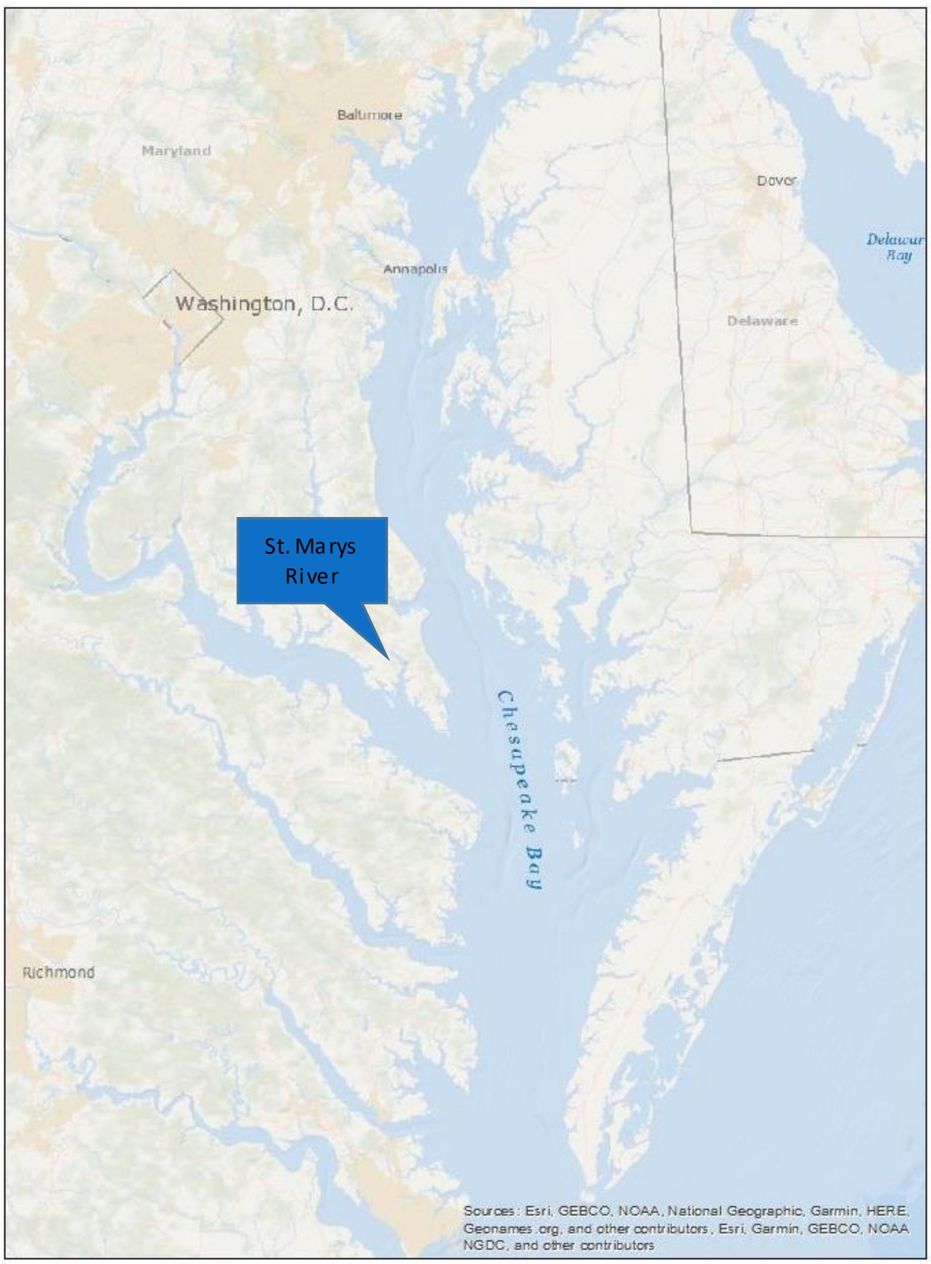
Upper St. Marys River Oyster Restoration Tributary Plan

A Blueprint for Restoring Oyster Populations in the Upper St. Marys River per the Chesapeake Bay Watershed Agreement

March 2020

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



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The Upper St. Marys River Oyster Restoration Tributary Plan is meant to be an adaptive, living document. The expectation is that as new information becomes available the plan will adapt to reflect changing conditions as restoration and monitoring progress. 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.

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Executive Summary

The 2014 Chesapeake Bay Watershed Agreement, which guides the work of the Chesapeake Bay Program, calls for state and federal partners to "Continually increase finfish and shellfish habitat and water quality benefits from restored oyster populations" and to "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 the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (GIT). For Maryland, the Sustainable Fisheries GIT convened the Maryland Interagency Workgroup (hereafter, "the Workgroup") to plan, implement, and track progress toward this goal. The Workgroup developed the Upper St. Marys River Oyster Restoration Tributary Plan to: (1) describe how the river's restoration goal was established and (2) describe plans to achieve the restoration goal. The Plan details the restoration site selection process and the reef construction, seeding, and monitoring required to bring the Upper St. Marys River Oyster Sanctuary in line with the oyster metrics definition of a successfully restored tributary. It includes a map of areas targeted to receive substrate and seed 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. Scientific and public consultation were sought by the Workgroup, and were incorporated into the Plan.

Consistent with the Chesapeake Bay Oyster Metrics success criteria, the Workgroup developed a full implementation restoration goal of 60.6 acres for the river. There are 35.1 acres of existing reefs in the river that already meet the target density goals for a restored reef. Thus, an additional 25.5 acres of restoration work are needed in the river to meet the restoration goal (Table 1).

The Department of Natural Resources applied for a Maryland Department of Environment and U.S. Army Corps of Engineers permit for the placement of reef building substrate within the substrate and seed area reefs. Based on public comment received during the permit application process, the restoration goal for the river was changed from 60.6 acres to 59.7 acres. The restoration goal of 59.7 acres will achieve 85.5% restoration. The cost estimate for completing the remaining 24.6 acres is $1,835,800.

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

Table 1. Summary of Upper St. Marys River acreages and costs before and after revision based on public comment.

	Original	Revised
Currently Restorable Oyster Habitat (CROH)	69.8 acres	69.8 acres
Restoration Goal	60.6 acres	59.7 acres
Premet Reefs*	35.1 acres	35.1 acres
Area to be Restored	25.5 acres	24.6 acres
% CROH	86.8%	85.5%
Estimated Seed Cost		$966,800
Estimated Substrate Cost		$869,000
Total Cost Estimate		$1,835,800

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

Section 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 the Chesapeake Bay Program’s Sustainable Fisheries Goal Implementation Team.

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 (and toward a previous oyster goal, related to Executive Order 13508 in 2009; Federal Leadership Committee for the Chesapeake Bay 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 Upper St. Marys 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 covering at least 30 percent of the target restoration area at six years post restoration;
- A ‘target’ of 50 oysters and 50 grams dry weight per square meter covering at least 30 percent 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 percent of the currently restorable oyster habitat (CROH) has oyster reefs that meet the reef-level metrics above (restorable habitat is defined as the area that, at a minimum, has appropriate bottom quality and water quality for oyster survival) *and*
- 8 to 16 percent of historic habitat (Yates Bars), and preferably more, has oyster reefs that meet the reef-level metrics above.

Like all Goal Implementation Teams under the Chesapeake Bay Program, the Sustainable Fisheries GIT has crafted management strategies that describe the steps necessary to achieve each goal in the Chesapeake Bay Watershed 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 (Chesapeake Bay Program 2015) calls for state-specific workgroups to develop tributary-specific plans to restore oysters in each of the ten target rivers, consistent with the Oyster Metrics success criteria.

In 2012, the Fisheries GIT established the Maryland Oyster Restoration 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 (MD 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 Department of Natural Resource 2010 oyster regulation to inform its work.

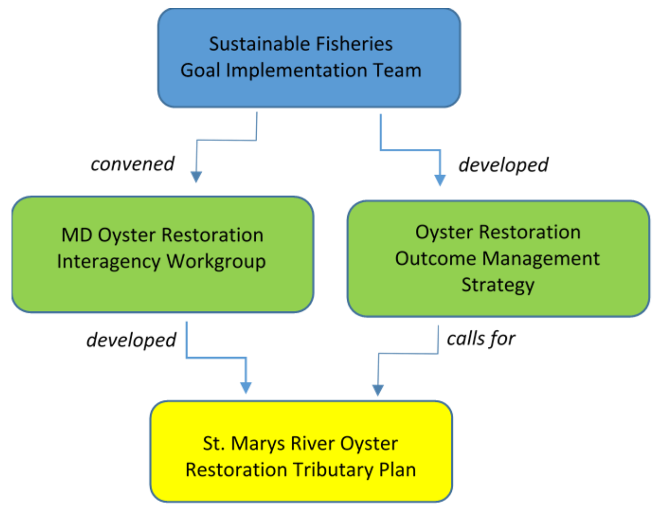

Figure 1. Organizational framework for large-scale oyster restoration in the upper St. Marys River under the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team. Similar workgroups exist in Virginia.

Section 2: Selection of Upper St. Marys River as a Target Tributary

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

- The 2012 U.S. Army Corps of Engineers' 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 St. Marys River was designated as a Tier One tributary, indicating that it is suitable for oyster restoration.
- The upper portion of the river has been closed to public fishery commercial oyster harvest since being designated as an oyster sanctuary in 2010.
- The river has historically exhibited strong oyster recruitment.

- Oyster restoration activities in the sanctuary since 2010 include projects from the St. Mary's River Watershed Association, Marylanders Grow Oysters, and St. Mary's College. The St. Mary's River Watershed Association has constructed a reef using reefballs, concrete rubble, shell piles and spat-on-shell. Marylanders Grow Oysters, a public outreach program, currently plants oysters at four sites within the sanctuary; however, they will be planting oysters on restoration areas to supplement low density areas within the premet sites. There are approximately 100 waterfront homeowners and community organizations in the St. Marys River who are a part of the Marylanders Grow Oysters program. They grow spat-on-shell in about 660 cages off their docks and tend to them in the fall and through the winter. These oysters are then planted on areas within the sanctuary in the spring, after surviving their vulnerable first months of life. Both of these groups plant on a total 1.8 acres within the sanctuary. St. Mary's College plants spat annually in the sanctuary on a 6.6-acre reef (MD DNR 2016).
- There was strong support from the local community, including St. Mary's College, the St. Marys River Watershed Association, and the local adjacent landowners, many of whom are members of the Marylanders Grow Oysters program.

In December 2017, the Department of Natural Resources, with input from the Maryland Oyster Advisory Commission, recommended the St. Marys River Sanctuary as the fourth candidate for large-scale oyster restoration to the Sustainable Fisheries GIT. The Oyster Advisory Commission was asked to consider areas that were already a sanctuary, areas that were not close to the first three large-scale restoration areas, and areas that could be restored with minimum expense to the taxpayer. The selection was based on the findings of the USACE Master Plan, MD DNR's Fall Oyster Survey and MD DNR patent tong survey data, the Maryland oyster sanctuary list, and bottom survey data from the Maryland Geological Survey 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) located outside of the sanctuary, and tributary size.

In December 2018, the Sustainable Fisheries GIT formally approved the St. Marys River oyster sanctuary as the fourth Maryland tributary for large-scale oyster restoration under the '10 tributaries' goal.

Section 3: Prerestoration Status of the St. Marys River Oyster Sanctuary

The St. Marys River Sanctuary is located in the upstream portion of the St. Marys River. It is a mesohaline region with a salinity typically between 12 to 14 ppt., but salinities above or below these levels in a severe drought or freshet, especially a freshet. The mouth of the river empties into the Potomac River. The sanctuary, created in 2010, encompasses 1,304 surface acres, of which 89 acres are historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 10 historic oyster bars within the sanctuary. The area is classified as a conditionally restricted shellfish harvest area by the Maryland Department of the Environment (MDE) due to the potential for contamination of shellfish by fecal coliform and other bacteria (MD DNR 2016). There are six active oyster aquaculture leases within the sanctuary and six aquaculture lease applications pending.

The MD DNR Fall Oyster Survey has sampled one to three bars within the area annually since 1990. The average number of small-sized oysters per bushel was similar before and after the sanctuary was created; however, biomass and the average number of market-size oysters increased 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 (MD DNR 2016).

The Workgroup used data from MD DNR patent tong surveys conducted in 2012 and 2015 to determine the status of the oyster populations on habitat within the sanctuary. Assisted by NOAA spatial analysis, this information was used to determine initial restoration construction areas (already meets goal, seed-only, and substrate and seed; Appendix A). A systemic patent tong survey was conducted in the fall of 2018 by Oyster Recovery Partnership, and this information was used to determine target restoration areas in this plan (Appendix B).

Section 4: Oyster Restoration Goal

Section 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, when restoration efforts are complete, oyster reefs should cover 50 to 100 percent 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 criteria were used to define CROH (this represents the revised CROH version accepted by the Fisheries GIT; Lazar 2017):

- River extent: This was based on the area designated as a sanctuary in 2010. This river segment is 1,304 acres.
- Depth interval: The Baywide Bathymetry Grid developed by the Chesapeake Bay Program and a NOAA sonar survey from 1960 were interpolated to define restoration depths. Depths between 4 feet and 20 feet were considered restorable for the purposes of defining 'currently restorable oyster habitat.' The 20-foot maximum depth cutoff was used due to concerns about potential hypoxia (low dissolved oxygen levels) at greater depths. The shallow depth limit was based on the practical limit of the vessels used for restoration activities, as well as the limits of the acoustic surveys used to create the restorable bottom analysis. However, for substrate placement, a depth limit of 6 feet post construction was used to allow for safe navigation over the substrate.
- Benthic habitat (river bottom) type: Benthic habitat was classified using the Coastal and Marine Ecological Classification Standards (CMECS) using the 2010 Maryland Geologic Survey results updated with 2012 and 2015 patent tong data. The following types were considered currently restorable: anthropogenic oyster rubble, sand with shell, biogenic oyster rubble, and muddy sand with shell.
- Water quality: Interpolated water quality data are based on field samples collected at the Chesapeake Bay Program monitoring sites 2001-2006 and were derived with the Chesapeake Bay Interpolator. The USACE 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 dissolved oxygen is a mean bottom value of 5.0 mg/l for the interval June-August 2001-2006. Recent observed dissolved oxygen levels from MDE sampling sites within the sanctuary from 2009-2016 in May-September have average dissolved oxygen levels above the 5.0 mg/l threshold (Appendix A).

Using the above criteria, 69.8 acres were classified as 'CROH' (Appendix A). Therefore, to meet the first prong of the Oyster Metrics definition of a restored tributary, between 34.9 and 69.8 acres will need to be restored. (Figure 2).

The second prong of the Oyster Metrics success criteria calls for at least 8 to 16 percent of the historic oyster habitat acreage of oyster reefs in the river to be restored (Figure 2). In the St. Marys River Sanctuary, there are 89 acres of historic Yates Bar habitat; 16 percent of historic reef acreage is estimated at 14.24 acres. Thus, meeting the first prong (34.9 to 69.8 acres) will also meet the second prong (14.24 acres).

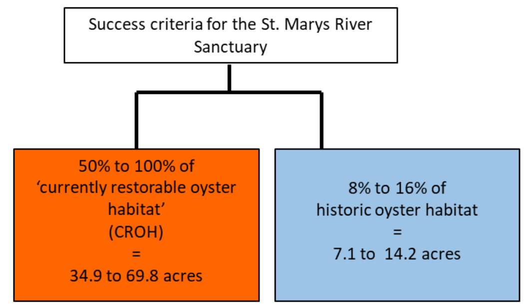

Figure 2. Oyster Metrics two-prong tributary-level success criteria, as applied to the St. Marys River Sanctuary.

Section 4.2: Setting the Oyster Restoration Target

Once the Workgroup determined the restoration target should be between 34.9 to 69.8 acres, it worked to set a specific target 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, and 2) existing functional oyster shell habitat that can be restored by only planting hatchery oysters. Unlike CROH, the total area and locations identified as "suitable" are constrained by a suite exclusionary parameters that include: buffers around docks, aids to navigation, and aquaculture leases; 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:

- Submerged aquatic vegetation (SAV) beds: There are historic and recent SAV beds in the St. Marys River. The 2007-2016 SAV beds cover a total of 7.7 acres within the sanctuary with 0.1 acres of area for restoration removed for intersecting with SAV beds (Appendix A).
- Exclusion zones: No restoration work was planned underneath private docks or on private leases. The key bar (Pagan oyster bar) for the MD DNR Fall oyster survey and the St. Marys River Watershed Restoration site were also excluded (Appendix A).
- Proximity buffers: Areas within 150 feet of leases, within 250 feet of U.S. Coast Guard navigational aids, and within 50 feet of private docks for seed-only restoration or within 250 feet of private docks for substrate restoration sites were not considered for oyster restoration work (Appendix A).

Using the above parameters, the workgroup determined 60.6 acres are available for restoration, or 86.8 percent of the CROH (Figure 3).

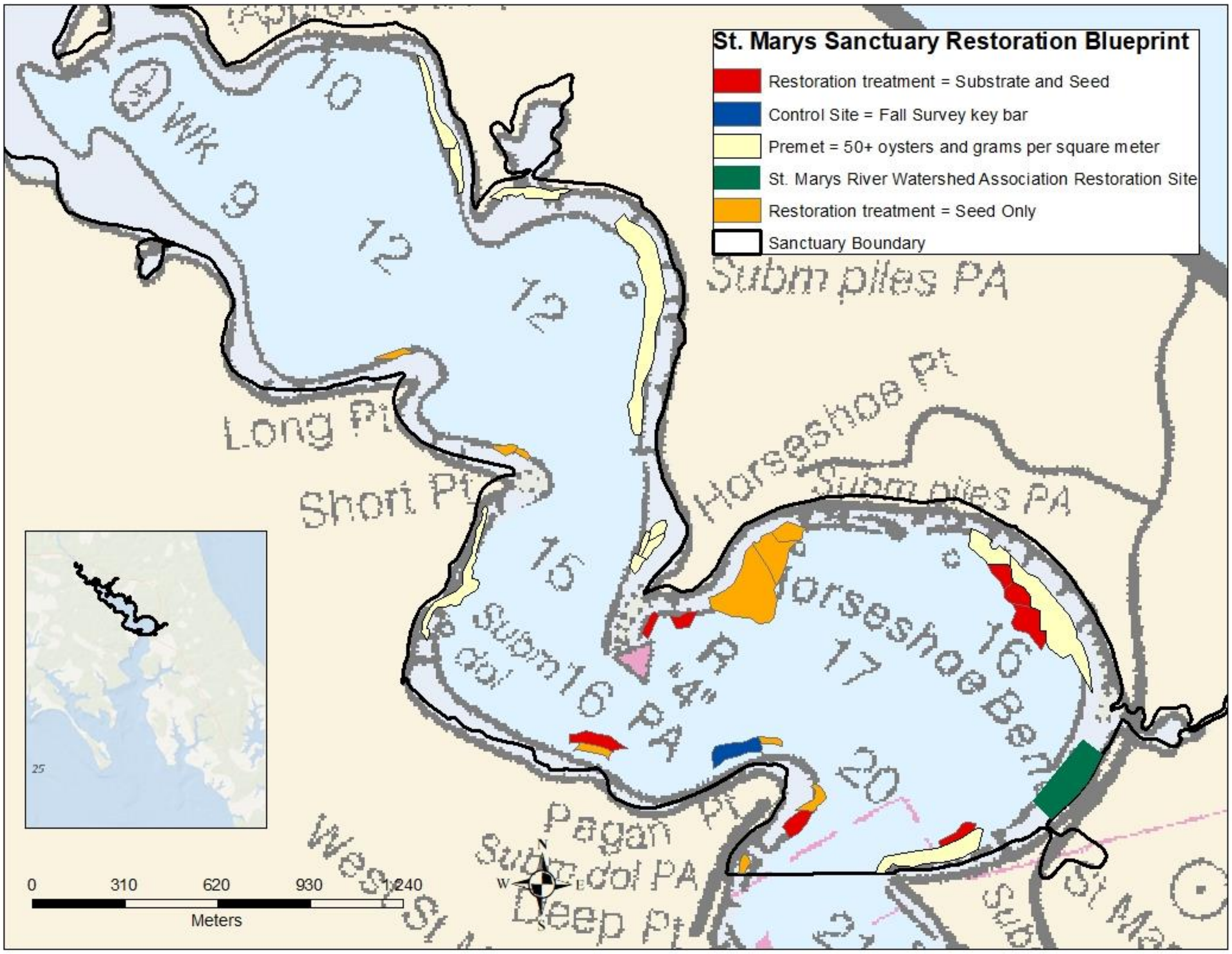

Figure 3. Upper St. Marys River sanctuary restoration blueprint map.

Section 5: Determining Restoration Treatment for Planned Reefs

Once the 60.6 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 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 spat-on-shell). The parameters in Table 2 were used to delineate treatment type. Table 3 shows the areas targeted for restoration along with the planned restoration treatment type (seed only or substrate and seed). In areas that are slated for substrate and seed restoration, moving existing oysters will be considered before restoration to avoid burying live oysters.

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

Criteria	**Restoration Treatment Type**	
	seed only restoration treatment	**substrate + 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. St. Marys River sanctuary restoration acreage.

Restoration Treatment	**Acres**
Seed Only	15.8
Substrate and Seed	9.7
Premet*	35.1
Total Target Restoration	**60.6**
*Premet reefs meet density and biomass targets prior to restoration work in the river.	

To determine prerestoration oyster density, the Workgroup examined MD DNR patent tong survey data from 2012 and 2015 and additional patent tong data collected by ORP in 2018. Areas that already met the Oyster Metrics target oyster density (50+ oysters per square meter) and oyster biomass (50+ grams per square meter) were considered naturally restored, and will not receive restoration treatment. Patent tong surveys conducted by MD DNR in 2012 and 2015 that utilized a stratified random sampling design were used to ground truth the Maryland Geological Survey sonar survey, determining the bottom suitable for restoration. A systematic patent tong survey conducted by Oyster Recovery Partnership in 2018 was then used to determine the type of restoration construction that should occur (Appendix B). 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. Water depth of 7+ feet was required for planned substrate reefs to avoid navigational conflicts.

Pagan Point bar, which is 2.2 acres, is a key bar and disease bar for MD DNR Fall Oyster Survey; therefore, it will not receive any treatment. It will be a control site. It is a reef that would have been classified as premet based on the oyster density and biomass data from the 2018 patent tong survey.

Section 6: Acreage Revision

The Department of Natural Resources applied for a joint Maryland Department of Environment (MDE) and U.S. Army Corps of Engineers tidal wetlands permit (permit # 19-WL-0561) for the placement of reef building substrate within the St. Marys River sanctuary. A MDE public hearing was held at St. Mary's College on November 14, 2019 in which MD DNR presented the plan for construction and addressed public comment. Based on public feedback and concern regarding minimum construction depth in relation to sailboat draft, MD DNR revised the permit application. The revised application included site-specific considerations and changing the minimum preconstruction depth over all reef areas to 8' for a minimum post construction clearance of 6'9" (Table 4). One reef was too small (<0.5 acres) for substrate placement after new depth considerations, so MD DNR applied for the placement of reef balls in the area (0.14 acres). The reef balls will be placed in a minimum of 10' of water for a minimum post construction clearance of 8'. Two reefs are revised to use 6" of substrate for the reef building base with 1-3" of spat-on-shell placed on top of the substrate. One of these reefs is in an area that received a high level of public concern for draft and the second area is in close proximity to the St. Mary's College mooring balls. The Workgroup agreed upon a 6" base and minimum 11' post construction clearance with the college on this reef to mitigate potential concerns of large draft boats on the mooring balls. All other reefs will receive the planned 12" substrate base and 1-3" of spat-on-shell on the substrate with a minimum post construction clearance of 6'9". The revision to the construction permit changed the substrate and seed acreage from 9.7 to 8.8 and a revised restoration goal for the river of 60.6 acres to 59.7 acres. The restoration goal of 59.7 acres will achieve 85.5% restoration (Figure 4).

Table 4. Full implementation and revised based on public comment implementation acreages for substrate and seed reefs, revised treatments, and minimum depths.

Substrate and Seed Areas	Full Implementation Acreage	Revised Implementation Acreage	Revised treatment	Minimum Pre Construction Depth	Minimum Post Construction Depth
Reef 1	0.53	0.14	Reef balls	10'	8'
Reef 2	0.75	0.65	6" substrate	8'	7'3"
Reef 3	1.02	0.97	12" substrate	8'	6'9"
Reef 4	1.26	1.26	12" substrate	8'	6'9"
Reef 5	2.36	2.36	12" substrate	8'	6'9"
Reef 6	0.92	0.92	6" substrate	11'9"	11'
Reef 7	1.21	1.08	12" substrate	8'	6'9"
Reef 8	1.69	1.43	12" substrate	8'	6'9"

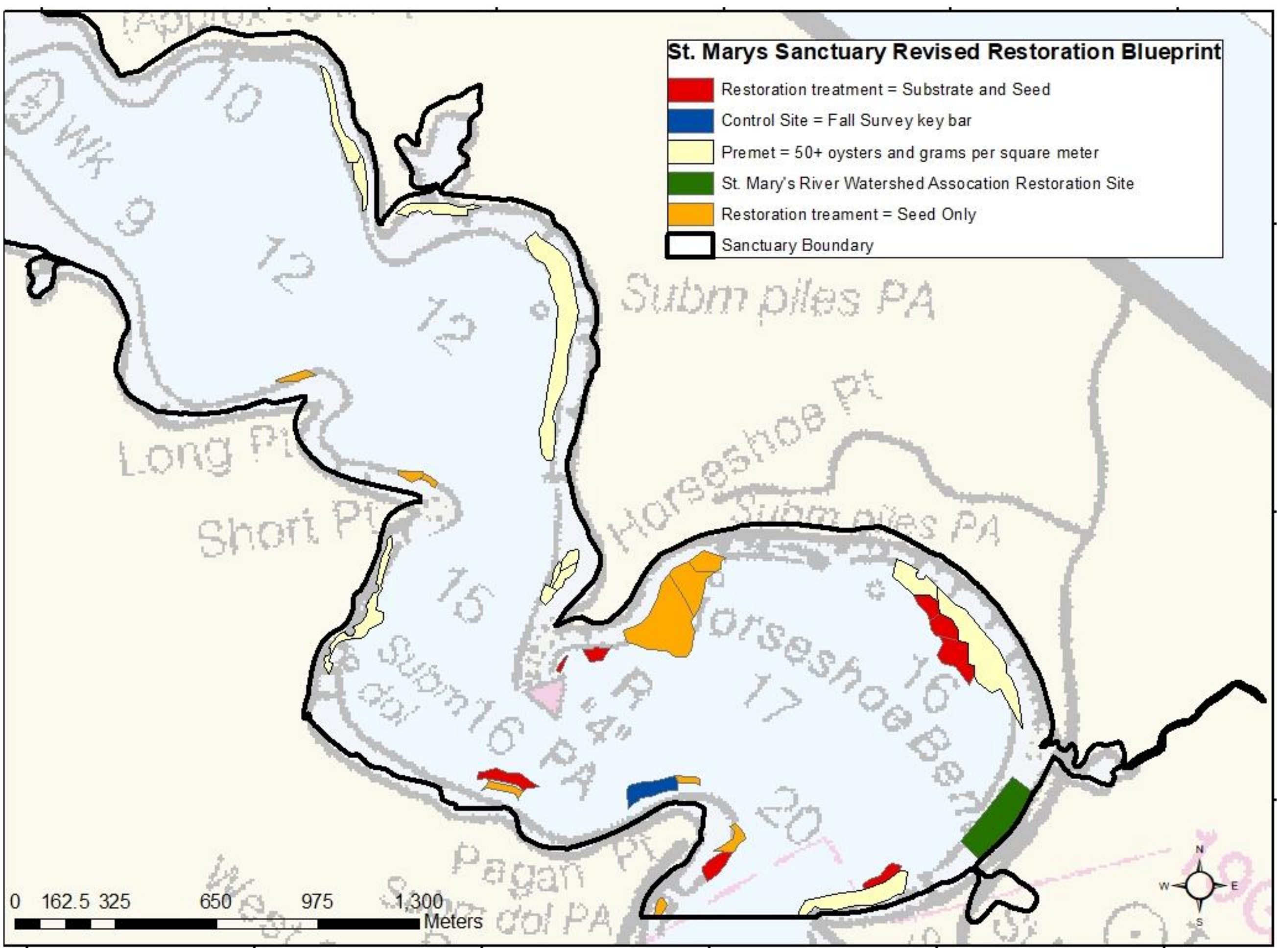

Figure 4. Revised based on public comment Upper St. Marys River sanctuary restoration blueprint map.

Section 7: Cost Estimate and Time Frame for Completion

The Workgroup developed a cost estimate of $1,835,800 to complete the revised restoration acreage of 59.7 acres.

Section 7.1: Oyster Seed Needs and Cost Analysis

The total maximum potential seed for restoration is 241.7 million spat on shell (SOS) at a total projected cost of $966,800 (Table 5).

Table 5. St. Marys River sanctuary seed requirements and cost estimates.

Reef Treatment	Suitable Acres for Restoration	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)	Potential Second Seeding per Acre	Potential Second Seeding Bushel of Spat on Shell per Acre	Potential Seed required for Second Seeding (millions)	Potential Cost of Second Seeding
Seed Only*	15.8	5.0 M	800	79	$316,000	2.0 M	320	31.6	$126,400
Substrate and Seed*†	8.7	5.0 M	800	43.5	$174,000	2.0 M	320	17.4	$69,600
Seed Only-Premet**	35.1	0 M	0	0	0	2.0 M	320	70.2	$280,800
Total	**59.6**			**122.5**	**$490,000**			**119.2**	**$476,800**

*While some of these seed-only sites had initial, prerestoration 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 spat on shell for the initial planting and 2 million seed per acre, or 320 bushels of spat on shell 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.
†The substrate and seed acreage and cost estimates do not include the 0.14 acres slated for reef ball construction.

The tributary plan calls for planting spat-on-shell on reefs that do not already meet restoration metrics. For planning purposes, the Workgroup made a very conservative assumption that there would be no natural spat set over the course of implementation when calculating the total planting density required; however, St. Marys tributary has a strong history of natural recruitment and will likely have natural spat set (Table 5). Thus, to account for any natural recruitment, the planting will be conducted in two deployments: an initial large planting at year 0 and a smaller second planting at year 4 (if required based on the results of the 3 year monitoring).

Initial Planting:

The target planting density for the initial planting is 5 million spat-on-shell per acre which was calculated based on survival and larvae setting rates.

Using monitoring data from the Harris Creek sanctuary, the Workgroup set assumed survival rates for first-year planted spat-on-shell at 8 percent. The Workgroup used the projected annual survival of 78 percent for out-year survival of both planted spat-on-shell and existing oysters (those on the reef prior to restoration), based on a 32-year average mortality rate on a bar (Pagan Bar) within the St. Marys Sanctuary from the MD DNR Fall Oyster Survey (Tarnowski 2017).

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

Out-year annual survival rate = 78 percent

Existing oysters on reef: Annual survival rate = 78 percent

Initial, spat-on-shell 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 spat on shell seeding target is 5 million per acre. Assuming 500-600 shells per bushel, this equates to planting a minimum of 800 bushels of spat-on-shell 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 spat-on-shell. 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 spat-on-shell 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 spat-on-shell per acre. If higher density seed is used (ex: 1.5 million spat per tank), then additional spat-on-shell 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 spat-on-shell. 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 2,000,000 per acre, but actual second plantings will be based on the year 3 monitoring densities.

Section 7.2: Substrate Needs and Cost Analysis

A projected 12,719 cubic yards of substrate are needed to implement the tributary plan (8.7 acres). This projection assumes that 7.1 acres of substrate reefs in the St. Marys River Sanctuary will be built at a height of 12 inches and 1.6 acres of reef will 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, while constructing 6-inch-high reefs requires 806.5 cubic yards of substrate per acre.

The total projected cost for building reefs with substrate is $869,000 (Table 6). This includes preconstruction sonar, substrate deployment, and postconstruction sonar where substrate is placed to ensure that there are no high spots during construction to ensure 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 construction 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 St. Marys 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, noncalcium 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, but is not being considered as a substrate for the St. Marys restoration.

Substrate and seed restoration is projected to begin in 2021 (Table 7), however, this is dependent on the date of issuance for the tidal wetlands permits needed for substrate construction.

Table 6. St. Marys River sanctuary estimated substrate and cost.

Reef Treatment	Suitable Acres for Restoration	Substrate Required per Acre (cubic yards)	Substrate Cost*†
Seed Only	15.8	0	0
Substrate and Seed- 12" reef base	7.1	1,613	$781,000
Substrate and Seed- 6" reef base	1.6	806.5	$88,000
Premet**	35.1	0	0

* Assumes a 12-inch reef height is $110k per acre and a 6-inch reef height is $55k per acre.
**Premet Reefs meet density and biomass targets prior to restoration work in the river.
†Does not include cost estimate for 0.14 acres of reef balls.

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	2024	2026
Substrate and Seed	2021	2024	2025	2027
Premet**	N/A	2022	2023	2025
*As reef construction and hatchery production allow. **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.				

Section 8: Monitoring

Section 8.1: Monitoring for Oyster Metrics Criteria:

The main objective of monitoring efforts in the St. Marys River Sanctuary is to determine if restored reefs meet the success criteria of the Oyster Metrics standards. 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 St. Marys 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 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 weight/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 weight 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 two year classes at 6 years 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	Suitable Acreage for Restoration	Assessment Protocol	Estimated cost for 1st monitoring	Estimated cost for 2nd monitoring	Total Estimated Cost
Seed Only	15.8	Patent tong***	$22,120	$22,120	$44,240
Substrate – rock*	8.7	Diver**	$20,880	$20,880	$41,760
Substrate – mixed shell*	8.7	Patent tong***	$12,180	$12,180	$24,360
Premet****	35.1	Patent tong***	$49,140	$49,140	$98,280

*Undetermined which substrate to be used for restoration.
**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.

Section 8.2: Diagnostic Monitoring

In addition to monitoring to evaluate restored reefs per the Oyster Metrics criteria, it is wise to include further monitoring that will help determine the causes of the success or failure. These are deemed "diagnostic" monitoring parameters. These include water quality and oyster disease parameters. Understanding these parameters alongside metrics of restoration success will allow practitioners to understand not only whether or not the project succeeded, but why. Water quality monitoring costs were developed assuming the following: water quality (dissolved oxygen, salinity, conductivity, temperature, pH, turbidity, and chlorophyll a) costs were developed using a YSI EXO2 single continuous monitor data logger deployed on a pier within the sanctuary. Monitoring will occur 12 months per year. Alkalinity, total suspended solids, ammonium, phosphate, nitrite, nitrite + nitrate, total nitrogen, and total phosphorus will be measured monthly when the sensors are changed in the data logger. Oyster disease information will be obtained from the MD DNR Fall Oyster Survey.

Section 9: Management

The Upper St. Marys 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 St. Marys River Sanctuary.

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Appendix A

Upper St. Marys River Restorable Bottom Assessment 02/25/2019

Background

This document identifies the potential area suitable for oyster restoration in the St. Marys River Sanctuary based on existing spatial data. GIS layers were geoprocessed using decision thresholds similar to those used for the other Maryland restoration projects. Some of these values will change after the 2018 systematic patent tong survey results are incorporated. The final products in this draft are:

1. An inventory of available restoration-relevant spatial data,
2. An estimate of "evidence-based" restoration target of Currently Restorable Oyster Habitat, (CROH) based on side-scan sonar and patent tong survey data,
3. A draft estimate of Historic Oyster Habitat (HOH),
4. Estimate of area that currently meets the restoration density target (50 live oysters/m^2), and
5. An estimate of the total area that could be restored with Substrate-and-Seed and Seed Only methods given a series of spatial constraints.

Summary 1: Targets and Restorable Bottom Estimates (Prior to the 2018 Systematic Oyster Survey)

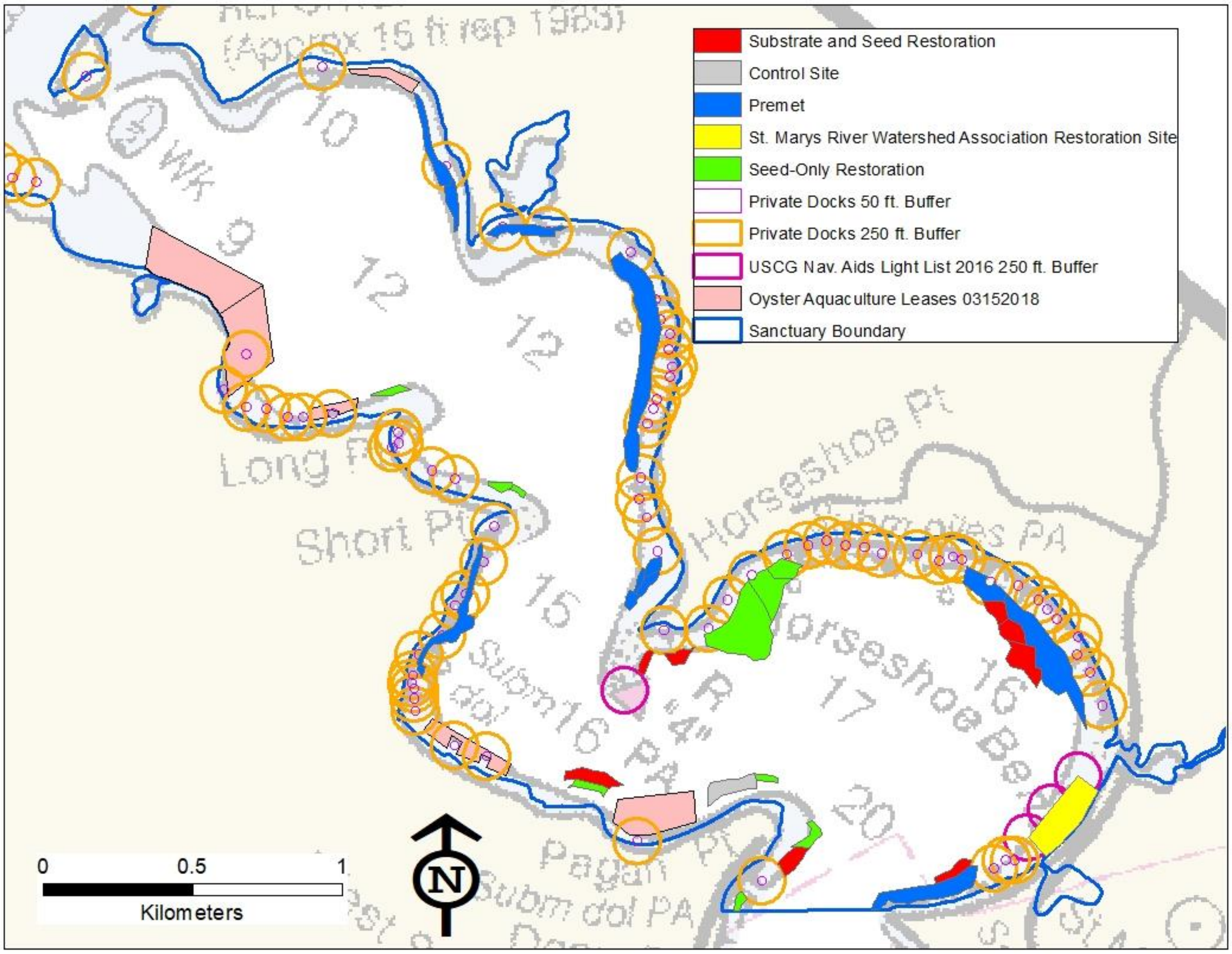
Currently Restorable Oyster Habitat (CROH) target (min. depth = 4.0 ft. MLLW)	**69.8 acres**
50% of CROH target	**34.9 acres**
Area meeting the restoration density target (50 live oysters/m^2, min. depth = 4.0 ft. MLLW)	**25.8 acres**
Estimated bottom suitable for Substrate and Seed restoration (min. depth = 7.0 ft. MLLW)	**12.8 acres**
Estimated bottom suitable for Seed Only Restoration (min. depth = 4.0 ft. MLLW)	**18.8 acres**
Sum area: meets target + Substrate + Seed Only	**57.4 acres**
Percent of CROH that meets target + Substrate + Seed Only	**82.2%**

Summary 2: Restorable Area (Prior to the 2018 Systematic Oyster Survey)

	Layer	Area (acres)	Data Source
	Sanctuary	1304	MD DNR
	Bottom Survey Extent (source area)	1053.9	MGS & DNR
Substrate and Seed area			
Step	Geoprocessing Layer	Area Remaining After Geoprocessing (acres)	
1	Depth 6-20 ft. (inclusion)	826.2	New St. Marys Bathymetry Grid
2	Mud and Shell Dominant Bottom (exclusion)	35.7	NCBO CMECS Habitat Characterization
3	Interpolated Oyster Density >= 5 animals/sq. meter (exclusion)	24.6	DNR Patent Tong Survey 2012 & 2015
4	Existing Oyster Leases (exclusion)	23.9	DNR Aquaculture Tool
5	Navigation Aid Buffers 250 ft (exclusion)	23.2	2016 USCG Light List
6	Private Dock 250 ft Buffers (exclusion)	17.3	2003 Orthophoto
7	MGO & Watershed Association Sites (exclusion)	17.3	DNR & Watershed Association
8	St. Mary's College Reef Site (exclusion)	17.3	Watershed Association
9	SAV 2007-2016 Boundary (exclusion)	17.2	VIMS
10	Polygons < 0.5 acres (exclusion)	14.2	
11	Depth < 7 ft. (exclusion; allows 6 ft. clearance over 1 ft. reef) Final Substrate Area (10 polygons, 0.53 – 3.0 acres)*	12.8	New St. Marys Bathymetry Grid
Seed Only area			
Step	Geoprocessing Layer	Area Remaining After Geoprocessing (acres)	
1	Depth 4-20 ft. (inclusion)	914.6	New St. Marys Bathymetry Grid
2	Shell Dominant Bottom (inclusion)	43.3	NCBO CMECS Habitat Characterization
3	Interpolated Oyster Density ≥ 50 animals/sq. meter (exclusion)	27.4	DNR Patent Tong Survey 2012 & 2015
4	Existing Oyster Leases (exclusion)	25.2	DNR Aquaculture Tool
5	Navigation Aid Buffers 250 ft. (exclusion)	23.9	2016 USCG Light List
6	MGO & Watershed Association Sites (exclusion)	23.2	DNR & Watershed Association
7	St. Mary's College Reef Site (exclusion)	23.2	Watershed Association
8	SAV 2007-2016 Boundary (exclusion)	23.2	VIMS
9	Final Seed Only Area (11 polygons, 0.5-7.1 acres, slivers deleted)*	18.8	

NCBO=National Oceanic and Atmospheric Administration Chesapeake Bay Office, CMECS=Coastal and Marine Ecological classification Standard, DNR=Department of Natural Resources, USCG=U.S. Coast Guard, VIMS=Virginia Institute of Marine Science, MGO=Marylanders Grow Oysters, MGS=Maryland Geological Survey, SAV=submerged aquatic vegetation
*NOTE: These are irregular boundaries that provide an estimate of the footprint of the actual blueprint. Final total area of blueprint sites may be slightly smaller (simplify boundaries) or slightly larger (expand boundaries) based on case-by-case consensus.

Summary 3: Restorable Area Map (Prior to the 2018 Systematic Oyster Survey)

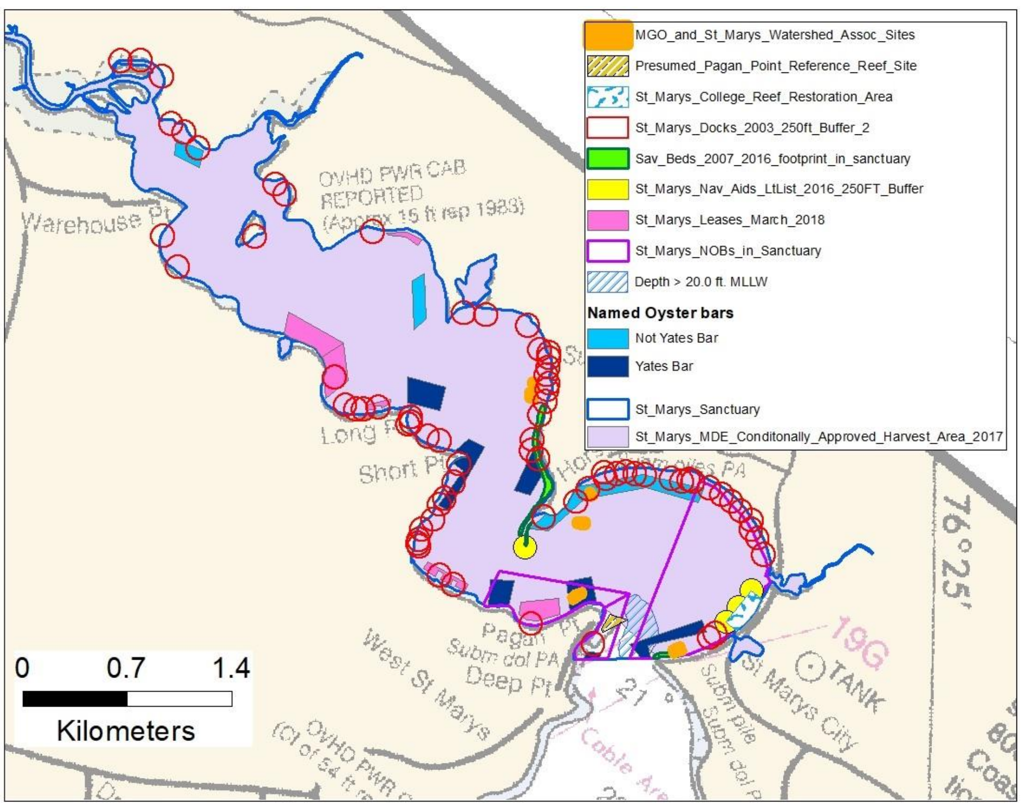


Seed-only restorable bottom that intersects with dock buffers has not been removed in the above map and in restorable bottom estimates. If intersection with the 250-foot buffer is removed, then seed-only restorable bottom decreases from 18.8 acres to 14.8 acres. If intersection with the 50-foot buffer is removed, then seed-only restorable bottom decreases from 18.8 acres to 18.2 acres.

NOTE: Restoration area present here is described by irregular boundaries that provide an estimate of the footprint of the actual blueprint. For the Little Choptank and the Tred Avon rivers, the final blueprint was edited collaboratively by DNR and NOAA based on examination of all available spatial data. Final total area of blueprint sites may be slightly smaller (simplify boundaries) or slightly larger (expand boundaries) based on case-by-case consensus and by availability of more current survey data.

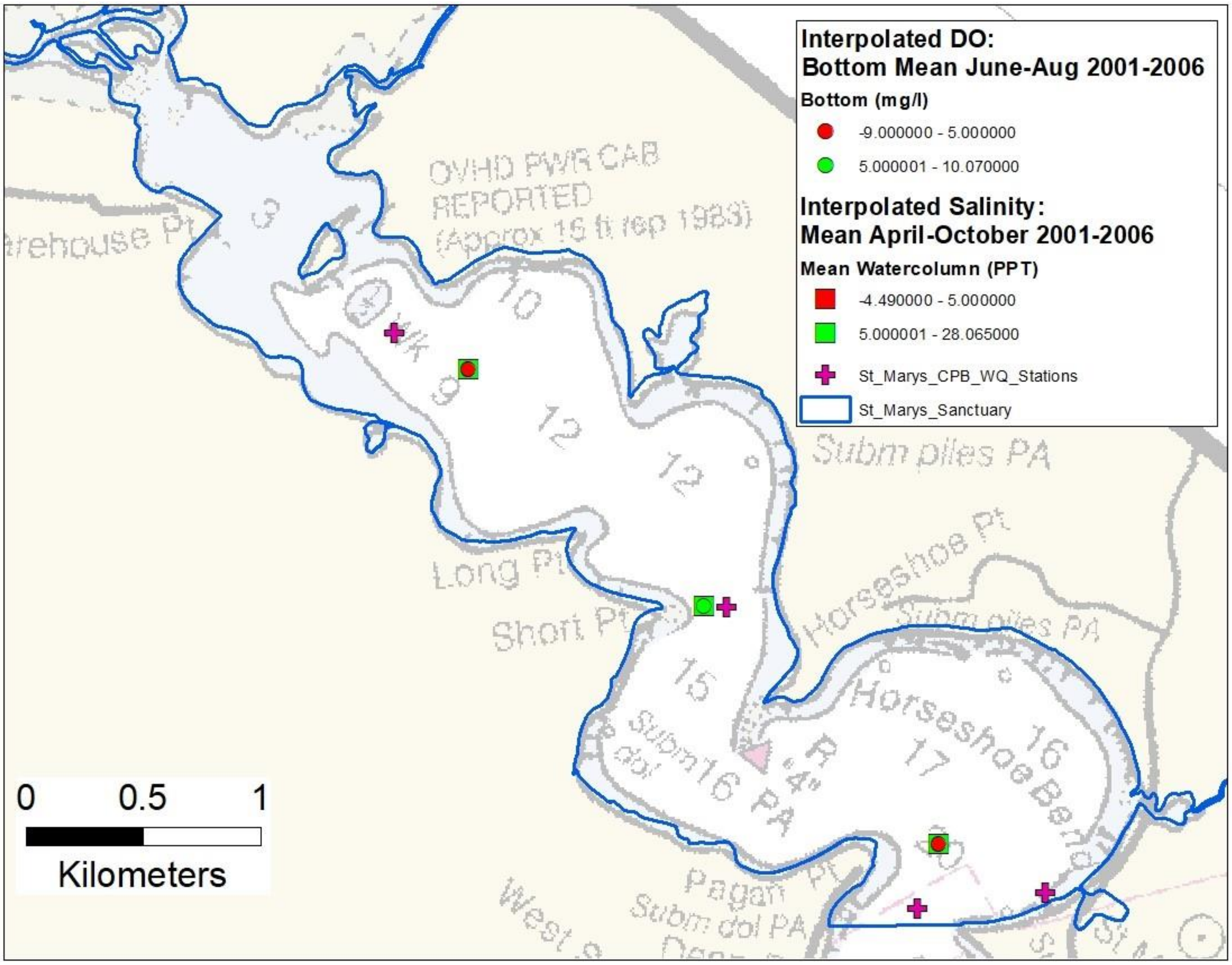
Spatial Data Inventory

Category	Number of polygons	Acres
Sanctuary Boundary	1	1303.7
MDE Conditionally Approved Harvest Area	1	1280.3
Benthic Habitat Characterization Footprint	71	1059.9
NOBs in Sanctuary	3	211.7
Named Oyster Bars in Sanctuary	10	88.9
Yates Bars in Sanctuary (Subset of named)	6	53.4
Leases in Sanctuary	6	36.0
Depth greater or equal to 20 ft.	1	20.1
SAV Footprint 2007-2016	3	7.7
Marinas	0	0
Docks 250 ft. Buffer	73	329.1
Maintained Navigation Channels	0	0
MGO & Watershed Association Restoration Sites	8	1.8
St. Marys River Watershed Association Restoration Reef Site Boundary	1	6.6
Pagan Point Reference Site (presumed)	1	2.2



Interpolated Salinity and Dissolved Oxygen

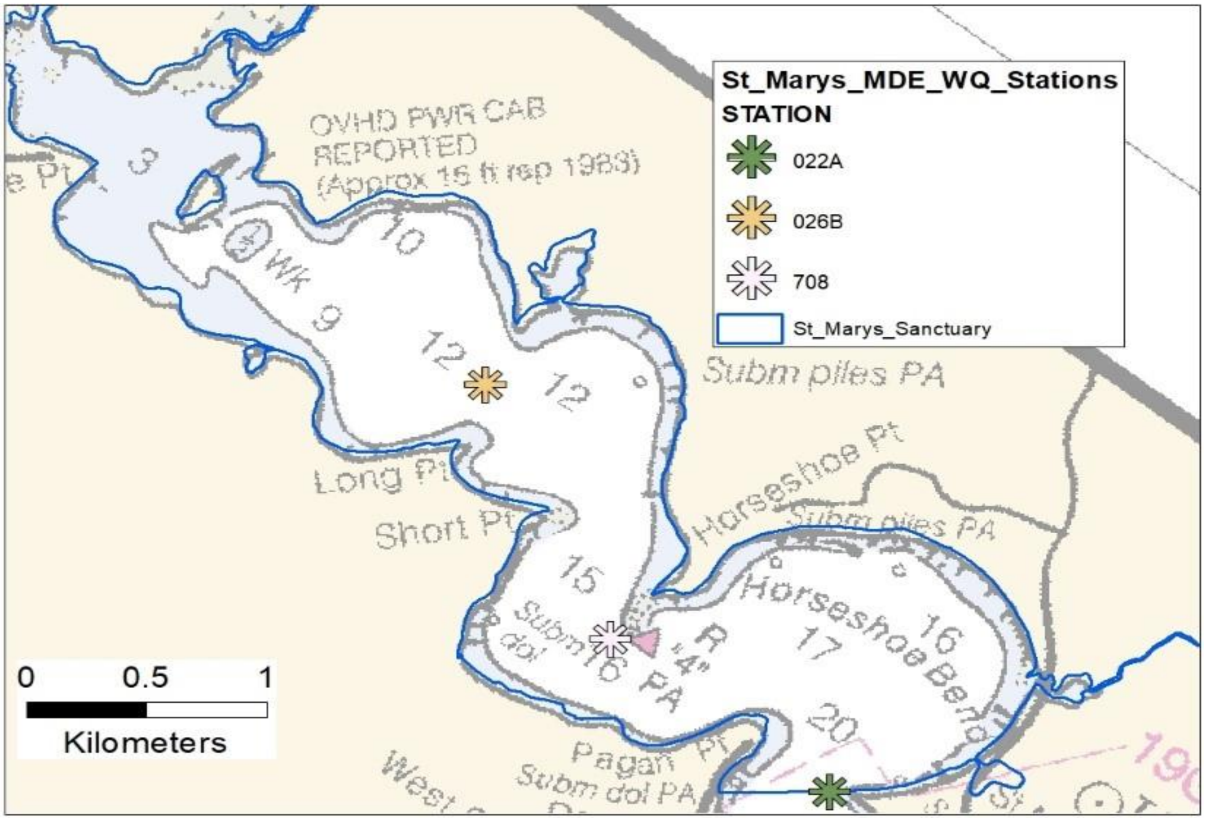
U.S. Army Corps of Engineers Master Plan Criteria



Interpolated water quality data are based on field samples collected at the Chesapeake Bay Program monitoring sites 2001-2006 and were derived with the Chesapeake Bay Interpolator. The U.S. Army Corps of 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 dissolved oxygen 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 dissolved oxygen levels may be critical (red circles) in the deeper areas of the central river channel.

Recent Observed Salinity and Dissolved Oxygen

Maryland Department of the Environment Sampling Sites



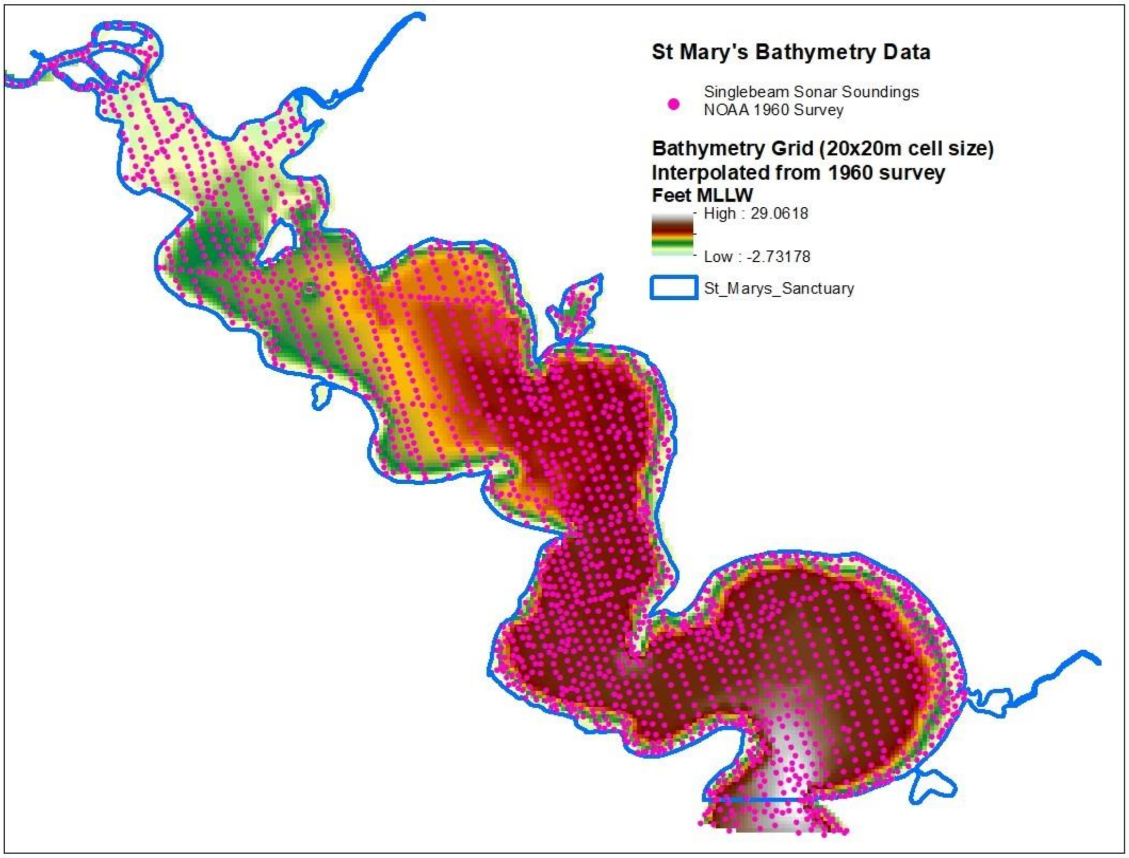
Maryland Department of the Environment Water Quality Surface Salinity Summary: April-October

Station	Year	Rainfall Year	Average of Salinity	Std. Dev of Salinity	Q1 of Salinity	Median of Salinity	Q3 of Salinity
All	2009	Dry	12.43	2.37	11.20	12.50	14.20
All	2010	Wet	12.76	2.52	11.20	12.75	14.60
All	2011	Wet	11.62	2.91	9.90	11.80	13.78
All	2012	Average	12.77	2.54	11.20	12.75	14.70
All	2013	Average	12.55	2.41	11.20	12.45	14.45
All	2014	Average	12.30	2.54	10.60	12.10	14.33
All	2015	Dry	12.61	2.40	11.20	12.60	14.38
All	2016	Average	12.65	2.50	11.23	12.75	14.38
		All	12.43	2.56	10.90	12.50	14.50

Maryland Department of the Environment Surface Dissolved Oxygen (DO) Summary: May to September

Station	Year	Rainfall Year	Average of DO (mg/L)	Std. Dev of DO (mg/L)	Q1 of DO (mg/L)	Median of DO (mg/L)	Q3 of DO (mg/L)
All	2009	Dry	7.56	0.27	7.38	7.55	7.73
All	2010	Wet	6.94	0.99	6.70	7.20	7.50
All	2011	Wet	7.28	0.82	6.50	7.15	7.75
All	2012	Average	7.51	1.29	6.93	7.65	8.50
All	2013	Average	7.94	1.36	7.73	7.85	8.58
All	2014	Average	8.00	1.50	6.73	7.65	9.08
All	2015	Dry	7.75	1.16	6.90	7.50	8.10
All	2016	Average	6.73	1.55	5.68	6.10	7.38
		All	7.48	1.20	6.63	7.45	8.18

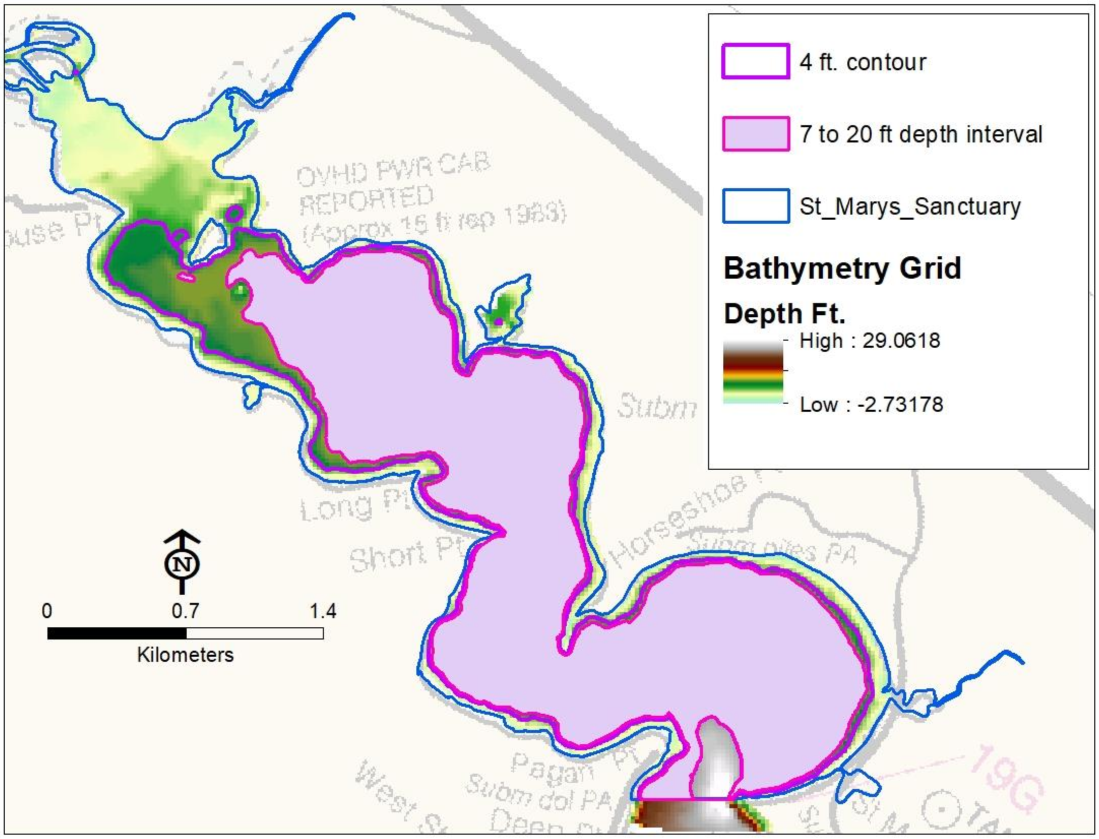
St. Marys Sanctuary Depth Model



Restoration planning in Harris Creek, Little Choptank, and Tred Avon planning used the Baywide Bathymetry Grid developed by the Chesapeake Bay Program (CBP). The CBP model was deficient in the St. Marys in that there were no 4-foot grid cells.

Point data from 1960 survey soundings (source data for the CBP grid and NOAA navigation charts) were interpolated into a new grid (above). 4-, 6-, 7-, and 20-foot (MLLW) contours were extracted from the new grid and were used to define restoration depth limits.

Depth Contours

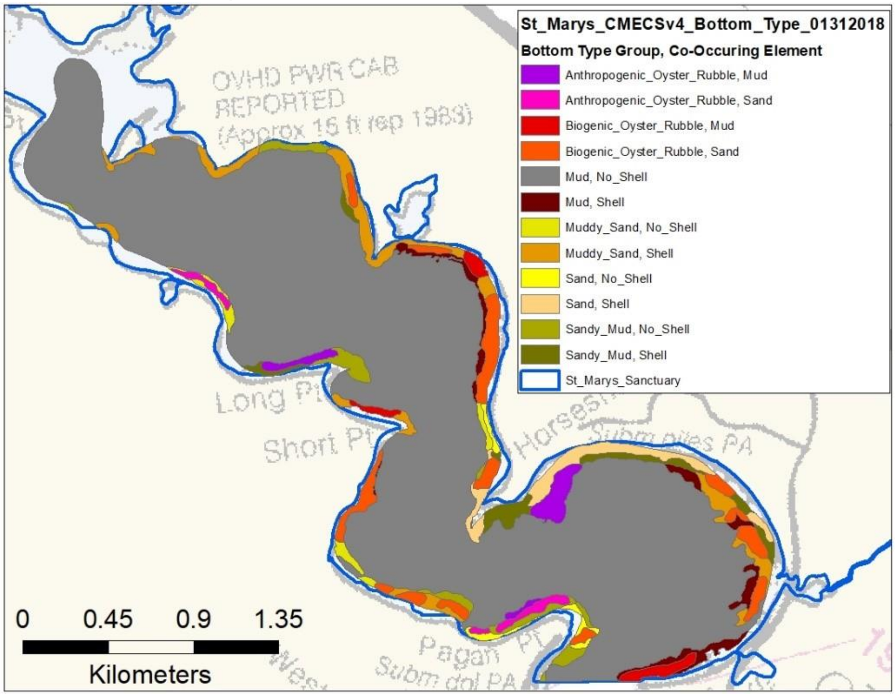


Depth data for the St. Marys Sanctuary. The U.S. Army Corps of Engineers Master Plan absolute criteria for maximum depth is 20 feet MLLW.

Targeted depths determined by the restoration workgroup are:
Seed-Only: 4-20 feet
Substrate-and-Seed: 7-20 feet

Bottom Type

(Based on Maryland Geological Survey 2010 Habitat Characterization Updated with 2012 & 2015 Patent Tong Data)



Area Summary: Existing Benthic Habitat Based on Survey Data

Bottom Type Group	Co-Occurring Element	Number Polygons	Sum Acres	Percent
Muddy Sand	No Shell	6	7.6	0.7
Anthropogenic Oyster Rubble	Sand	3	7.7	0.7
Sand	No Shell	5	8.5	0.8
Biogenic Oyster Rubble	Mud	3	9.9	0.9
Anthropogenic Oyster Rubble	Mud	3	14.6	1.4
Sandy Mud	Shell	7	14.7	1.4
Sandy Mud	No Shell	10	20.0	1.9
Sand	Shell	4	20.5	1.9
Mud	Shell	8	20.7	2.0
Muddy Sand	Shell	13	36.7	3.5
Biogenic Oyster Rubble	Sand	13	39.1	3.7
Mud	No Shell	1	854.1	81.0
Totals			1053.9	100.0

Restorable Bottom Target Estimates

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 Restorable Oyster Habitat (CROH) for depth >= 4 ft. MLLW

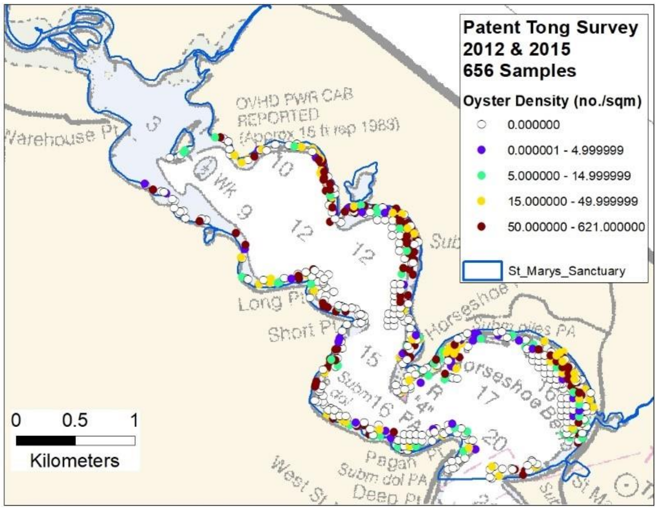
Bottom Type Group	Co-Occurring Element	Sum Acres
Anthropogenic Oyster Rubble	Sand	3.9
Sand	Shell	6.4
Biogenic Oyster Rubble	Mud	6.6
Anthropogenic Oyster Rubble	Mud	11.6
Muddy Sand	Shell	19.5
Biogenic Oyster Rubble	Sand	21.7
	Sum Acres (CROH) =	69.8
	50% of CROH=	34.9

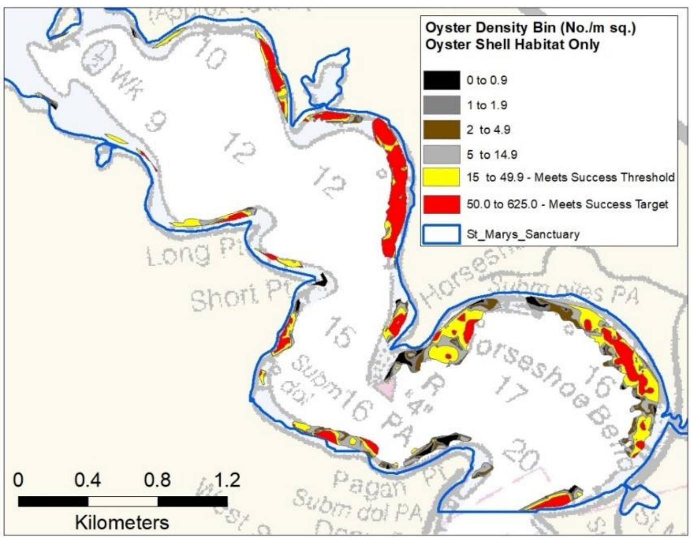
NOTE: St. Marys River Watershed Association restoration site (~6 acres) is not captured in above table.

Method 2: Historic Oyster Habitat (HOH) based on the Yates survey of 1911 and named oyster bar "Additions." Consistent with the U.S. Army Corps of Engineers (USACE) Native Oyster Restoration Master Plan, the actual restoration target would range from 8-16% of HOH.

REGION	BARNAME	COUNTY	YATES BARS	AREA (ACRES)
UPPER ST. MARYS RIVER	BISCOE	SM	Yates	6.3
UPPER ST. MARYS RIVER	BRYAN	SM	Yates	10.0
UPPER ST. MARYS RIVER	HORSESHOE BEND	SM	Addition	24.3
UPPER ST. MARYS RIVER	HORSESHOE	SM	Yates	8.4
UPPER ST. MARYS RIVER	MARTIN POINT	SM	Addition	6.1
UPPER ST. MARYS RIVER	PAGAN	SM	Yates	8.1
UPPER ST. MARYS RIVER	SEMINARY	SM	Yates	9.4
UPPER ST. MARYS RIVER	SHORT POINT	SM	Yates	10.3
UPPER ST. MARYS RIVER	TIPPITY WITCHITY	SM	Addition	5.1
UPPER ST. MARYS RIVER	WEST ST. MARYS	SM	Yates	1.1
			Sum Acres (HOH) =	88.9
			16% of HOH =	14.2
			8% of HOH =	7.1

Live Oyster Density (2012 & 2015 DNR Surveys)





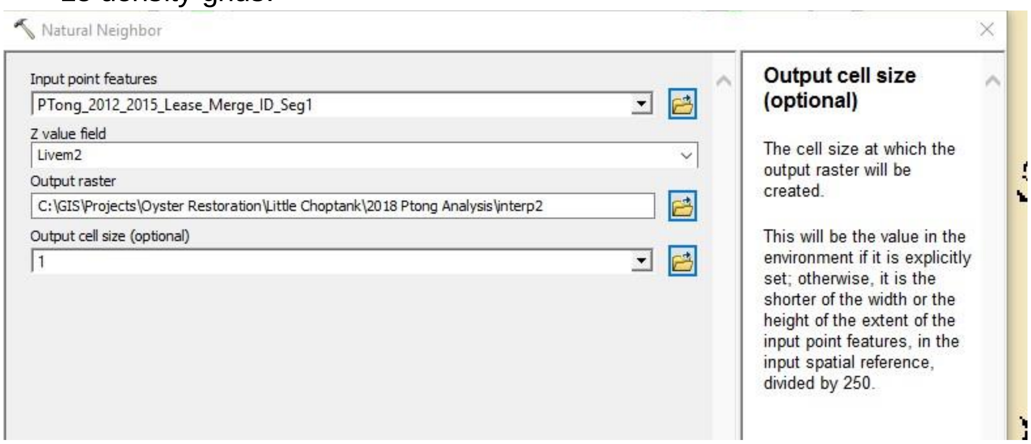
Interpolated Oyster Density Area Summary Table. Depth ≥ 4 ft. MLLW

Live Oyster Density per square meter Bin	Number Polygons	Sum Acres
0 to 0.9	205	5.5
1 to 1.9	309	4.2
2 to 4.9	129	9.7
5 to 14.9	75	13.8
15 to 49.9	24	24.2
50.0 to 625.0 (meets target)	58	25.8
Totals	800	83.1

NOTE: St. Marys River Watershed Association restoration site densities are not captured here.

Methods Used to Estimate Area That Meet Restoration Success Threshold (15-49 oysters/m^2) and Target (≥ 50 oysters/m^2) Densities

1) Source data: 2012 & 2015 regular patent tong survey merged with 2012 tong survey of selected leases (filename:PTong_2012_2015_Lease_Merge)
2) Separate survey points into 15 shoreline segments. This is done so interpolation does not cross the river or cross land.
3) Remove points that are within CMECS mud polygons. No interpolation from samples non-oyster habitat.
4) Interpolate density points within each of the 15 shoreline segments, then merge the resulting 15 density grids.



5) Classify interpolated grid into bins of: 0, 1-1.9,2-4.9,5-14.9,15-49.9,& >= 50
6) Convert classified grid to polygons
7) Clip interpolated oyster density polygons with CMECS bottom type polygons with shell (both as a dominant component and as a co-occurring element). This is done so interpolated live oyster density is only identified for river bottom that has oyster shell. (filename:Interpolated_oyster_density_Merged).

   NOTE: This analysis will assign high oyster densities to bottom types classified as geological sediment with oyster shell as a co-occurring element (non-shell dominant bottom).

Substrate and Seed Restorable Bottom Geoprocessing Methods and Log

GEOPROCESSING TEMPLATE: 1-15-2013 Little Choptank River Restorable Bottom Assessment

Source ArcMap Project: St_Marys_Substrate_Seed_Blueprint_Geoprocess_MAP_03_14_2018

Source Geodatabase: St_Marys_River_Oyster_Restoration_BluePrint_GeoDatabase_02_08_2018.gdb

Source Polygon: STM_Habitat_Survey_Extent.

Area = 1053.9 acres.

Steps:

1) Clip with (keep inside)depth 6-20ft (Singlebeam_1960_6_to_20FT_Depth_Interval)

Ensures area within 6-20 ft. contour

Output polygons =SubstrateSeed_Step_1. Area = 826.2 acres. **DONE**

2) Delete CMECS mud and shell bottom polygons

Ensures area is on sand, sand & shell, muddy sand, muddy sand & shell, sandy mud, and sandy mud & shell.

Output polygons = SubstrateSeed_Step_2. Area = 35.7 acres. **DONE**

3) Erase (keep outside) oyster density >= 5per m sq. (interpolated_oyster_density_GT_5_ERASER).

Ensures bottom has live oyster densities < 5 per m. sq.

Output polygons =Subst_and_Seed_Step_3 . Area = 24.6 acres. **Done**

4) Erase (keep outside)lease bottom (St_Marys_Oyster_Aquaculture_Leases_03152018)

Ensures area not on leases

Output polygons =Subst_and_Seed_Step_4 (no intersection w/leases). Area = 23.9 acres. **Done**

5) Erase (keep outside)250 ft. navigation aid buffer (St_Marys_Nav_Aids_LtList_2016_250ft_Buffer)

Ensures area not adjacent to navigation aids

Output polygons =Subst_and_Seed_Step_5. Area = 23.2 acres. **Done**

6) Erase (keep outside)250ft Private Dock buffers (St_Marys_Docks_2003_250ft_Buffer).

Ensures area not adjacent to private docks

Output polygons = Subst_and_Seed_Step_6. Area =17.3 acres. **Done**

Substrate and Seed Polygons Continued

7) Erase (keep outside) MD Grows Oysters Sites (MGO and St_Marys_Watershed_Assoc_Sites).

   Ensures area not on MGO or Watershed Association Restoration Sites

   Output polygons = Subst_and_Seed_Step_7. Area =17.3 acres. **Done**

8) Erase (keep outside) College Reef Restoration Site (St_Marys_College_Reef_Restoration_Area).

   Ensures area not on St. Marys River Watershed Association Reef Site

   Output polygons = Subst_and_Seed_Step_8. Area =17.3 acres. **DONE**

9) Erase (keep outside) 2007-2016 SAV Beds (SAV_Beds_2007_2016_Footprint_in_sanctuary).

   Ensures area not on SAV bed location

   Output polygons = Subst_and_Seed_Step_9. Area =17.2 acres. **Done**

10) Merge Contiguous Polygons and delete all < 0.50 acres Area =14.2 acres. **Done**

11) Clip with 7 ft. contour. Area = 12.8 acres **Done**
    Ensures 6 feet of clearance over a 1 ft. reef.

    Output polygons = Subst_and_Seed_Step_11_FINAL_6ft_Clearance
    Area =12.8 acres.
    Total polygons = 10
    Minimum area = 0.53 acres
    Maximum area = 2.9 acres

    Note: Minimum area for reefs already constructed are

    Harris Creek – 0.47 acres

    Little Choptank – 0.18 acres

    Tred Avon – 0.74 acres

Seed Only

Restorable Bottom Geoprocessing Methods and Log

GEOPROCESSING TEMPLATE: 1-15-2013 Little Choptank River Restorable Bottom Assessment

Source ArcMap Project: St_Marys_Seed_Only_Blueprint_Geoprocess_MAP_03_15_2018

Source Geodatabase:
St_Marys_River_Oyster_Restoration_BluePrint_GeoDatabase_02_08_2018.gdb

Source Polygon: STM_Habitat_Survey_Extent.

Area = 1053.9 acres.

<u>Steps:</u>

1) Clip with (keep inside)depth 3-20ft (Bathy_3_20ft_Clipper)

   Ensures area within 4-20 ft. contour

   Output polygons =SeedOnly_1. Area 914.6 acres. **Done**

2) Clip with (keep inside) CMECS shell bottom (CMECS_Shell_Bottom_Clipper)

   Ensures area is on shell bottom

   Output polygons =SeedOnly _Step_2. Area 43.3 = acres. **Done**

3) Erase (keep outside)area with oyster density > 50.0/m**2 (Interpolated_oyster_density_GT_50_ERASER)

   Ensures area is not on bottom that meets density target metric.

   Output polygons =SeedOnly _Step_3. Area = 27.4 acres. **Done**

4) Erase (keep outside)lease bottom (St_Marys_Oyster_Aquaculture_Leases_03152018)

   Ensures area is not on existing oyster leases.

   Output polygons =SeedOnly _Step_4. Area = 25.2 acres. **Done**

5) Erase (keep outside)250 ft navigation aid buffer (St_Marys_Nav_Aids_LtList_2016_250ft_Buffer)

   Ensures area not adjacent to navigation aids

   Output polygons = SeedOnly_Step_5. Area = 23.9 acres. **Done**

6) Erase (keep outside) MD Grows Oysters Sites (MGO and St_Marys_Watershed_Assoc_Sites).

   Ensures area not on MGO or Watershed Association Restoration Sites

   Output polygons = SeedOnly_Step_6. Area= 23.2 acres. **Done**

Seed Only Continued

7) Erase (keep outside) College Reef Restoration Site (St_Marys_College_Reef_Restoration_Area).

Ensures area not on St. Marys River Watershed Association Reef Site

Output polygons = SeedOnly_Step_7. Area = 23.2 acres. **Done**

8) Erase (keep outside) 2007-2016 SAV Beds (SAV_Beds_2007_2016_Footprint_in_sanctuary).

Ensures area not on SAV bed location

Output polygons = SeedOnly_Step_8. Area = 23.2 acres. **Done**

9) Merge Contiguous Polygons and delete all < 0.5 acres

Output polygons = SeedOnly_Step_9_FINAL. Area = 18.8 acres.

Total polygons = 11

Minimum area = 0.51

Maximum area = 7.12 acres

Note: Minimum area for planted Seed-Only sites are

Harris Creek – 1.26 acres

Little Choptank – 0.7 acres

Tred Avon – 0.47 acres

a) Step 9 Less 50 ft. dock buffer.

   Output polygons = SeedOnly_Step_9_FINAL_less_50ft_dock_buff. Area = 18.2 acres.

b) Step 9 Less 250 ft. dock buffer.

   Output polygons = SeedOnly_Step_9_FINAL_less_250ft_dock_buff. Area = 14.8 acres.

St. Marys River Sanctuary Restoration Blueprint Version 03/19/2019

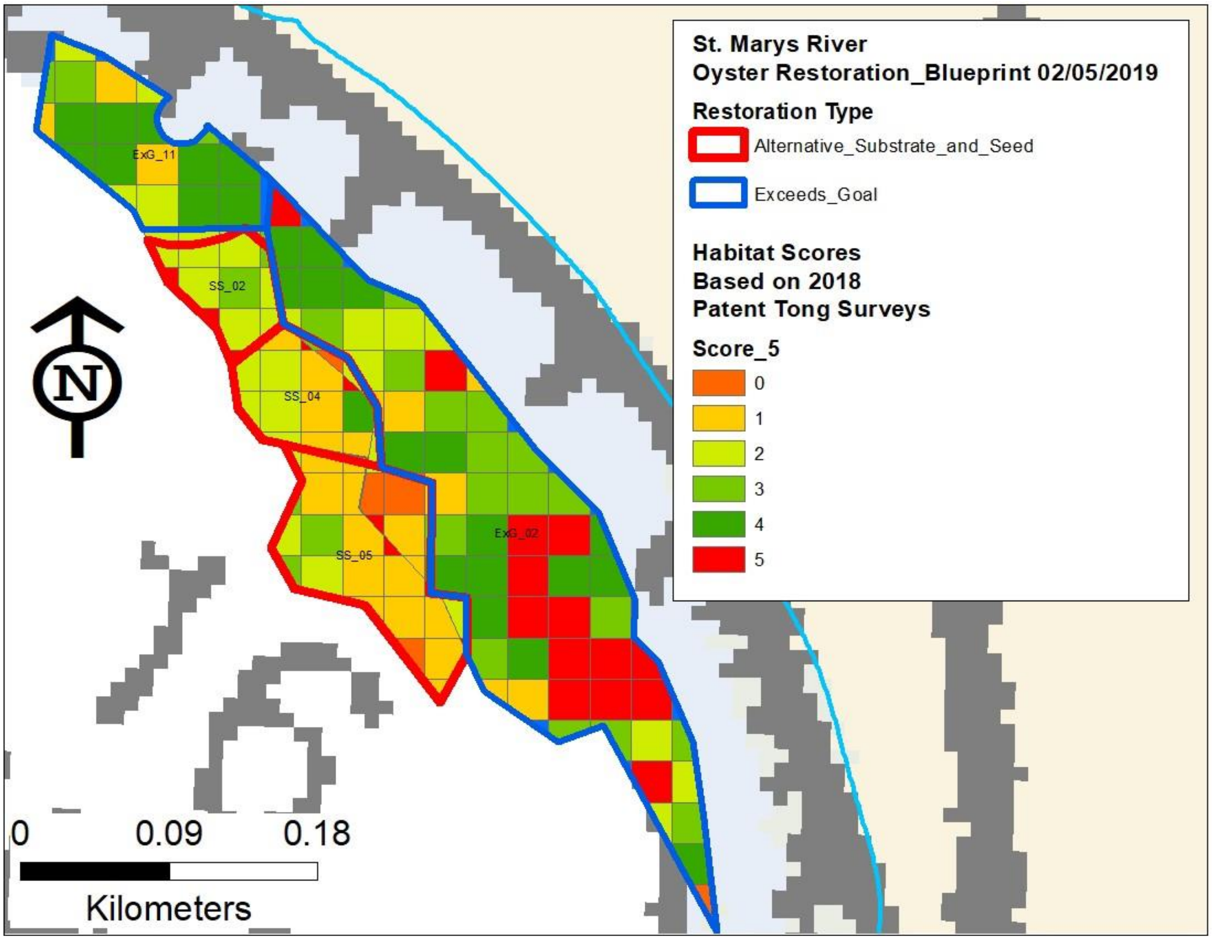


Figure Appendix A-1. In addition to general restoration criteria outlined below, boundaries of the 03/19/2019 Blueprint are based on ORP habitat quality scores derived from 2018 patent tong surveys. Boundaries were modified in January and February 2019.

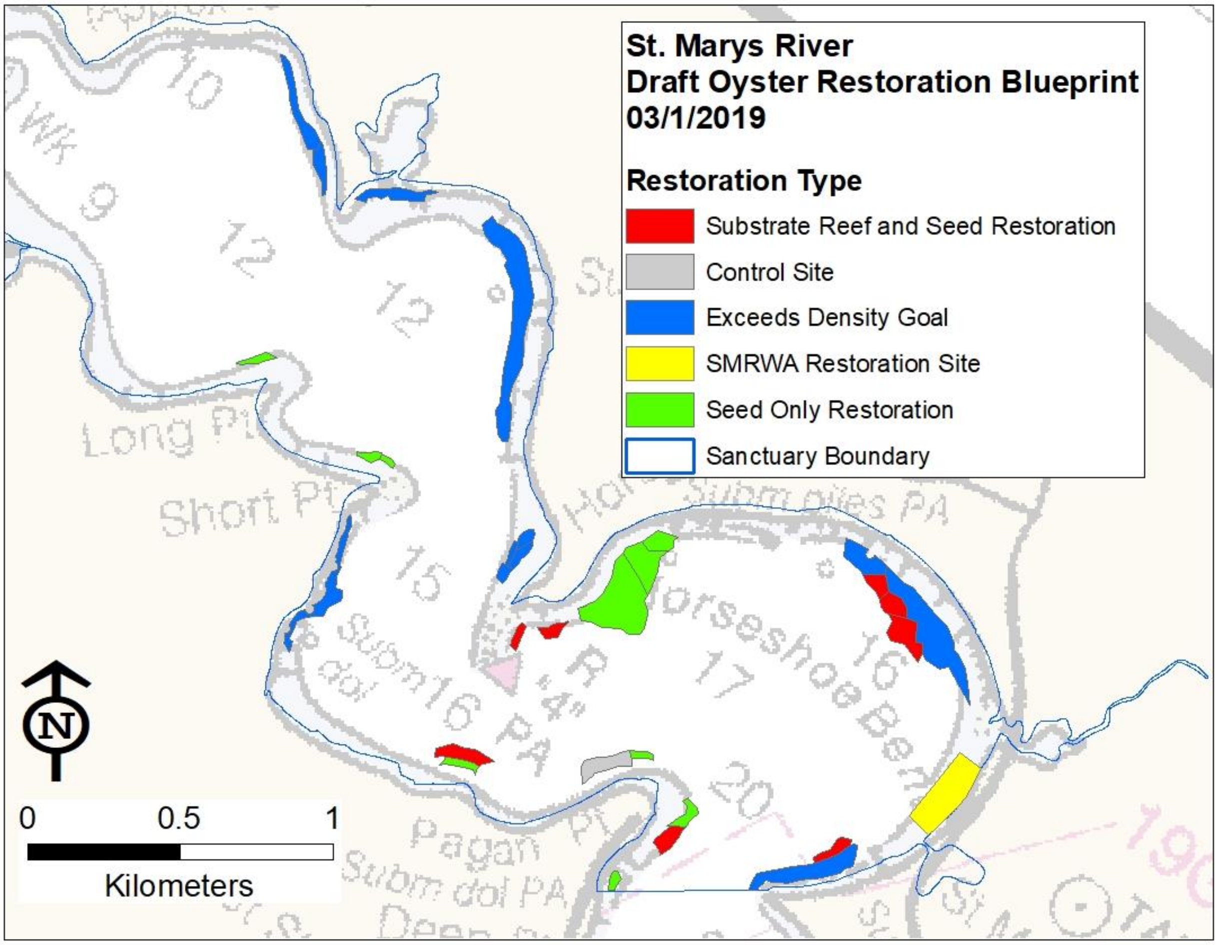


Figure Appendix A-2. St. Marys River oyster restoration blueprint version 03/19/2019.

Blueprint Area Summary

		Area (acres)		
Restoration Type	No. Sites	Minimum	Maximum	Sum
Seed Only	10	0.2	8.1	15.8
Substrate & Seed	8	0.5	2.4	9.7
Total Area (Seed only and Substrate Reefs)				25.5
Control-Site	1	2.0	2.0	2.0
Premet	12	0.3	10.2	35.1
SMRWA Restoration Site	1	6.6	6.6	6.6
Total Area (all sites)				69.3

General Seed-Only Restoration Criteria

- Depth: 4-20 ft.
- Bottom Type: on shell dominant bottom.
- Oyster Density: < 50 per sq. meter
- Lease Proximity: Not within 150 ft. of leases
- Navigation Aid Proximity: Not within 250 ft. of navigation aids
- Dock proximity: Not within 50 ft. of private docks
- SAV Proximity: No intersection with SAV beds

General Substrate and Seed Restoration Criteria

- Depth: 7-20 ft.
- Bottom Type: sand, sand & shell, muddy sand, muddy sand & shell, sandy mud, and sandy mud & shell (not on shell dominant bottom). And on hard subsurface sediments identified by sub-bottom profiling sonar.
- Oyster Density: < 5 per sq. meter
- Lease Proximity: Not within 150 ft. of leases
- Navigation Aid Proximity: Not within 250 ft. of navigation aids
- Dock proximity: Not within 250 ft. of private docks
- SAV Proximity: No intersection with SAV beds

Appendix B

2018 Patent Tong Data Methods and Analysis

Sampling Site

An oyster reef preconstruction site assessment survey was conducted to identify benthic habitat suitable for oyster population growth in the St. Marys River Sanctuary and to determine the type of restoration construction needed. Benthic habitat were 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 MD 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 MD DNR (Appendix A). Areas identified from this geospatial analysis were targeted for this systematic patent tong survey to groundtruth potential restoration sites.

Sampling Design

Sampling sites were 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 were removed from the sampling frame because they were 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 were sampled using a 25 x 25m systematic grid cell with sampling locations in the center of each grid.

Sample planning was coordinated by Oyster Recovery Partnership (ORP) and sample collection was managed by Versar, Inc. A chief scientist from Versar, Inc. guided the vessel crew and scheduled each daily sampling event. Sampling was conducted during daylight hours and generally required six to eight hours to complete. Navigation to sampling sites was 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 using patent tongs deployed from the F/V *Hooker*. Patent tongs are a specialized commercial fishing gear used to harvest oysters in the Chesapeake Bay (Figure 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 used were 1.16m by 1.27m patent tongs, which sampled a 1.47m^2 area of the bottom.

The coordinates of each patent tong sample were collected when the patent tongs reached the sediment surface. A DGPS antenna was positioned adjacent to the location where the patent tongs were deployed so no position offset was required. Once the grab was brought to the surface of the water, several qualitative measurements to document the depth of sediment covering shell (surface sediment), the percent of shell not covered by sediment (exposed shell), the amount of material in the sample (patent tong fullness), and the substrate composition were made from observations of the sample before the sample was brought onboard for processing (Figure 2; Table 1).

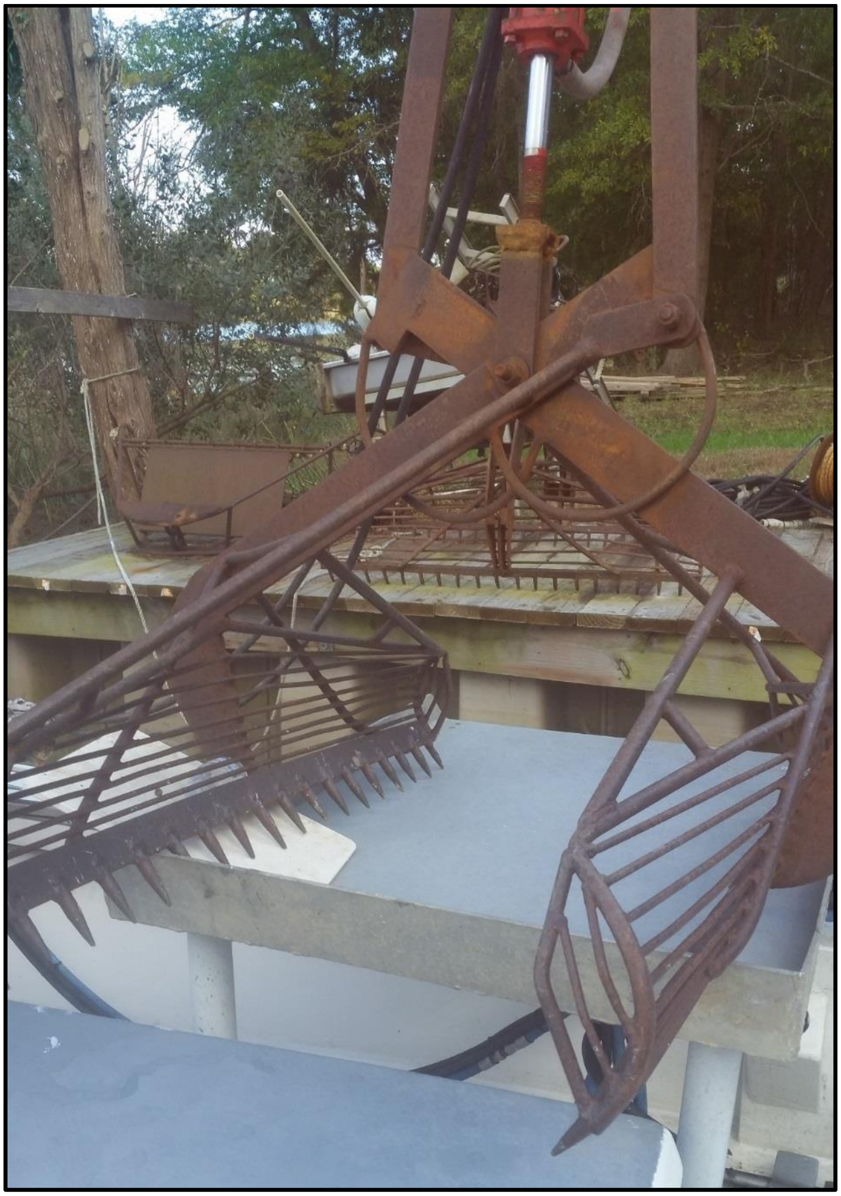


Figure Appendix B-1. Picture of patent tongs.

In each sample, all oysters were counted, identified as live or dead, and a minimum of 30 live oysters were measured for each sample. Oyster clumps, the number of oysters associated with a clump, and the substrate type that oysters were attached to were 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 were also documented from each sample. The percent of the sample covered by fouling organisms and specifically percent fouling by tunicates and mussels were documented for each sample as well. The volume of oysters and the volume of shell were measured for each sample. Percentage of gray shell and shell hash was assessed.

Surface and bottom water temperature, dissolved oxygen, pH, and salinity were collected during each sampling event at representative locations over each oyster reef using a 6600 multiparameter water quality sonde (YSI Corporation, Yellow Springs, Ohio). Other environmental and station specific variables collected at each site included sample number, date and time, depth of water, vessel name, and staff present.

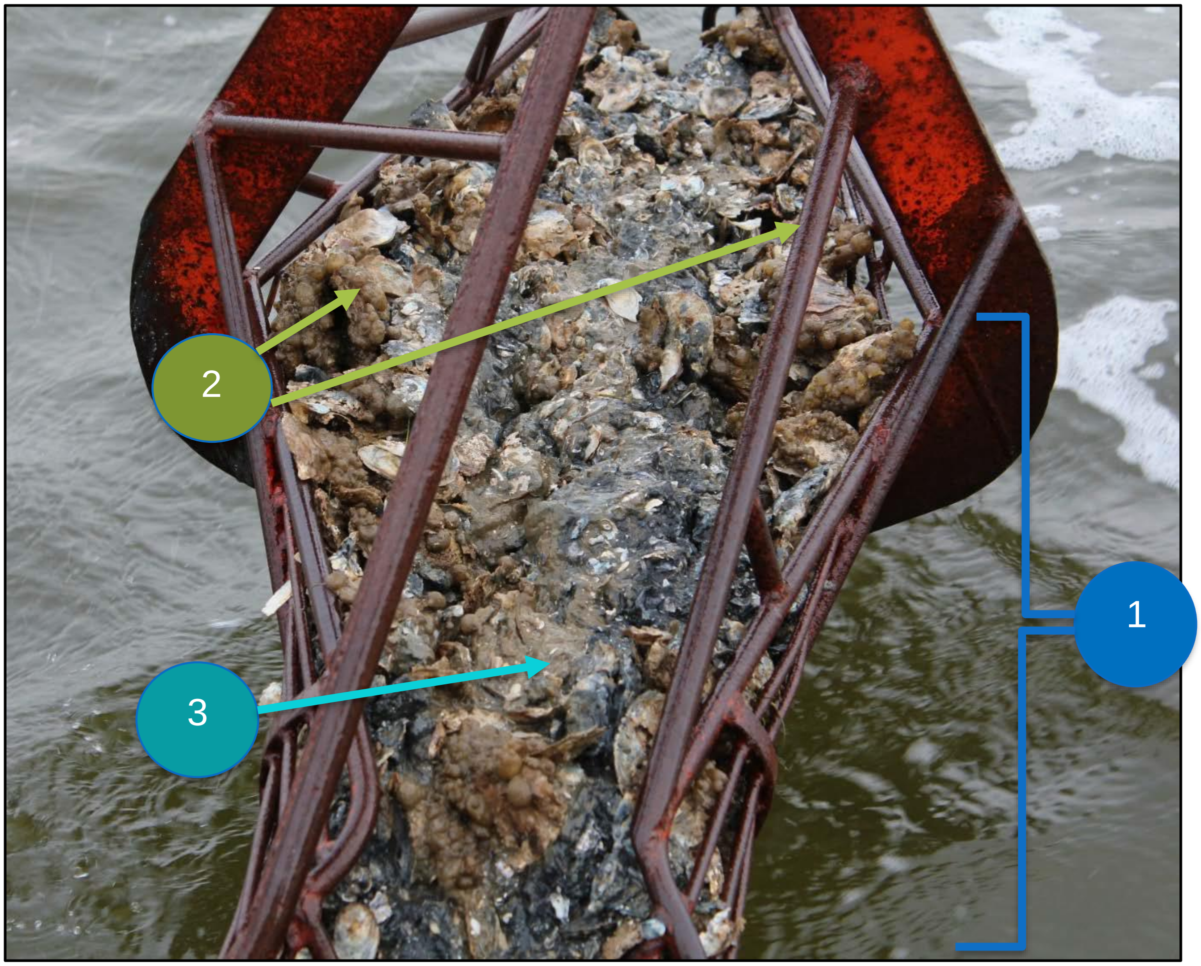


Figure Appendix B-2. Picture of representative patent tong sample. Numbers and arrows correspond to substrate characteristics documented before the sample was brought onboard for processing. Bubble 1 represents the portion of the sample that is observed to document the Patent Tong Fullness Index. Bubble 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 were compiled and entered into the ORP Oyster Restoration Monitoring and Assessment relational database. Quality control and assurance was performed on all survey data and included 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 were 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 percent 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. Percentage 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

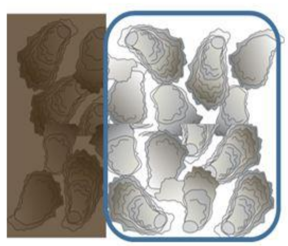
Two analytical approaches were used to determine if sites needed restoration, if they were suitable for restoration, and the type of restoration activity that would be required.

The first approach used determined whether a site needed 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 were calculated and standardized to number per m^2 from the area sampled by patent tong. Live oyster density was averaged over all samples collected at the individual site. Using the oyster shell heights collected in each patent tong sample, oyster biomass estimates were 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 was then summed for the entire sample and standardized using the same method as density estimates. Average biomass was calculated across all samples collected at the site.

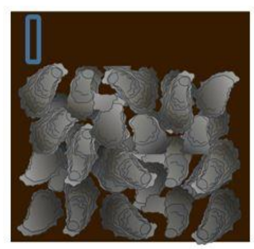
Sites with oyster density and biomass greater than 50 oysters and grams per m^2 over more than 30% of the site were determined premet and did not need initial restoration construction efforts.

The second approach used was an index of habitat quality to determine whether a site was suitable for restoration and if so, the type of restoration required. An index of habitat quality was developed to determine whether oyster habitat was 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 were used to develop the index (Figure 3):

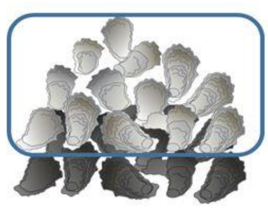
- Exposed Shell
- Primary Substrate and Secondary Substrate
- Surface Sediment
- Number of Live Oysters
- Surface Shell, calculated as = (Total shell volume x % gray shell) – total shell volume. (Total sampled shell and surface shell volume were estimated for each individual sample. Field measurements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



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



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



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

Figure. Appendix B-3. Graphical interpretation of Exposed Shell, Surface Sediment, and Surface Shell Volume variables for each patent tong sample. Base oyster graphics from Tracy Saxby, Integration 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 were considered predictors of the suitability of the bottom to support an oyster population through seed-only restoration construction or substrate and seed restoration construction. A set of criteria for each variable was developed to construct the final index of habitat quality (Table 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**
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.
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 were given a binary score expressed as a 1 or 0, with a result of 1 assumed to be suitable restoration construction and 0 being unsuitable. A final habitat suitability score for each grid cell was derived as the sum of each benthic component score at the individual grid cell using the equation:

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

The result of habitat suitability score determined whether a sampling grid cell was suitable for restoration construction based on a ranking between zero and five. Ranks of 1 or 2 being suitable for substrate and seed restoration, ranks of 3 requiring additional review, and ranks of 4 and 5 being suitable for seed only restoration. A rank of 0 was considered unsuitable for restoration.

The final habitat suitability index was entered into ArcMap (ESRI, Version 10.5) and all ranks for each site were 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 were visually inspected to determine whether a site was a candidate for restoration construction and the type of construction. Sites with a majority of 4- and 5-ranked sites were considered suitable for seed-only restoration construction. The site level resolution of samples also allowed for modifications to the dimensions of the site if areas of the site were considered suitable. Areas that were considered unsuitable could be removed through GIS processing techniques and the remaining habitat would be considered suitable for seed-only restoration construction (Figure 4 and 5). Areas that were ranked from 1-3 were considered for substrate and seed restoration.

Oyster density and biomass data were also assessed for each grid. If the oyster density and biomass were both greater than 50 oysters per m^2 and 50 grams per m^2 and covered an area of at least 30 percent of the reef, then the reef was considered premet for the restoration targets and was not considered for initial restoration construction. Final acreages for each restoration type determined from the systematic patent tong survey are reported in Table 3.

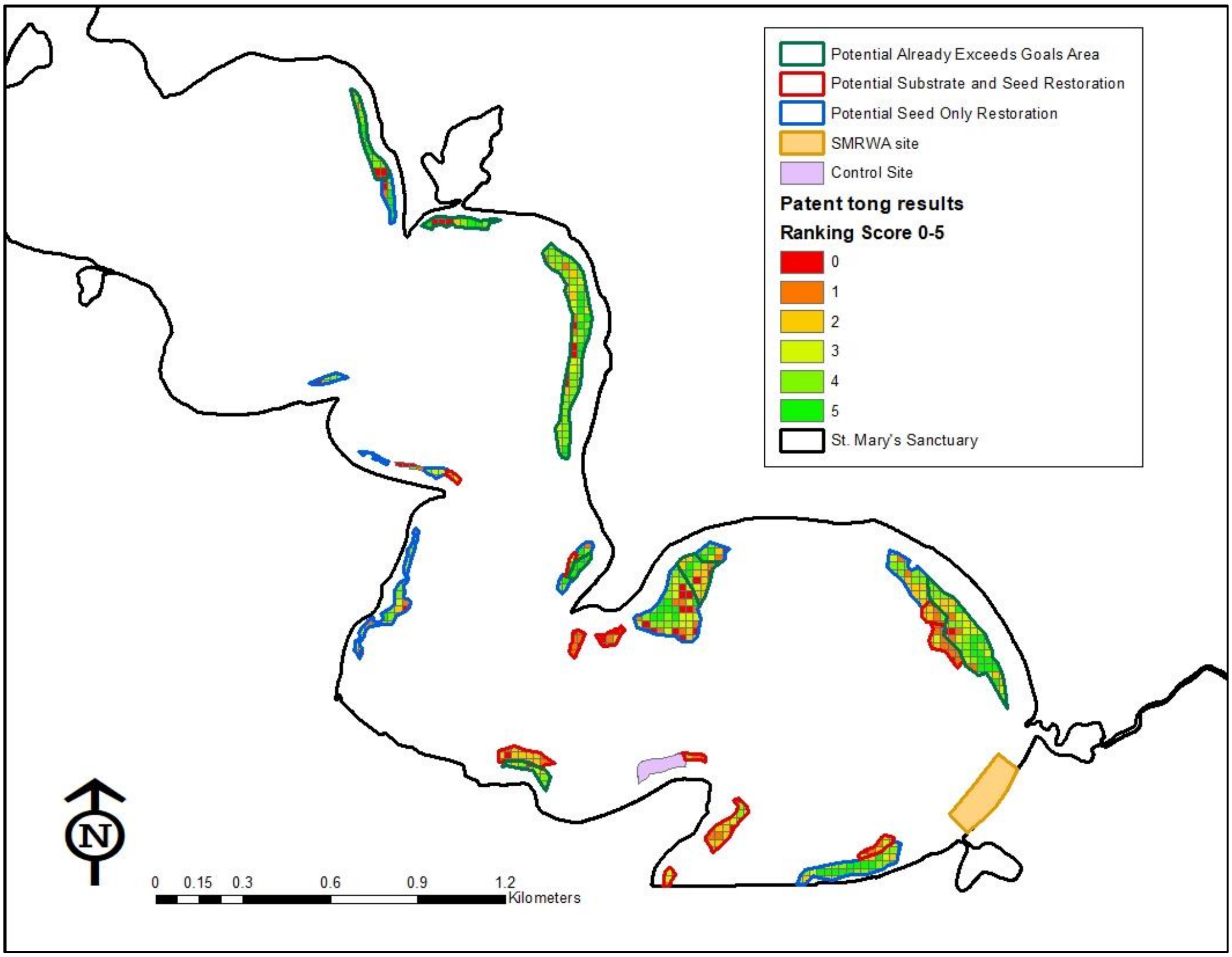


Figure Appendix B-4. Ranks from the patent tong survey to determine habitat suitability.

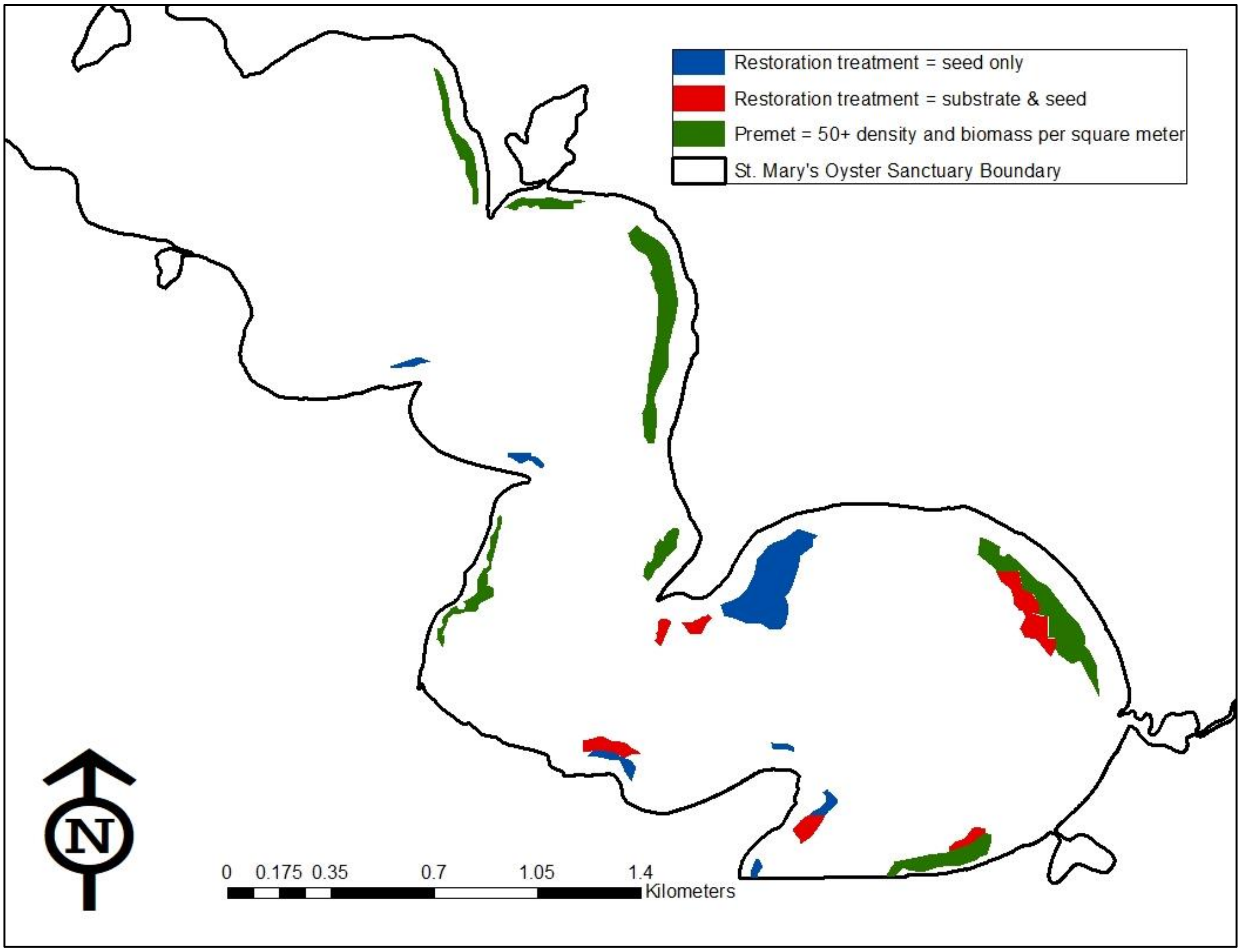


Figure Appendix B-5. Resulting restoration treatment on reefs determined from the patent tong analysis.

Table Appendix B-3. Revised acreages available for restoration after the systematic patent tong survey analysis.

	Preliminary Acreages	Revised Acreages
Premet*	27.4	35.1
Available Substrate and Seed Restoration	10.9	9.7
Available Seed Only Restoration	23.8	15.8
Available Total Area	62.1	60.6

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