sq. meter (outside)	424.9	
12	Merge contiguous polygons and delete polygons < 0.5 acres	409.3	
Final	Final Seed-Only Area (60 polygons, 0.5-58.3 acres	409.3	
	Modifications based on recent groundtruthing and bathymetry data, additional aquaculture leases, and removal of reef area approaching the Rumbley harbor channel entrance	283.8	2/20/2020

1) Table above shows the geoprocessing steps and spatial data layers used to determine the initial area (07/15/2019 - 409.3 acres) and location of bottom suitable for restoration with hatchery seed-only (SOS).
2) The current blueprint seed-only area (02/20/2020 – 283.8 acres) reflects modifications to above based on recently available groundtruthing data.

Appendix B

Bottom Groundtruth Survey: Systematic Patent Tong Data Methods and Analysis

Sampling Site

An oyster reef preconstruction site assessment survey will be conducted to identify benthic habitat suitable for oyster population growth in the Manokin River Sanctuary and to determine the type of restoration construction needed. Benthic habitat are stratified based on upon *a priori* assumptions of benthic condition and the presence of oyster habitat delineated from previous survey work, including spatial analysis of data from the DNR and MGS Bay Bottom Survey showing bottom extent, bathymetry data from sonar surveys, NOAA's bottom type habitat characterization and patent tong data for oyster populations conducted by DNR (Appendix A). Areas identified from this geospatial analysis are considered restorable bottom, suitable for restoration, and are targeted for this systematic patent tong survey to groundtruth potential restoration sites.

Sampling Design

Sampling sites will be generated from systematic sampling grids developed in ArcMap (ESRI, Version 10.5) and draped over GIS layers. The nature of the application of grids to irregularly shaped GIS layers creates partial grid cells within some of the habitat stratum. Some partial grids are removed from the sampling frame because they are either too small or too narrow to be sampled effectively.

Sampling Methods

Preconstruction assessment protocols require fine-scale resolution information to determine whether benthic habitats are suitable for oyster population growth. Therefore, all strata are sampled using a 25 x 25m systematic grid cell with sampling locations in the center of each grid.

Sample planning and collection is coordinated by Oyster Recovery Partnership (ORP). Sampling is conducted during daylight hours and generally requires six to eight hours to complete. Navigation to sampling sites is done using a differential global positioning system (DGPS) attached to a laptop with ArcMap (ESRI, Version 10.1) running as a navigational program.

The benthic condition of oyster reef habitat was assessed beginning in fall 2019 using patent tongs deployed from the F/V Billie Jean. Patent tongs are a specialized commercial fishing gear used to harvest oysters in the Chesapeake Bay (Figure B-1). Patent tongs function much like a benthic grab and are well suited to quantify the condition of benthic habitat through the retrieval of the sediment surface layer which could include oysters, shell, or other sediment features. The grab is lowered to the bottom in an open position and oysters and other surface sediment features are collected by closing the grab, which effectively scrapes the surface layer of an oyster reef or other substrate type depending on where the sample is taken. The patent tongs sampled a 1.875 m^2 area of the bottom.

The coordinates of each patent tong sample are collected when the patent tongs reach the sediment surface. A DGPS antenna is positioned adjacent to the location where the patent tongs are deployed so no position offset is required. Once the grab is brought to the surface of the water, several qualitative measurements are recorded to document the depth of sediment covering shell (surface sediment), the% of shell not covered by sediment (exposed shell), the amount of material in the sample (patent tong fullness), and the substrate composition. The sample is then brought onboard for processing (Figure B-2; Table B-1).

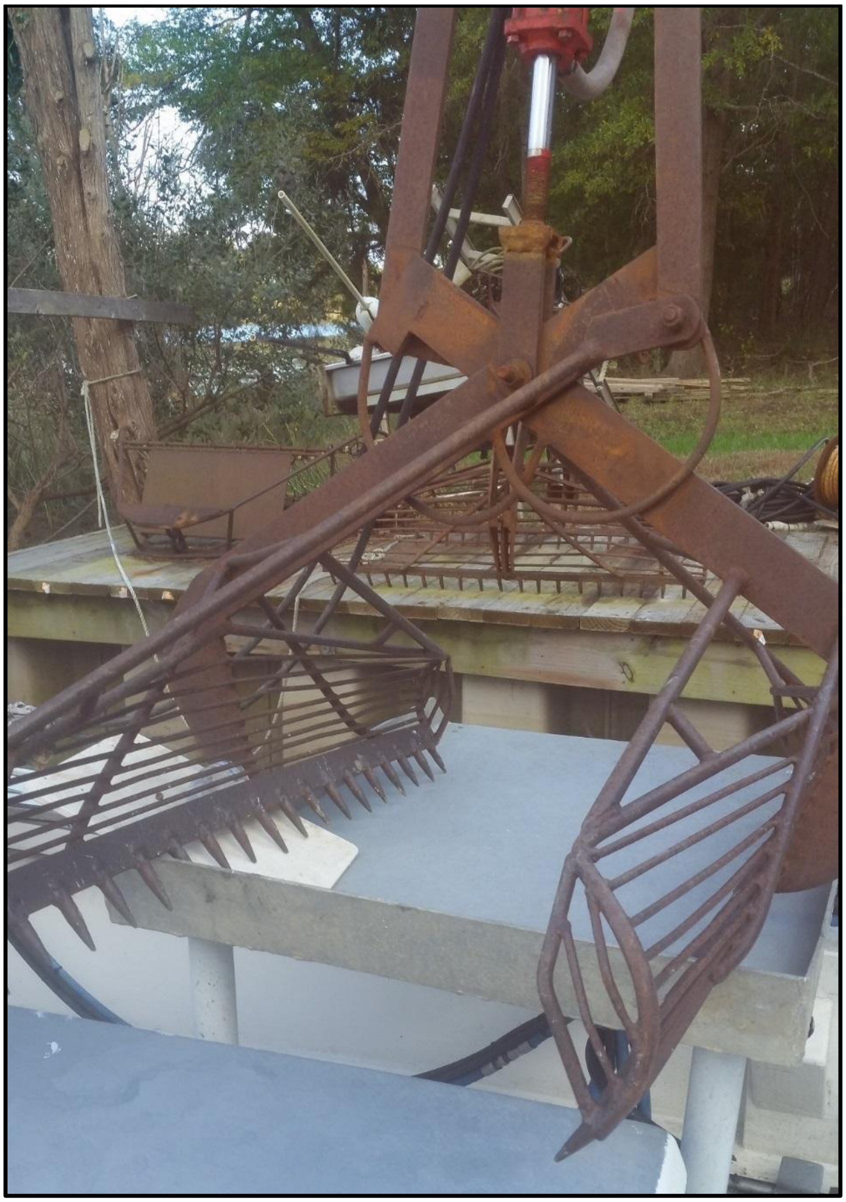


Figure Appendix B-1. Picture of patent tongs.

In each sample, all oysters are counted, identified as live or dead, and a minimum of 30 live oysters are measured for each sample. Oyster clumps, the number of oysters associated with a clump, and the substrate type that oysters are attached to are documented. In addition to the minimum of 30 live oyster heights measured, the shell height and total count of dead (box) and recently dead (gapers) oysters are also documented from each sample. The percentage of the sample covered by fouling organisms and specifically% fouling by tunicates and mussels are documented for each sample as well. The volume of oysters and the volume of shell are measured for each sample. Percentage of gray shell and shell hash is assessed.

Surface and bottom water temperature, dissolved oxygen, pH, and salinity are 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, vessel name, and staff present.

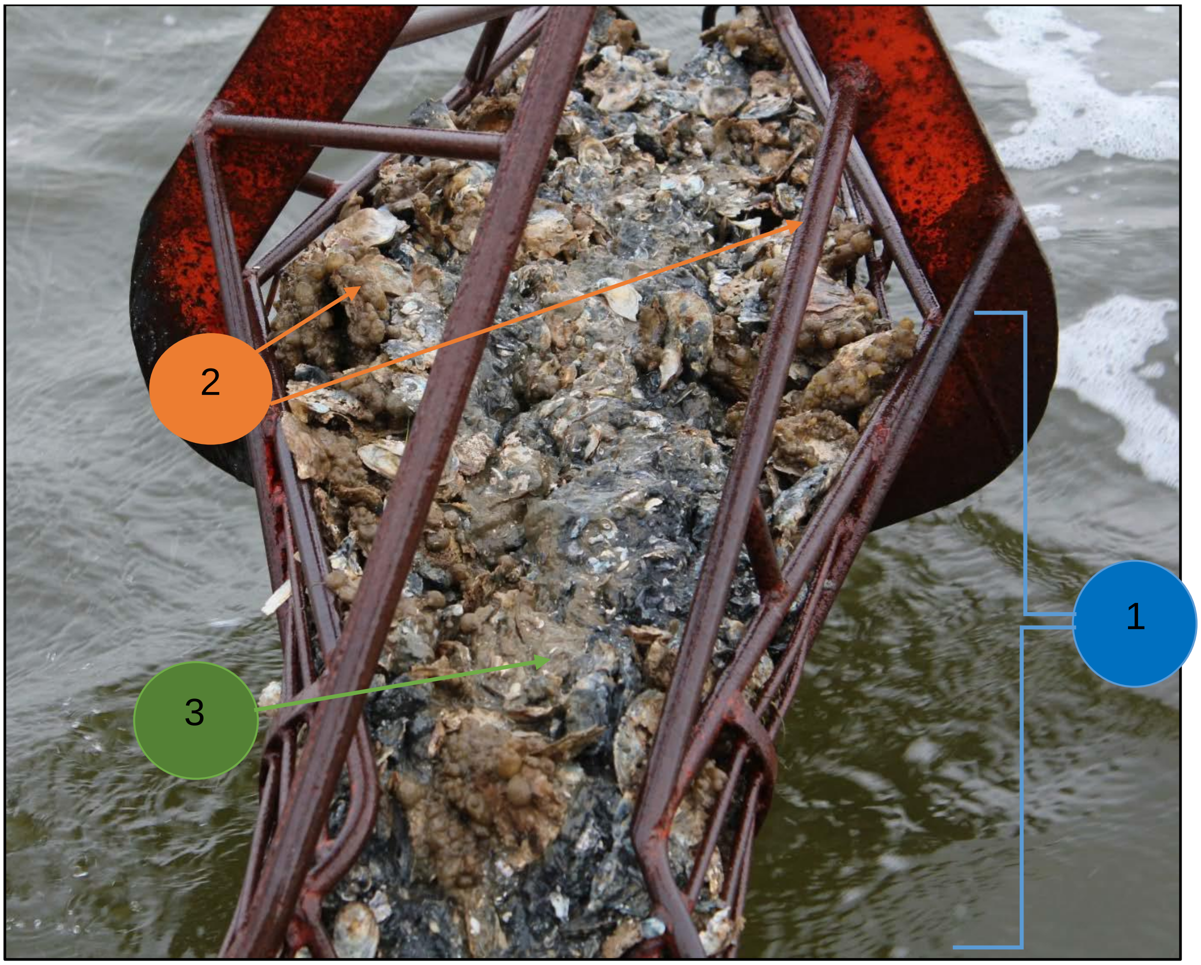


Figure Appendix B-2. Picture of representative patent tong sample. Numbers and arrows correspond to substrate characteristics documented before the sample was brought onboard for processing. Bubble 1 represents the portion of the sample that is observed to document the Patent Tong Fullness Index. Bubble 2 represents the portion of the sample that is observed to document Exposed Shell. Bubble 3 represents the portion of the sample that is observed to document Surface Sediment depth. Colors of each bubble correspond to descriptions of each measurement in Table 1.

Data Management

All data are compiled and entered into the ORP Oyster Restoration Monitoring and Assessment relational database. Quality control and assurance is performed on all survey data and includes comparisons of randomly selected digital data to the field data sheets, summarizing data to review for outliers or out of range values, and plotting sample coordinates to ensure samples are collected within site boundaries.

Table Appendix B-1. List of substrate characteristics and substrate composition descriptors documented for each sample collected.

Substrate Characteristics	
Patent Tong Fullness Index	Estimate of the amount of substrate in a patent tong grab before tongs were rinsed. 0= No substrate, grab empty; 5= Patent tong full of substrate.
Exposed Shell	Estimate in 25% increments of the% of the substrate surface that is covered with shell. 100% exposed shell will have shell visible over the entire sample surface.
Surface Sediment	Estimate of the centimeter depth of surface sediment observed in the patent tong grab. 0 surface sediment would indicate no surface sediment present.
Substrate Composition	
Primary Substrate	Dominant substrate observed in the entire sample. Substrate types include mud, sand, sandy mud, oysters, clumped shell, loose shell, shell hash, and gravel.
Secondary Substrate	Secondary substrate observed in the entire sample. Substrate types include mud, sand, sandy mud, oysters, clumped shell, loose shell, shell hash, and gravel.
Tertiary Substrate	Tertiary substrate observed in the entire sample. Substrate types include mud, sand, sandy mud, oysters, clumped shell, loose shell, shell hash, and gravel.
% Gray Shell	Percent of the total shell that is estimated to be buried based on black colorization.
% Shell Hash	Description of the shell quality. % of the sample that is composed of shell hash.
Total Volume	Total volume of loose shell and oyster in the tong sample.
Oyster Volume	Volume of live, gaper, and box oysters in the tong sample.
Number of Live Oysters	Number of live oysters in the sample.

Habitat Assessment Data Analysis

Two analytical approaches are used to determine if sites needed restoration, if they are suitable for restoration, and the type of restoration activity that is required.

The first approach determines whether a site needs restoration based on the abundance and biomass of oysters currently on the site. Using the number of oysters counted in each patent tong sample; oyster density estimates are calculated and standardized to number per m^2 from the area sampled by patent tong. Live oyster density is averaged over all samples collected at the individual site. Using the oyster shell heights collected in each patent tong sample, oyster biomass estimates are calculated for individual oysters using the equation $W = 0.000423 * L^{1.7475}$ where W = dry tissue weight in g and L = shell height in mm (Mann and Evans 1998). Biomass is then summed for the entire sample and standardized using the same method as density estimates. Average biomass is calculated across all samples collected at the site.

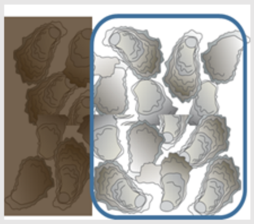
Sites with greater than 50 oysters and greater than 50 grams of biomass per m^2 over more than 30% of the site are determined premet and do not need initial restoration construction efforts.

The second approach uses an index of habitat quality to determine whether a site is suitable for restoration and if so, the type of restoration required. An index of habitat quality is developed to determine whether oyster habitat is suitable for seed-only restoration construction, substrate and seed restoration construction, or not suitable for either (e.g. an area consisting of all mud that cannot support restoration). Five benthic habitat components observed from samples are used to develop the index (Figure B-3):

- Exposed Shell
- Primary Substrate and Secondary Substrate
- Surface Sediment
- Number of Live Oysters
- Surface Shell, calculated as = Total shell volume - (Total shell volume x % gray shell). (Total sampled shell and surface shell volume were estimated for each individual sample. Field measurements of shell resources included total shell volume and the % of black [buried] shell estimated in a sample for patent tong samples. Total shell volume is standardized by the area sampled by patent tong. Surface shell estimates are calculated as the % of the total sampled shell volume that is not considered black shell.)

Five Benthic Habitat Components observed from patent tong samples:

1. **Exposed Shell**: expressed as percent exposed

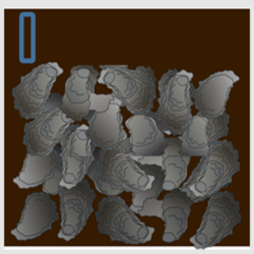


Top down view of patent-tong grab. This example shows the amount of exposed shell on the right as 75% of the sample exposed.

2. **Substrate Type**: primary and secondary substrates recorded

Substrate types include mud, sand, sandy mud, oysters, clumped shell, loose shell, shell hash, and gravel.

3. **Surface Sediment**: expressed as depth in centimeters



Buried shell with sediment on top. The surface sediment depth score is based on the depth of the sediment depicted in the blue area on top of the oysters.

4. **Number of Live Oysters**: calculated per square meter

5. **Surface Shell Volume**: calculated per square meter

Entire shell volume sampled by patent tongs with surface shell depicted on top and the darker shells underneath is gray shell.

Figure Appendix B-3. Five benthic habitat components observed from patent tong samples, exposed shell, substrate type, surface sediment, number of live oysters and surface shell volume.

Base oyster graphics from Tracy Saxby, Integrations and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/).

The index was developed using best professional judgement by members of the Maryland Oyster Restoration Interagency Workgroup. The benthic component variables are considered predictors of the suitability of the bottom to support an oyster population through seed-only restoration or substrate and seed restoration construction. A set of criteria for each variable was developed to construct the final index of habitat quality (Table B-2).

Table Appendix B-2. Five benthic habitat components used to develop the index of habitat quality and the criteria used to rank each component (For determination of the suitability of the bottom for seed-only or substrate and seed restoration construction).

Benthic Component	**Suitable for Oysters (score of 1)**
Exposed Shell Score	50% exposed or greater
Bottom Type Score	Oyster, loose shell, or shell hash. Sand or sandy mud and the secondary bottom type is either oyster, loose shell, or shell hash. Sand or sandy mud and the surface sediment = 0 cm.
Surface Sediment Score	Less than 5 cm
Number of Live Oysters Score	Greater than 5 oysters per square meter
Surface Shell Volume Score	Greater than 10 liters per square meter.

Benthic components are given a binary score expressed as a 1 or 0, with a result of 1 assumed to be suitable for restoration and 0 being unsuitable. A final habitat suitability score for each grid cell is derived as the sum of each benthic component score at the individual grid cell using the equation:

$$\begin{aligned} &Habitat\ Suitability\ Score \\ &= Exposed\ Shell\ Score + Bottom\ Type\ Score + Surface\ Sediment\ Score \\ &\quad + Number\ of\ Live\ Oyster\ Score + Surface\ Shell\ Volume\ Score \end{aligned}$$

The result of habitat suitability score determines whether a sampling grid cell is suitable for restoration based on a ranking between zero and five. Ranks of one or two are suitable for substrate and seed restoration, ranks of three require additional review, and ranks of four and five are considered suitable for seed-only restoration. A rank of zero is considered unsuitable for restoration.

The final habitat suitability index is entered into ArcMap (ESRI, Version 10.5) and all ranks for each site are connected to the site grid and projected to create a spatially explicit map of habitat suitability at the site level. The quantity and distribution of site rankings are visually inspected to determine whether a site is a candidate for restoration construction and the type of construction. Sites with a majority of 4- and 5-ranked sites are considered suitable for seed-only restoration. The site level resolution of samples also allows for modifications to the dimensions of the site if areas of the site are considered suitable. Areas that are considered unsuitable can be removed through GIS processing techniques and the remaining habitat will be considered suitable for seed-only restoration construction. Areas that were ranked from 1-2 are considered for substrate and seed restoration. Areas that are ranked 3 are subject to additional review to determine if they are suitable for seed-only restoration or substrate and seed restoration.

Oyster density and biomass data are also assessed for each grid. If the oyster density and biomass are greater than 50 oysters per m^2 and 50 grams per m^2 and cover an area of at least 30% of the reef, then the reef is considered premet for the restoration targets and will not be considered for initial restoration construction.

Fall 2019 Groundtruthing Results

Ten days of sampling were conducted in September and October 2019 aboard a contracted vessel, the F/V *Billie Jean.* Seven sites, totaling 75.1 acres were sampled (Figure B-4; Table B-3). Over 500 patent tong grabs were collected during the first round of Manokin Sanctuary sampling (Table B-4). All size classes of oysters were observed, from spat to over 150 mm (Figure B-5).

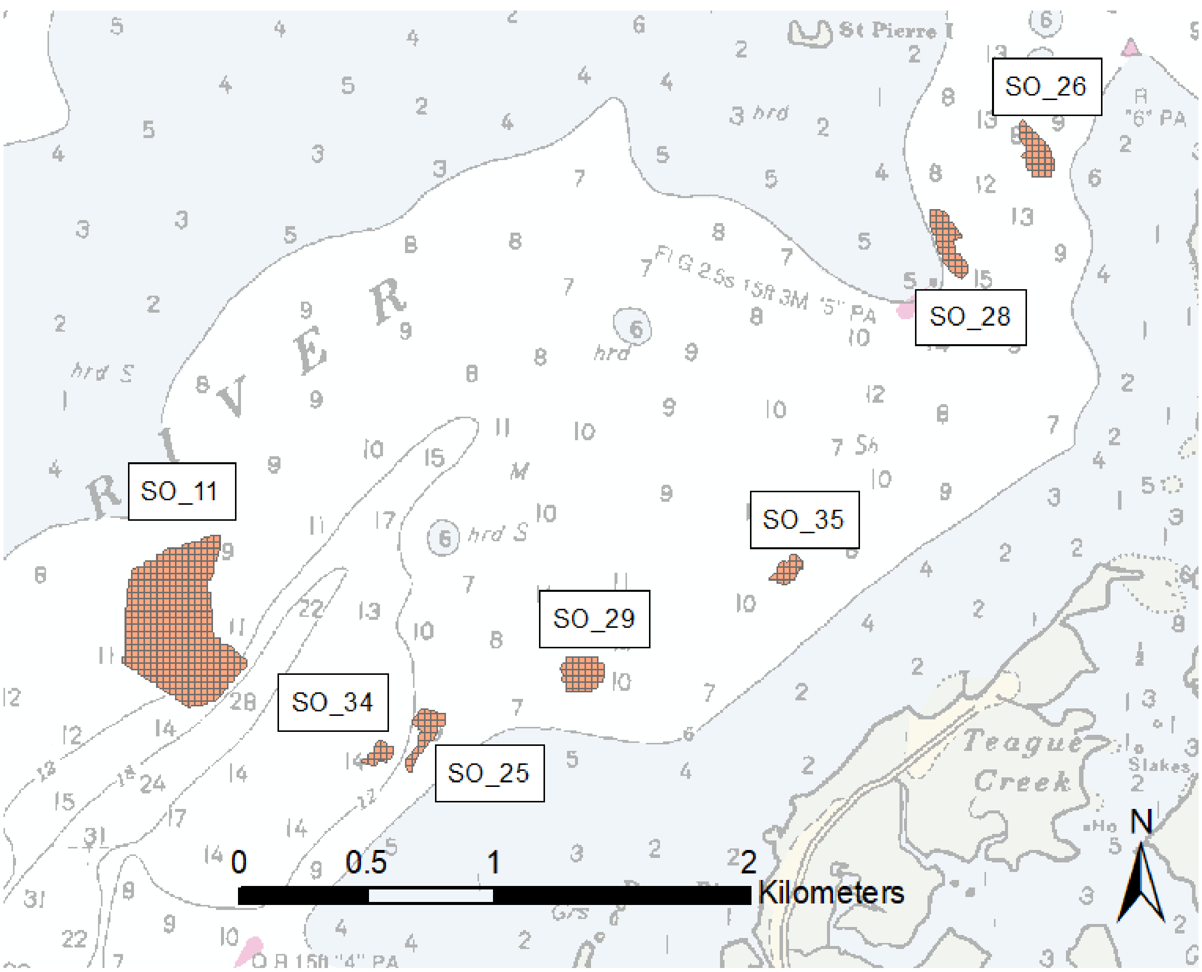


Figure Appendix B-4. Sites chosen for the first round of groundtruthing in the Manokin Sanctuary, with 25 x 25m grid applied.

Table B-3. Seed-only sites designated for the first round of Manokin Sanctuary pre-construction surveys. Patent tong data comes from DNR surveys over the period of 2012-18.

Site ID	Area (acres)	Patent Tong bottom type	CMECS Classification
SO_11	51.7	Mud shell grit	Biogenic oyster rubble, mud
SO_25	3.7	Mud sand	Biogenic oyster rubble, sand
SO_26	4.7	Mud	Biogenic oyster reef, mud
SO_28	5.7	N/A	Biogenic oyster rubble
SO_29	5.1	Mud sand	Anthropogenic shell
SO_34	1.9	Mud	Biogenic oyster
SO_35	2.3	N/A	Biogenic oyster rubble, mud

Table B-4. Results of 2019 patent tong survey at the site level. SD represents standard deviation.

Site ID	Dominant Substrate Type	Average Live Density (per m^2)	SD Live Oyster Density	Average Total Volume (L/m^2)	SD Volume	Samples taken (N)	% of Cells Scoring 4 or 5
SO_11	Loose shell	14.55	12.09	5.86	2.74	340	74.1
SO_25	Shell hash	2.65	3.75	3.52	2.22	28	14.3
SO_26	Loose shell	4.35	2.69	4.13	1.46	32	34.4
SO_28	Loose shell	4.77	7.05	3.21	1.86	37	21.6
SO_29	Loose shell	12.49	11.06	4.66	2.94	35	62.9
SO_34	Mud	6.07	9.14	3.11	3.37	13	23.1
SO_35	Mud	1.53	1.76	2.73	0.87	16	6.3

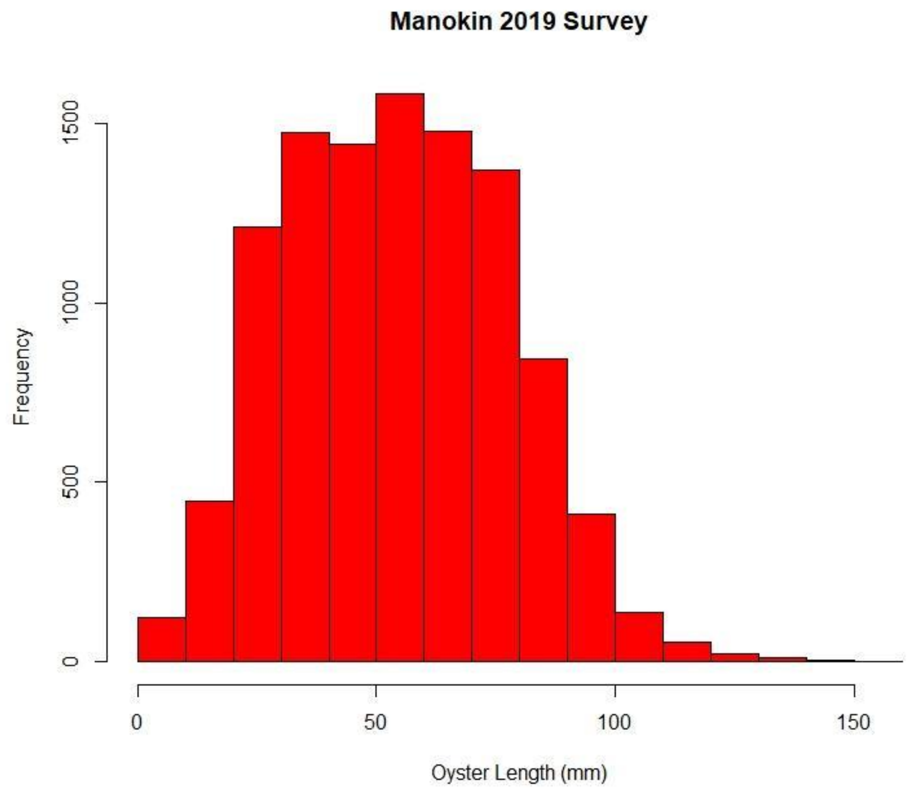


Figure Appendix B-5. Length-frequency histogram for all oysters measured in Manokin Sanctuary during fall 2019 groundtruthing survey.

Based on patent tong samples, no sites were classified as premet, meaning no areas displayed live oyster density greater than or equal to 50 oysters/m^2 and live oyster biomass greater than or equal to 50 g/m^2. SO_11 had the most samples meeting seed-only restoration requirements, with nearly three-quarters of cells scoring a four or five. It also had the highest density of live oysters per square meter. This site remained as seed-only treatment, with a slight change to the reef boundary (Figure B-6).

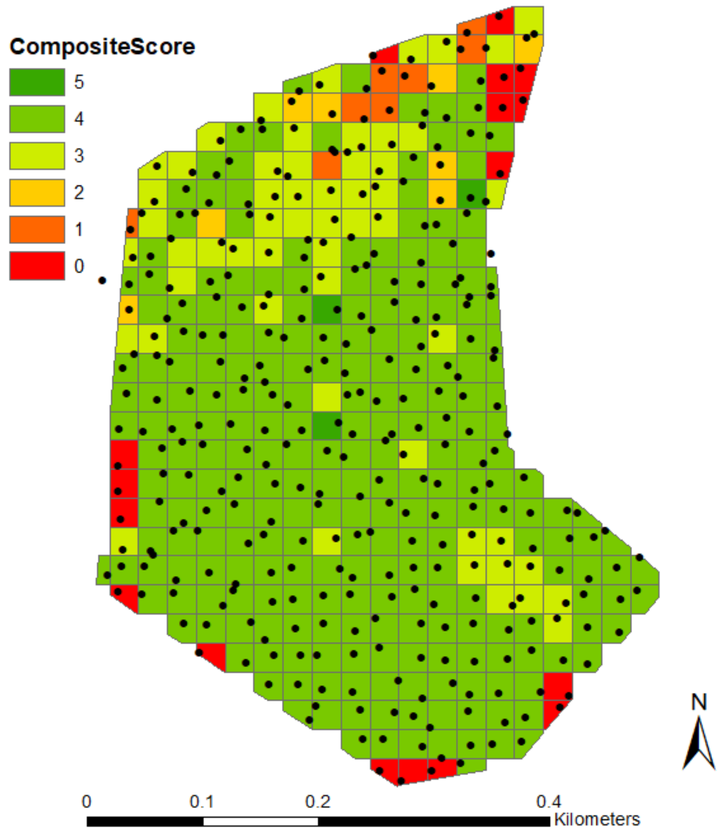


Figure Appendix B-6. Composite scores for each grid cell of SO_11. Black dots represent actual locations of patent tong grabs.

SO_25 and SO_35 had the lowest density of live oysters of the sites sampled. SO_34 remained as a seed-only restoration treatment site, while SO_25 was reclassified as a substrate and seed restoration treatment site (Figure B-7).

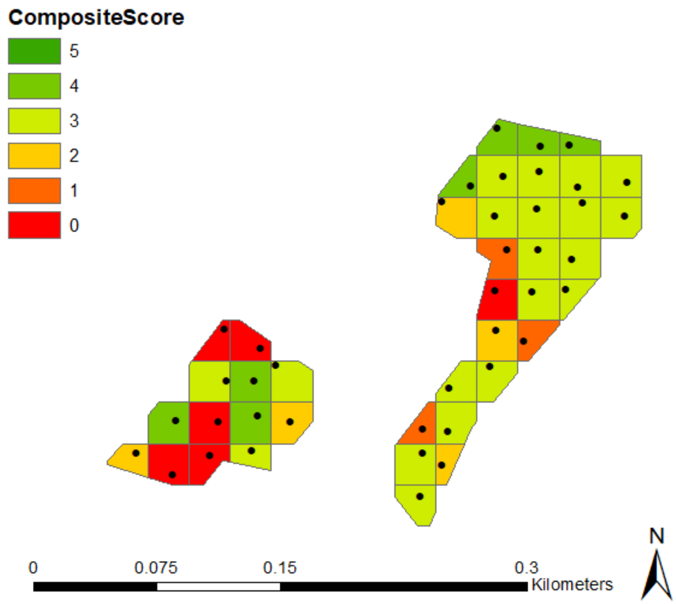


Figure Appendix B-7. Composite scores for each grid cell of SO_34 (left) and SO_25 (right). Black dots represent actual locations of patent tong grabs.

SO_29 had a high proportion of samples scoring four or five, and is suitable for seed-only restoration (Figure B-8).

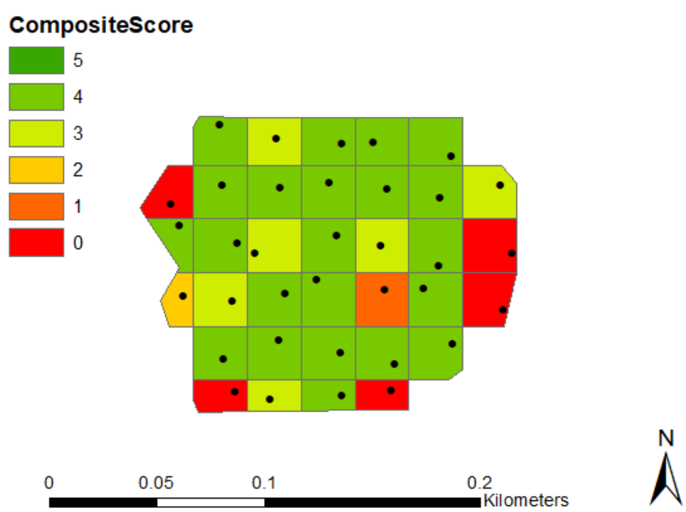


Figure Appendix B-8. Composite scores for each grid cell of SO_29. Black dots represent actual locations of patent tong grabs.

SO_35 was reclassified as a substrate and seed restoration treatment site (Figure B-9). This site had both the lowest average volume of material and lowest density of live oysters per square meter.

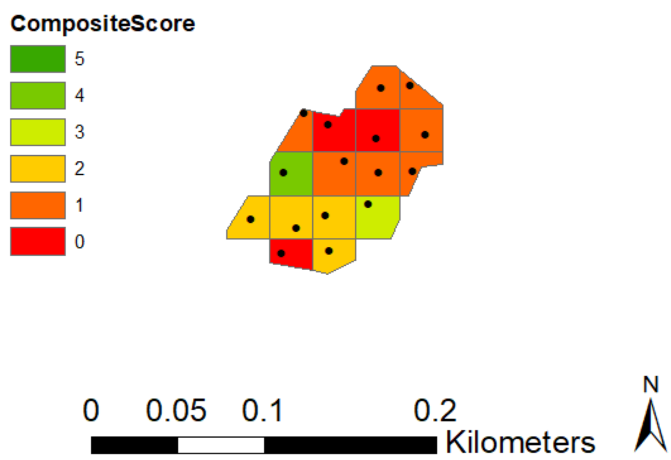


Figure Appendix B-9. Composite scores for each grid cell of SO_35. Black dots represent actual locations of patent tong grabs.

SO_28 and SO_26 after further review remained as seed-only restoration treatment sites (Figure B-10).

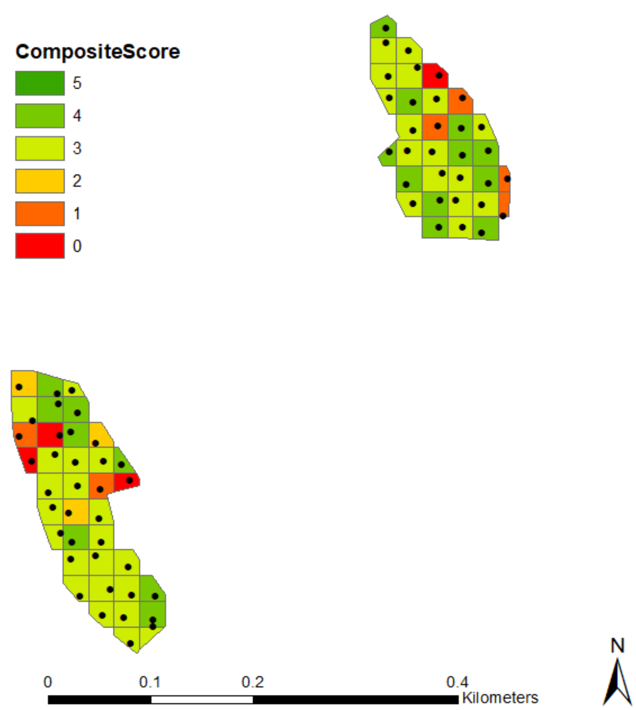


Figure Appendix B-10. Composite scores for each grid cell of SO_28 (left) and SO_26 (right). Black dots represent actual locations of patent tong grabs.

Appendix B References

Mann, R. and D.A. Evans. 1998. Estimation of Oyster, *Crassostrea virginica*, Standing Stock, Larval Production, and Advective Loss in Relation to Observed Recruitment in the James River, Virginia. Journal of Shellfish Research 17(1): 239-253.