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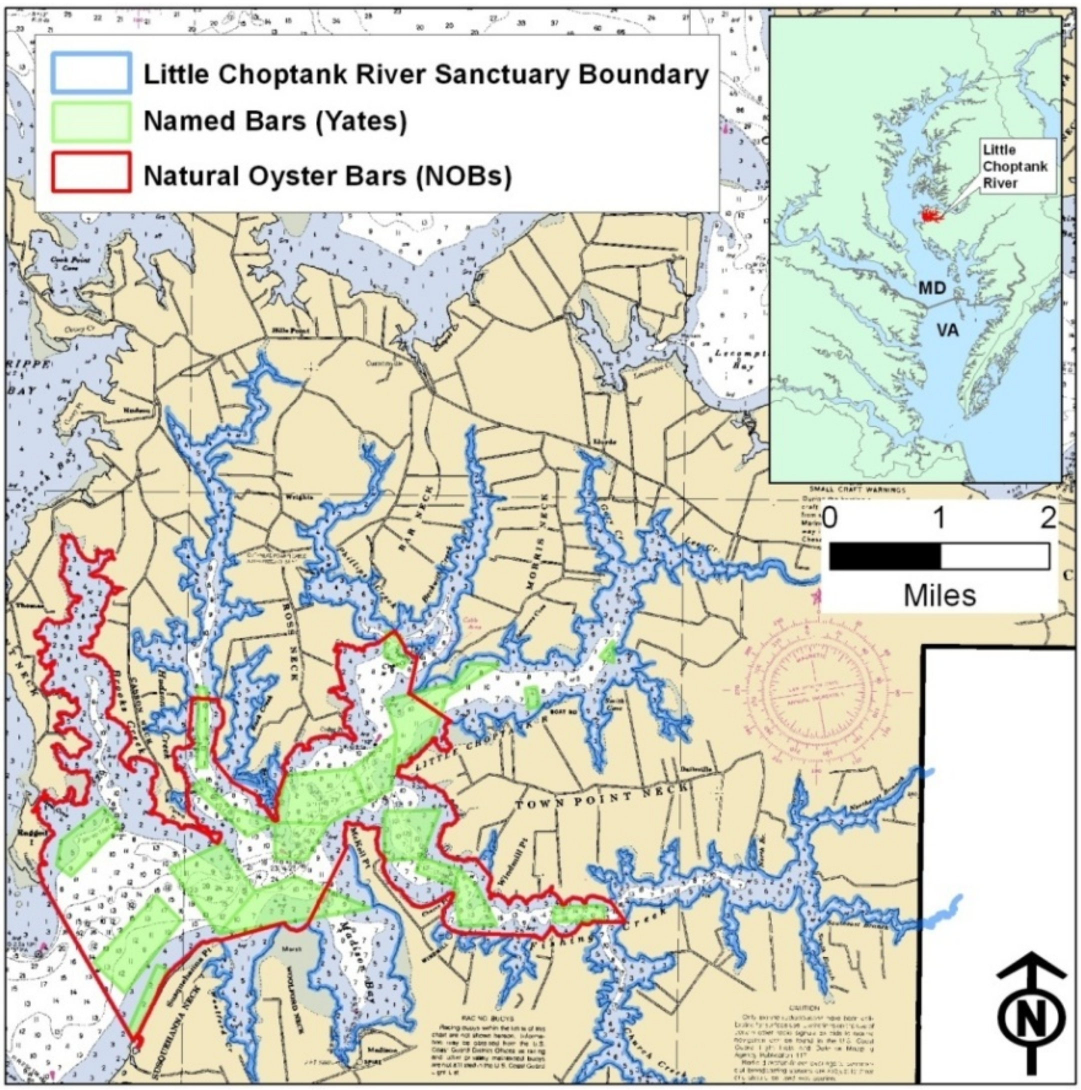
Little Choptank River Oyster Restoration Tributary Plan:
A blueprint for sanctuary restoration

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

February 2015



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The Little Choptank River Oyster Restoration Tributary 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.

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

Little Choptank River Oyster Restoration Tributary Plan

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The appendices are available on the Internet at:
ftp://ftp.chesapeakebay.net/noaa/Little%20Choptank%20appendices/

Executive Summary

In May 2009, President Obama issued Executive Order 13508, "Chesapeake Bay Protection and Restoration." The oyster outcome associated with this executive order calls for large-scale, tributary-based oyster restoration. Similarly, the 2014 Chesapeake Bay Watershed Agreement calls for restoring oyster populations in 10 Chesapeake tributaries by 2025. The Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (GIT) is charged with advancing this goal. The GIT previously convened the Oyster Metrics Workgroup, which established a Bay-wide, science-based, consensus definition of a "restored tributary" per the executive order goal. The GIT has now convened interagency workgroups in Maryland and Virginia to plan restoration work in each state, in consultation with appropriate partners.

Based on consideration of salinity levels, available restorable bottom, protection from harvest, historical spat set, and other criteria, the Maryland Interagency Workgroup, in consultation with Maryland oyster restoration partners, selected Harris Creek as the first tributary for large-scale oyster restoration. The Little Choptank River oyster sanctuary is the second tributary selected for restoration.

What follows is the Little Choptank River Oyster Restoration Tributary Plan. It details the restoration site selection process, and the reef construction, seeding, and monitoring required to bring the Little Choptank oyster *sanctuary* in line with the oyster metrics definition of a successfully-restored tributary. It calls for restoring 440 acres of oyster reefs in the Little Choptank sanctuary, and includes:

- a description of the process used to develop the tributary plan,
- a map showing which areas of the river are targeted to receive plantings of substrate (reef material) and oyster seed,
- a needs analysis for oyster seed and substrate,
- a cost analysis, and
- a plan to implement, monitor, and track progress of the restoration sites.

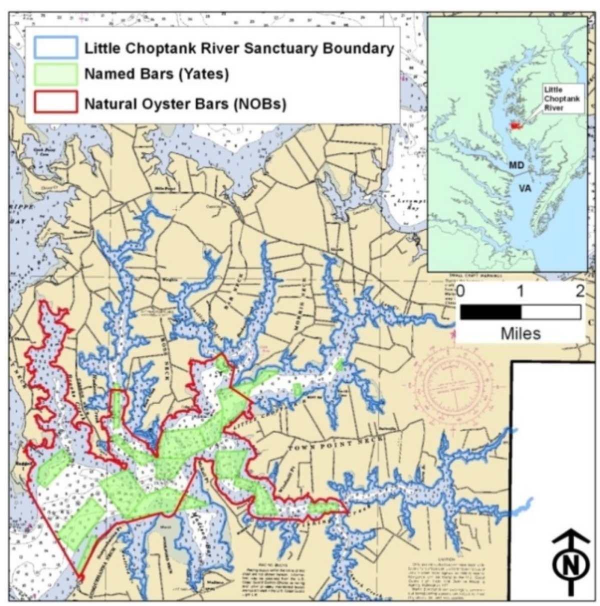

Figure 1: Little Choptank River Oyster Sanctuary Location Map

The implementation time frame will depend primarily on availability of funding. Existing hatchery oyster seed production capacity is sufficient to allow for full implementation of this plan in 3 to 5 years from its start. However, other tributaries are being restored simultaneously, and there are competing demands for hatchery seed. These will likely extend the completion timeframe.

For planning purposes, this document assumes a worst-case scenario where the Little Choptank does not receive any natural recruitment (spat set) over the course of plan implementation. Until 2000, the river regularly received large spat sets. From 2000 through 2011, only one significant spat set occurred, and even that was lower than historic levels. In contrast, during 2012, substantial spat set occurred in the river. It is possible that the river may receive future natural spat sets during the implementation time frame, yielding additional oysters at no seeding cost. Thus, it is likely that the seed and seed cost estimates herein are high. Ultimately, the intent is for the added broodstock to reproduce and contribute to spat sets in the Little Choptank oyster sanctuary to levels recorded prior to 2000.

Along with the Harris Creek project, this plan represents an unprecedented scale of oyster restoration in a single tributary in Maryland. Significant data collection and analysis went into the development of the Little Choptank tributary plan, including benthic sonar mapping with video and patent tong ground truthing to identify suitable bottom for restoration;, water quality analysis; examination of historic oyster bars; consideration of past and current oyster recruitment; two coordinated, pre-plan surveys to determine current oyster populations in the Little Choptank oyster sanctuary (survey covered all sites where sonar survey showed shell signature), and a subsequent pre-construction population survey in 2014. Additionally, public participation was encouraged during an open house to obtain input on the plan.

DNR, NOAA, and USACE are charged with implementation of the Little Choptank tributary plan. However, the productive collaboration of academic, non-governmental, and local groups involved in Chesapeake Bay restoration will greatly help achieve restoration success.

A draft version of this plan was developed in late 2013; that plan was adapted based on a 2014 oyster population survey. In-water reef construction and seeding began in summer 2014, based on the adapted draft plan. This updated document assembles all available data and analyses into a final plan. It is intended as a living document, and will be modified as new information becomes available.

Summary: Little Choptank River Oyster Restoration Tributary Plan

Total Acres Targeted for Restoration	**440**
Total Seed Required	**1.9 billion**
Total Substrate Needed (cubic yards)	**314,600**
Total Implementation Cost (restoration and monitoring)	**$29 million**

Little Choptank River Oyster Restoration Tributary Plan

Context and Scope:

President Obama's Executive Order 13508 called for federal agencies to establish specific measurable environmental goals for restoring the Chesapeake Bay. These environmental goals were laid out in the May 2010 *Strategy for Protecting and Restoring the Chesapeake Bay Watershed*. This strategy called for restored oyster populations in 20 Chesapeake Bay tributaries by 2025. The 2014 Chesapeake Bay Agreement later adapted this goal to 10 tributaries by 2025. In support of these policies, the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (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. The 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 Little Choptank tributary plan. The following criteria were among those set forth in the metrics report:

- A successfully-restored reef should:
  - have a mean density of 50 oysters or more and 50 grams dry weight or more per square meter (m^2), covering at least 30 percent of the target restoration area at 6 years post restoration;[1]
  - have two or more age classes present; and
  - exhibit 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 bottom has oyster reefs that meet the reef-level metrics above. Restorable bottom is defined as area that, at a minimum, has appropriate bottom quality and water quality for oyster survival).
- An ideal candidate tributary is one where 50 to 100 percent of the currently restorable bottom is equivalent to at least 8 percent, and preferably more, of its historic oyster bottom.

In 2012, U.S. Army Corps of Engineers (USACE) drafted a native oyster restoration master plan that evaluated tributaries of the Chesapeake Bay to determine those tributaries with the potential to support large-scale oyster restoration efforts. In 2012, the GIT established the Maryland Interagency Workgroup consisting of representatives from the National Oceanic and Atmospheric Administration (NOAA), USACE's Baltimore District, and the Maryland Department of Natural Resources (DNR). The purpose of this group is to facilitate oyster

[1] In addition, a minimum threshold for restoration success was set at a mean density of 15 oysters and 15 grams dry weight biomass/m^2 covering at least 30 percent of the target restoration area at 6 years post restoration activity. Minimum threshold is defined as the lowest levels that indicate some degree of success. However, this tributary plan is focused on the 50 oysters/m^2 target density for a successfully restored reef.

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 and the Maryland Oyster Restoration and Aquaculture Development Plan as the foundations of its work. Working with the consulting scientists, the workgroup has selected the first two tributaries for large-scale restoration focus: Harris Creek and the Little Choptank River oyster sanctuaries, both on Maryland's eastern shore. The tributary plan for Harris Creek has been finalized, and as of 2014 restoration work is more than half way complete.

Using the Harris Creek tributary plan as a model, and incorporating lessons learned, the purpose of this plan is to describe the actions necessary to bring the Little Choptank sanctuary's oyster population and habitat to the oyster metrics definition of a successfully-restored tributary. The plan includes specific areas targeted for restoration work, an analysis of the amount of seed and substrate required, and an estimated cost. Included too is a monitoring framework that will allow for the determination of whether or not Little Choptank oyster sanctuary can be considered "successfully restored" per the oyster metrics definition.

This plan estimates the funding required to restore and monitor the Little Choptank oyster sanctuary per the oyster metrics definition at $28.6 million. Some funds have already been identified (see implementation section); identifying the balance will need to be an ongoing effort for the oyster restoration partners. Even acquiring the large amount of required substrate (314,600 cubic yards) is a substantial challenge. This plan will clarify the needs, and allow government agencies, non-profit organizations, academics and other stakeholders to collectively identify the resources needed for implementation.

<u>Little Choptank Tributary Plan Process</u>

The Little Choptank Oyster Restoration Tributary Plan was accomplished using the following steps:

1. Identify tributary for restoration and set restoration acreage target:

   The Little Choptank oyster sanctuary was selected as the second candidate for large-scale oyster restoration (nearby Harris Creek being the first) by the Maryland Interagency Workgroup. The selection was based on the findings of the USACE master plan, DNR's fall 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 (Appendix A), potential for larval retention, oyster sanctuary status, and tributary size. The Little Choptank oyster sanctuary scored favorably for all criteria. The selection process and results were discussed with the consulting scientists.

2. Define restoration goal (target acreage):

As noted earlier, the oyster metrics report defined a successfully restored tributary as one where 50 to 100 percent of currently restorable bottom, constituting at least 8 percent of historic oyster habitat, consists of restored reefs. NOAA performed a restorable bottom analysis (Appendix B) for the Little Choptank oyster sanctuary, based on data from the USACE master plan, the oyster sanctuary boundaries, and bottom survey data from Maryland Geological Survey and NOAA. This analysis showed 685 acres of potentially restorable bottom in Little Choptank oyster sanctuary. Historically, there were 4,092 acres of oyster habitat identified by the Yates Survey in 1913; accordingly, 8 percent of the historic habit (4,092) is 327 acres. Hence, the restoration goal for Little Choptank oyster sanctuary was set at 343 to 685 acres to meet both of the success criteria defined by the Oyster Metrics Workgroup.

3. Conduct pre-restoration oyster population surveys:

NOAA contracted Versar, Inc., to perform a spatially-explicit population survey in Little Choptank oyster sanctuary. As part of a NOAA-funded Bay-wide project involving DNR, the Paynter Labs at the University of Maryland also conducted a Little Choptank oyster sanctuary population survey. These surveys were done in the winter of 2011-2012. Because a good spat set occurred in 2012, an additional population survey was conducted by DNR in April 2014 to update estimates of population density.

4. Develop a draft map summarizing major datasets:

The workgroup summarized the available geographic information systems (GIS) data in a map showing potential locations for different reef restoration treatments. From here, the workgroup selected areas suitable for two types of treatment: seed only, or substrate plus seed. The workgroup also identified areas currently meeting the oyster density goal, as determined by the population surveys. General planning guidance from the U.S. Coast Guard was also considered during this process. This guidance includes setbacks of 250 feet from marinas and navigational aids, and 150 feet from federally-maintained channels (Madison Creek and Slaughter Bay channels).

5. Conduct public open house:

A public open house was held in Cambridge, MD on February 27, 2014 to obtain input on the draft Little Choptank oyster restoration plan. A public hearing was held by the U.S. Army Corps of Engineers and the Maryland Department of the Environment on April 9, 2014 to solicit comments on the proposed restoration work.

6. Revise blueprint map:

Incorporating feedback from the open house, a revised map was created showing potential oyster restoration sites for each treatment type. Estimates were made for amount of seed and substrate needed. Updated cost estimates were derived from these estimates.

7. Send draft blueprint map and tributary plan to consulting scientists for review:

   In addition to input from the Coast Guard and the public, the workgroup sought input from a group of Chesapeake Bay scientists from the academic community, federal and state resource agencies, and non-profit organizations. (See list of consulting scientists at the beginning of this document). The plan was revised based on this input. It is expected that communication with the scientific community will be ongoing throughout restoration.

8. Finalize reef blueprint map and tributary plan:

   Using the inputs from the consulting scientists, the public, and the Coast Guard, the workgroup finalized the Little Choptank oyster sanctuary tributary plan. The plan will be a living document, to be updated as appropriate based on adaptive management.

9. Obtain Section 10 permit:

   DNR is currently limited to placing substrate in locations where 8 feet of water depth (clearance) will remain above the reef. The current water depth requirements severely limit the area upon which reefs can be constructed in the Little Choptank oyster sanctuary, and would prevent achieving the restoration goal. To obtain more area for reef construction, DNR has applied for a permit modification to allow for reef construction in waters as shallow as 6 feet, leaving 5 feet of clearance. This permit application is pending as of the publication of this document.

10. Implement seeding and substrate activities:

    The tributary plan is expected to be primarily implemented by NOAA and DNR. NOAA is contributing funds for seeding activities, as well as mapping and survey actions. DNR is contributing both to the seeding and substrate placement efforts, as well as mapping and survey activities. Both partners plan to fund and conduct project planning and monitoring efforts. USACE-Baltimore District is a partner in the tributary plan process. Reef construction began in April, 2014 using fossilized oyster shells. In July, 2014 construction of rock reefs began. Seeding with spat on shell from the Horn Point hatchery began in August, 2014.

12. Monitor project performance and adaptively manage:

Using the protocols discussed in the oyster metrics report, the workgroup will monitor the performance of the restoration sites in Little Choptank oyster sanctuary. Key parameters to be monitored include reef structure, population density, total reef population, and the number of age classes. Additionally, the workgroup will monitor water quality and other parameters that affect project success. Monitoring is planned to occur several times within 6 years of implementation. Depending on the results of the monitoring, additional seeding or other adaptive management actions will be undertaken. Details of the monitoring plan are found in the monitoring section of this document. NOAA, USACE-Baltimore District and DNR will produce annual reports describing progress that has been made on restoring the oyster population in Little Choptank River oyster sanctuary.

Data Used in the Little Choptank Tributary Plan

This section details the parameters considered in the selection of Little Choptank oyster sanctuary for intensive oyster restoration, the selection of restoration sites within the river, and the determination of location and type of reef treatment. Some of these parameters were considered in greater depth in the USACE master plan process and/or the Maryland Oyster Restoration and Aquaculture Development Plan process. They warrant mention here, though, since the Little Choptank tributary plan largely builds on these plans. Further description of each parameter is discussed below.

Table 1: Criteria Considered During the Little Choptank River Tributary Plan Process

Physiochemical	Water quality (dissolved oxygen (DO), salinity, temperature)
Physical	Bottom quality, sedimentation, depth
Biological	Location and quantity of existing oyster population, historical spat set
Other	Sanctuary boundaries; land use; location relative to other estuarine habitats (SAV); input from public, Coast Guard, and consulting scientists

Physiochemical Criteria

Little Choptank River is classified as a mesohaline tributary. Salinity and dissolved oxygen (DO) data were compiled and screened through USACE's master plan efforts by Versar, Inc. Point data were gathered by DNR, the Maryland Department of the Environment, the Alliance for Chesapeake Bay, and the Chesapeake Bay Program. The same salinity dataset was also used to evaluate Little Choptank River for the potential risk from freshets. Temperature is not a limiting factor in Little Choptank River and needed no further consideration. Details of the physiochemical selection criteria are provided in the USACE master plan.

Physical Criteria

Only areas between 4 and 20 feet in water depth were considered suitable for restoration. Deeper waters typically experience low DO conditions that are not suitable for oysters or the reef community. Shallower waters conflict with other uses of the waterway. Water depth between 4 and 6 feet deep was considered unsuitable for substrate additions due to concerns about navigational interference of placing alternate substrates. Thus, only water depths between 6 and 20 feet were considered suitable for substrate additions.

Adequate bottom must be available for oyster restoration. Hard bottom capable of supporting shell or other material likely to catch spat as well as areas that currently hold oyster shell were identified by bottom surveys using sonar in conjunction with various ground-truthing methods. Side-scan sonar surveys were conducted by the Maryland Geological Survey (MGS) in 2010 to identify bottom type, specifically, whether the bottom surface was exposed shell habitat, buried shell, or hard bottom. Seabed-type polygons were classified by NOAA using the Coastal and Marine Ecological Classification Standard (CMECS)[2] surface geology component. GIS polygons were created from combining the MGS 2010 side-scan sonar mosaic; NOAA Chesapeake Bay Office's 2011 video, ponar grabs, and acoustic classification; the Paynter Labs' 2011 patent-tong survey; Versar's 2012 patent-tong survey (Appendices B, C). These polygons were then altered using DNR's 2014 oyster population survey.

[2] Chesapeake Bay-CMECS is the integration of several digital maps that identify the boundaries and distribution of seabed materials and bottom habitats in the Chesapeake Bay. It is a hierarchical ecological classification system that is universally applicable for coastal and marine ecosystems. It was developed by the NOAA Coastal Services Center, in partnership with NatureServe and others, to create a standard classification system that integrates different types of data from multiple sources to fully characterize a specific area. Raw survey data were acquired by the NOAA Chesapeake Bay Office and the Maryland Geological Survey with acoustic seafloor survey systems and validated with video and sediment grab samples. Final seabed habitat polygons were classified using a variant of the CMECS. CB-CMECS places an emphasis on describing the American oyster reef community, and the sediments that encompass it. The oyster reef units described in CB-CMECS are those that can be acoustically derived and differentiated, and are classed based upon their morphological characteristics. CMECS reef attributes in addition to other spatial data sources inform the restoration potential of targeted sites. An example is the "aggregate patch reef" which describes oyster bottom that comprises shell mounds surrounded by soft sediments. Healthy oyster communities exist on this type of habitat, but in most cases restoration potential would be low. More CMECS information, including a description of the classifications, is at http://ftp.ncbo.cgclientx.com/ecoscience/Chesapeake_Bay_Benthic_Habitat_Polygons_CMECS/.

Biological Criteria

Oyster population assessments for size and density, funded by NOAA, were completed separately by Versar, Inc. and the Paynter Labs of the University of Maryland in January 2012 (See Appendix C). The Versar surveys provided spatially explicit estimates of oyster densities and population structure within the extent of restorable oyster bottom, based on a regular sampling grid. A total of 686 patent-tong samples were collected in the Little Choptank oyster sanctuary. Live oyster density estimates were determined for bottom depths ranging from 4 to 20 feet. The Paynter Labs conducted a separate population survey using a stratified-random sampling design. The two data sets were compared and found to be in agreement. They were then combined, interpolated, and used to current oyster populations on each existing reef. Patent tong samples were taken on higher quality shell bottom determined from the CMECS seabed map, lower quality shell bottom, and non-shell bottom. Because a significant spat set occurred in 2012, DNR conducted an additional population survey in April 2014, taking 289 patent tong grabs using a stratified random sampling design.

Spat set data compiled by DNR's fall survey from 1985 to 2012 were considered in an effort to understand larval settlement patterns in Little Choptank River (Appendix A). Fall survey spat set data are available for two locations in Little Choptank River: Ragged Point and Cason. This dataset was used to make the conservative assumption that there will be no natural spat set over the next 6 years (see seed needs analysis section below). This dataset is the most recent available, thus it was assumed to be most relevant to current conditions in the river. Historical spat set was also considered and used in selecting Little Choptank River as a target tributary (Krantz and Meritt from 1939-1975, see Appendix A).

The oyster diseases Dermo (*Perkinsus marinus*) and MSX (*Haplosporidium nelsoni*) are more virulent in higher salinity waters, leading to higher mortality in these areas. However, reproduction is more successful in higher salinity areas. To balance reproduction and disease-related mortality, mesohaline areas were considered to be high priority for restoration.

Harmful algal blooms (HAB) resulting from *Prorocentrum minimum* and *Karlodinium veneficum* have been documented in the Choptank River (Brownlee et al. 2005; Glibert et al. 2001), but Little Choptank River has not been identified to have significant HAB problems or susceptibilities.

Other Criteria

The State of Maryland has designated 9,216 acres within Little Choptank River as oyster sanctuary, where no wild harvest of oysters is permitted.

Land use in the watershed draining to Little Choptank River is largely agricultural with some forested and developed areas. This information was used by USACE in its oyster restoration master plan, which in turn informed the selection of Little Choptank River as a site for large-scale oyster restoration under Executive Order 13508.

No federally listed aquatic rare, threatened, or endangered species have been identified in the Little Choptank River watershed. However, six federally listed rare, threatened, or endangered species have been identified in the Little Choptank River watershed: Delaware fox squirrel, Eastern fox squirrel, cream tick-trefoil (plant), rare skipper (bird), swamp-pink (plant), and Torrey's Mountainmint (plant) (as listed by Landscope 2012 for Talbot County).

Submerged aquatic vegetation (SAV) habitat, as designated by the Chesapeake Bay Program, exists in the Little Choptank River. There has been no SAV identified in the main portion of the Little Choptank River since 2005. On average, there has been 140 acres of SAV beds in the Little Choptank River segment (LCHMH) in the past 10 years (2003-2012). SAV beds were more expansive in the decade prior to that, averaging 500 acres annually (1993-2002). In 2011, a number of the small creeks within the Little Choptank system (Hudson Creek, Back Creek, Phillips Creek, Beckwith Creek, and Smith Creek) supported SAV beds. Target restoration sites were cross-checked with SAV maps from the Virginia Institute of Marine Science from 2011, 2012 and 2013 to ensure that no reef construction or oyster planting would occur on SAV beds.

Based on the National Wetlands Inventory data, there are 17,792 acres of wetlands in Little Choptank River watershed.

Spatial Analysis

Initial analyses performed for the USACE master plan determined that salinity and dissolved oxygen were suitable throughout the Little Choptank River (USACE 2012). Spatial data were overlaid in ArcGIS to locate proposed restoration sites. This GIS analysis included the bottom classification, and population survey results (Versar, Paynter, and DNR). See Appendix C for interpolated oyster population density map.

The workgroup used three primary data layers for the GIS analysis. These layers were:

- A data layer identifying seabed suitable for substrate placement was defined based on areas determined to be existing mollusk (oyster) habitat with oyster densities of less than 5 oysters per square meter (population surveys), and CMECS bottom characterization of muddy sand, unclassified hard bottom, sand, and sandy mud.
- Versar and Paynter population survey data were interpolated to develop live oyster density polygons within CMECS shell bottom polygons and in depths greater than 4 feet and less than 20 feet. The interpolation method used was the Nearest Neighbor/Inverse Distance Weighted method.
- DNR population survey data were used to update and supplement the data from the Versar and Paynter population surveys.

Blueprint Map

The foundation of this tributary plan is the blueprint map showing locations of proposed restoration activities. Sites that met all the following criteria were considered suitable for restoration in the Little Choptank oyster sanctuary:

- Hard benthic habitat;
- Outside of a 250-foot radius around aids to navigation;
- More than 150 feet from the federally-maintained navigation channels (Madison Bay and Slaughter Creek channels);
- Not on leased bottom;
- Within a legal natural oyster bar;
- More than 250 feet from a marina;
- More than 250 feet from any dock or pier;
- Not identified by the general public or the Coast Guard as a concern;
- In areas with depths of 4 to 20 feet; and
- Have an existing population of fewer than 50 oysters per square meter[3].

Hard benthic habitat was defined as areas that, per acoustic surveys, were found to have the CMECS classifications of artificial reef, aggregate patch reef, fringe reef, patch reef, sand and scattered oyster shell, sandy mud, sand, and muddy sand. Buffers around navigational aids and federally-maintained navigational channels (Madison Bay and Slaughter Creek channels) were excluded.

The 20-foot maximum depth cutoff was used due to concerns about potential hypoxia 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 was used to allow for safe navigation over the substrate.

Using the above criteria, 685 acres were identified as suitable for restoration action. Next, a determination as made as to what restoration treatment was most suitable for each area. Two treatments were identified: planting seed only, and planting substrate with seed on top [3]. Adding seed only is less costly than adding both substrate and seed, and so it is the first-choice treatment. However, the seed-only option is only suitable where sufficient shell base currently exists. In the absence of existing suitable shell base, substrate must be added to create a hard reef structure. Seed oysters can then be planted on top of the new substrate base. Substrate may be any combination of oyster shell, clam shell, or alternative substrate

[3] Areas with more than 50 oysters per square meter currently meet the minimum density goal per the oyster metrics report, so these areas are not being targeted for initial seeding. However, they may need additional seeding in future years. This is further described in the seed needs section.

such as crushed concrete or rock. Reef balls can be added for additional three-dimensional structure, either with or without seed oysters set onto them.

For this effort, the existing density of oysters was a key consideration in determining whether areas with hard benthic habitat would be targeted for seed only, or substrate and seed. The assumption was that an area that supported existing oysters in quantity (by consensus, that amount was 5 oysters per square meter) should not be overplanted with substrate. This would risk smothering existing oysters. Also, the presence of oysters in such quantity served as an indication that existing substrate was suitable, thus the area would likely do well with the addition of seed only. Areas with hard benthic habitat and fewer than 5 oysters per square meter were further examined to determine if they could be restored using seed only, or if they required the addition of reef-building substrate, followed by oyster seed, to restore. Data sets including sonar maps, oyster density, ponar grabs , and shell quality characterization were considered on each site individually. Areas with substantial quantities of high-quality surface shell and with closer to 5 oysters per square meter were targeted for seed only. Areas that had little shell or predominately low-quality brown or black (anoxic) shell, and few oysters were targeted for substrate, followed by seed. The treatment type will be adapted as needed based on the additional pre-planting diver ground-truthing information. (See description below of ground-truthing protocol to be employed).

Additionally, areas shallower than 6 feet deep were considered unsuitable for substrate placement, due to navigational concerns. (Note that DNR’s current permit in the Little Choptank limits placement of substrate to areas where 8 feet of navigational clearance can remain over completed reef. Placing substrate in waters between 6 and 9 feet deep- assuming a 1-foot reef height will require a permit modification; DNR has applied for this permit modification). Restoration using the seed only treatment is targeted in waters 4-20 feet deep.

Table 2 is a summary of the criteria used to determine restoration treatment for each area .

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

Criteria	Restoration Treatment Type
Water depth less than 4 feet or greater than 20 feet	No action; unsuitable for restoration
Soft benthic habitat	No action; unsuitable for restoration
Areas with hard benthic habitat, and 50 oysters or more per m^2	No action initially; monitor to determine if additional seed is needed in future years
Areas with hard benthic habitat, and between 5 and 50 oysters/m^2	Add seed only (no substrate)
Areas with hard benthic habitat and fewer than 5 oysters/m^2	Review sonar maps, and oyster density, ground truth, and shell quality data to determine if these sites can be restored using seed only, or if they require substrate. *(See decision criteria in next two rows)*
Areas with hard benthic habitat, fewer than 5 oysters/m^2, AND with predominately white (oxic) shell, high quality shell, substantial surface shell, more oysters	Add seed only (no substrate)
Areas with hard benthic habitat, fewer than 5 oysters/m, AND with predominately brown or black (anoxic) shell, low quality shell, very little surface shell, few oysters, and in waters 6 to 20 feet deep	Add substrate, followed by seed

GIS was used to create maps showing the appropriate treatment type in each area. From here, workgroup members blocked off areas into somewhat-regular polygons to facilitate planting and tracking. Some areas were eliminated or changed in this process. For example, very small, odd-shaped appendages to the larger polygons and long, thin slices bordering unsuitable bottom were eliminated as they would likely be difficult to plant accurately. Also, areas less than one contiguous acre were eliminated. This process winnowed the 685 acres down to 499 acres.

Diver ground truthing has shown that sonar surveys often overestimate the area of hard bottom suitable for planting seed. Based on field experience, it was assumed that the area suitable for seed-only treatment, as determined by sonar, will be reduced by 30 percent upon examination by divers. A 30-percent reduction of the 196 seed-only acres resulted in a new target of 137 seed-only acres. An additional 43 acres currently meet density goals of 50+ oyster m^2 as established by the Oyster Metrics Team. Although these are not targeted for seeding immediately, it is likely, given anticipated mortality rates, that these areas will need to be seeded sometime during the restoration program. Combining the 43 acres that currently meet the density goal, the 137 acres slated to receive only seed oysters, the 230 acres requiring substrate & seed (half in waters in water 9-20 ft deep; half in waters 6-9 feet deep) yields a total of 442 acres. Table 3 shows the area slated for each type of restoration treatment, as well as the anticipated areal reductions.

Natural spat sets may occur in the Little Choptank sanctuary while this plan is being implemented. DNR monitors this river annually for spat set. If DNR data or other observations indicate a substantial natural spatset, additional oyster density surveys will be done on the river and the plan will be adapted accordingly.

<u>Blueprint Map Summary</u>

In summary, the oyster metrics report defined a successfully restored tributary as one where 50 to 100 percent of the currently restorable bottom, constituting at least 8 percent of historic bottom, meets the reef-level goals. In Little Choptank River, the restorable bottom analysis (Appendix B) showed 685 acres of restorable bottom, so the minimum goal is 342 acres of restored reefs. This tributary plan targets 442 acres, allowing for the possibility that some of that acreage may not respond sufficiently to the restoration activity.

Table 3: Acreage by Reef Treatment (with anticipated reductions)

Reef Treatment	Acres Identified in Blueprint Map	Suitable Acreage (Reduced by 30%, where applicable)
Currently meets target density of 50+ oysters/m^2	43	43
Reef treatment: Add seed only	196	137
Reef treatment: Add substrate and seed*	260	260
Total acreage requiring initial reef treatment	456	397
Total for all restoration sites	**499**	**440**

*130 acres in waters 9-20 ft deep; 130 acres in waters 6-9 ft deep

Figure 2 on the next page shows the areas targeted for restoration in the Little Choptank oyster sanctuary, along with the planned restoration treatment type (seed only or substrate and seed).

Appendix D offers both a high resolution map (very large file; good resolution but long download time), and a lower resolution map (smaller file). These allow the map below to be viewed in greater detail. Appendices are at ftp://ftp.chesapeakebay.net/noaa/Little%20Choptank%20appendices/

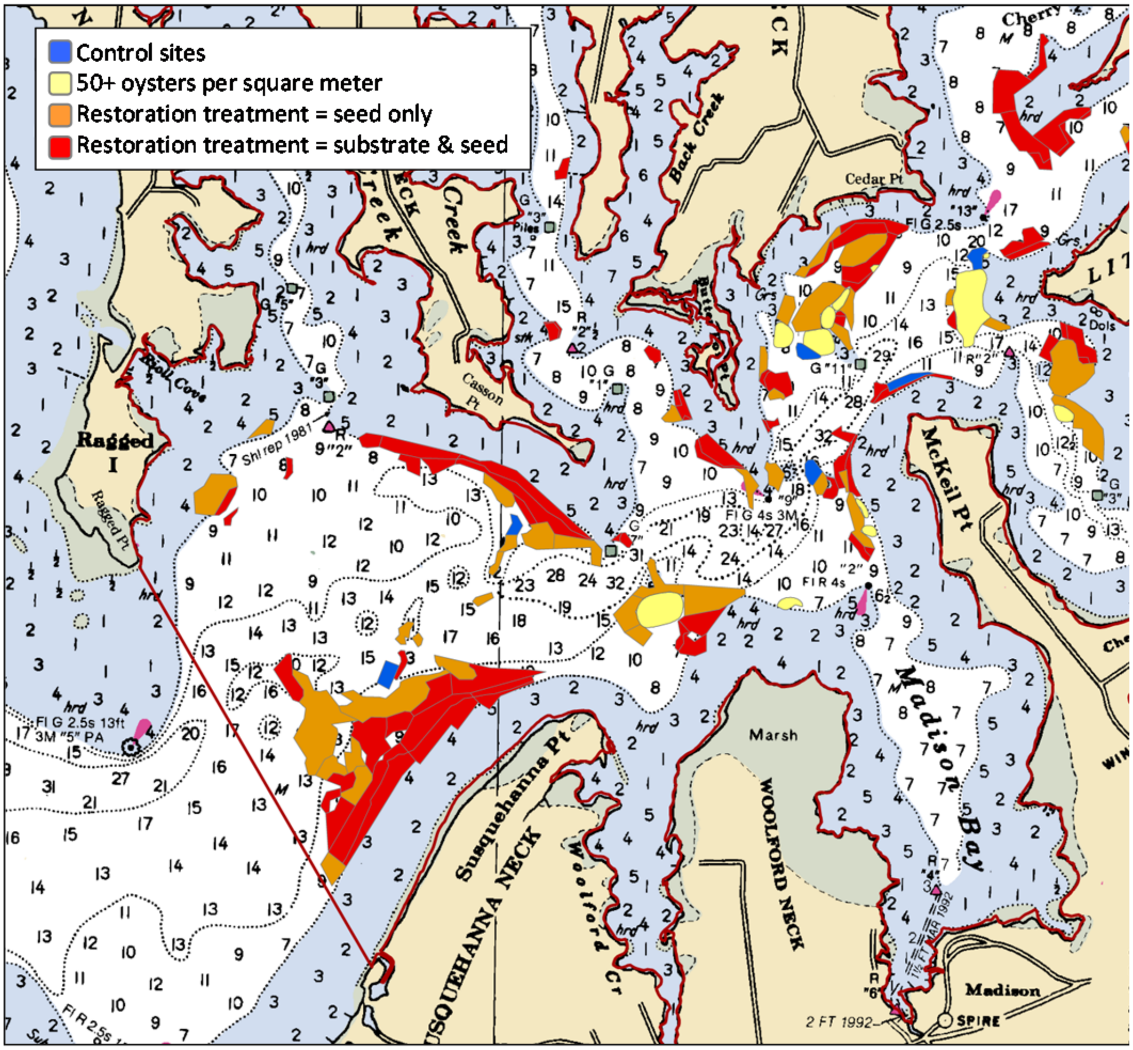

Figure 2: Blueprint Map

Ground Truthing

Prior to seeding, diver ground truthing will be performed on all sites targeted for seed-only treatment.. The purpose of the ground truthing is to validate the acoustic surveys, and to modify the boundaries of target sites (if needed) to ensure the treatment occurs on appropriate benthic habitat. Ground truthing of any given site is expected to occur within a few months prior to restoration work.

Diver ground-truthing protocol: Seed-only sites will undergo diver ground truthing. Diver ground truthing will be accomplished by running several transects within each target area. The number of transects depends on the size of the area. Typically, each transect will be 200 meters long, marked every 2 meters for reference. Transect lines will be laid out haphazardly within the target polygon; divers will then swim along the line and report the condition of the bottom every 2 meters. Parameters to characterize bottom condition will be recorded at each 2-meter interval. The parameters include: amount of exposed shell, substrate type, substrate penetration and oyster density. Divers will determine a score for each parameter. Table 4 outlines the score for each category, with increasing metric values indicating bottom-type improvement.

Table 4: Summary of Ground Truthing Protocols

Exposed Shell	Value	Substrate Type	Value *	Penetration (cm)	Value *
Zero	0	Silt	0	70	0
Very Little / Patch	1	Mud	1	40	1
Some	2	Sandy Mud	2	20	2
Exposed	3	Sand	3	10	3
Oyster Bar	4	Rock / Bar Fill / Debris	4	5	4
		Shell Hash	5	0	5
		Loose Shell	6		
		Oyster	7		

* Increasing metric values show bottom-type improvement

The data for each transect will be recorded directly into a Microsoft Access database created specifically for the Paynter Labs. The mode value of each category will be used to determine whether each transect can be categorized as preferred, acceptable, or unacceptable bottom. The bottom-type category will be determined as the category within which two of the three data types (exposed shell, substrate type and penetration) fall. This information will be then relayed to ORP staff and the workgroup to help make decisions about which target areas may not be suitable for planting spat on shell.

Table 5 outlines the requirements for each bottom-type categorization.

Table 5: Summary of Bottom-Type Categorization

Category	Exposed Shell Range	Substrate Type Range	Penetration Range
Preferred	3-4	4-7	5
Acceptable	2	3-4	3-4
Unacceptable	1-0	0-2	0-2

Seed Needs Analysis

A projected 1.87 billion seed oysters will be required to implement this plan. This number assumes that on all reefs with fewer than 50 oysters per square meter (the Oyster Metrics target density), 4 million spat-on-shell per acre will be added. The oyster metrics report calls for the target density to be achieved within 6 years of restoration activity, so this plan lays out oyster survival projections over 6 years. To do this, assumptions were made regarding survival rates of both planted seed and existing oysters. It is recognized that oyster survival rates are highly variable, and that the actual survival rate is unknown. However, for planning purposes it was necessary to make reasonable assumptions as to survival rates. These assumptions may be revised in future iterations of this plan if more accurate rates are determined through the recommended monitoring (see monitoring section below).

First-year planted spat-on-shell survival rate: Based on Volstad et al (2008) and Oyster Recovery Partnership's field experience with hatchery-produced spat-on-shell in Maryland, the workgroup set assumed survival rates for first-year planted spat-on-shell at 15 percent.

Out- year planted spat-on-shell survival, and annual survival rate of existing oysters: To deduce the out-year annual survival rate, the workgroup considered historic annual mortality from DNR's fall survey. This data set varies widely on the Little Choptank, ranging from 2 to 96 percent since 1985 (see Table 6).

Table 6: Little Choptank Annual Mortality Rates

Median 1985-2012	Median 2003-2012	Minimum	Maximum
21.5%	8%	2%	96%

As a conservative estimate, the workgroup used the 1985- 2012 median mortality rate of 21.5 percent as the projected annual mortality (rounded to 22 percent) for out-year survival of both planted spat-on-shell and existing oysters (those on the reef prior to restoration.)

Summary of oyster survival assumptions for the Little Choptank River:

Planted spat-on-shell: First year survival rate = 15 percent;
Out-year annual survival rate = 78 percent;

Existing oysters on reef: Annual survival rate = 78 percent.

Approximately 43 acres of reefs in Little Choptank oyster sanctuary already meet the oyster metrics density goal, thus initially they would require no additional seed to meet the goal. Reefs with fewer oysters will require more seed to meet the density goal. However, the oyster metrics report also lays out a goal of having at least two year classes present on each reef. Subsequently, this plan conservatively incorporates a second seeding of all reefs to achieve the two-year class goal, including the 43 acres that currently meet the goal. Natural spat set may make a second seed planting unnecessary. 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 for details). Annual monitoring is also called for on three sentinel sites in the river. If diver ground truthing, DNR fall surveys or other data indicate a natural spat set, additional population surveys may be required on areas that have not yet been restored.

A key unknown is the frequency and magnitude of natural spat sets that might occur in Little Choptank River over the implementation time frame, and what density of oysters might result from these spat sets. The workgroup dealt with this unknown by making a very conservative assumption that there would be no natural spat set over the course of implementation. This assumption was based on the fact that from 2000 to 2011, there were only two sizable spat set anywhere in the Little Choptank River. By making this assumption, the tributary plan calls for planting enough seed to reach the density goals in 6 years, even with no natural spat set in the river. The intent is to plan for a very conservative scenario, and adapt the tributary plan as needed should natural spat set occur. The tributary plan calls for an initial large planting on most reefs, followed by monitoring in year 3, and an additional, smaller planting in year 4 to ensure a multi-age-class population and target density after year 6.

A summary of the 1.87-billion seed calculation is provided in Table 7; the seeding cost estimate is provided in Table 8.

Table 7: Seed Needs and Oyster Survival Assumptions

Type of Reef Treatment	First Planting (seed per m^2, assuming 4 million seed per acre)	First Planting, Year 1 Survival	First Planting, Year 2-6 Annual Survival Rate	Second Planting, to Occur in Year 4 (seed per m^2)**	Second Planting Year 4 Survival	Second Planting, Year 5 and 6 Annual Survival	Existing Oyster Density (oysters per m^2)*	Existing Oysters, Year 1-6 Annual Survival Rate	Oyster Density After 6 Years – Surviving Oysters from Plantings and Existing Oysters (oysters per m^2)	Area Targeted for Restoration in Little Choptank River (acres)	Total Amount of Seed Needed for Treatment Type
Substrate & seed	989	0.15	0.78	123	0.15	0.78	0	N/A	54	260	1,170,000,000
Seed Only	989	0.15	0.78	123	0.15	0.78	5	0.78	54	137	616,500,000
Seed Only (initial density = 50+ oysters per m^2)	0	0	0.78	494	0.15	0.78	50	0.78	56	43	90,000,000
Total for Tributary Plan											**1,876,500,000**

* While some of these seed-only sites had initial, pre-restoration density of more than 5 oysters/m^2, it was assumed for planning purposes that all sites showing between 5 and 50 oysters/ m^2 had a starting density of 5 oysters/m^2.

** This assumes a second planting of 500,000 oysters/m^2 on substrate only sites, and on seed only sites, and assumes a second planting of 2 million oysters /m^2 on the sites which had an initial oyster density of 50+ oysters /m^2.

Table 8: Seed Cost Analysis

Reef Treatment	Area to Be Treated (acres)	Seed Required per Acre	Seed Required for Treatment Type	Seed Cost for Treatment Type (at $5,000 per million seed)*
Substrate & Seed	260	4,500,000	1,170,000,000	$5,850,000
Seed only	137	4,500,000	616,500,000	$3,082,500
Seed Only (initial density = 50+ oysters per m2)	43	2,000,000	90,000,000	$450,000
Total for Tributary Plan	**440**		**1,876,500,000**	**$9,382,500**

* $5,000 per million spat-on-shell, including planting costs, based on ORP estimates (Stephan Abel, personal communication, July 2013). Note that this is an average cost, but actual cost depends on the number of oysters the University of Maryland hatchery produces each year. For example, as of mid-2013, hatchery production was excellent, bringing average costs down to $4,200 per million, including planting costs.

Substrate Needs Analysis

A projected 314,600 cubic yards of substrate are needed to implement the tributary plan. Substrate may be any combination of oyster shell or alternative substrates such as clam shell, fossil shell, crushed concrete, rock, or reef balls. This projection assumes that substrate reefs in the Little Choptank will be built at heights of either 6 or 12 inches, averaging 9 inches. Constructing 9-inch-high reefs requires 1,210 cubic yards of substrate per acre. If higher reefs or lower reefs prove better for oyster survival, this plan will be adapted to favor oyster survivorship while efficaciously using substrate material. The computation of the substrate need is shown in Table 9, with the substrate cost estimated in Table 9.

Table 9: Substrate Needs Analysis

Reef Treatment	Area to Be Treated (acres)	Amount Substrate Needed per Acre (cubic yards)*	Amount of Substrate Needed for Treatment Type (cubic yards)
Substrate & Seed	260	1,210	314,600
Seed only	137	0	0
Seed Only (initial density = 50+ oysters per m2)	43	0	0
Total for Tributary Plan	**440**	**1,210**	**314,600**

* Assumes a 9-inch average reef height. Reefs heights will vary from 6 inches to 12 inches.

The estimated cost to purchase and place substrate for reef construction in the Little Choptank oyster sanctuary is approximately $60 per cubic yard. This amounts to approximately $73,000/acre for substrate, assuming an average reef height of 9 inches. The estimate was derived from a DNR contract for reef construction in Harris Creek and the Little Choptank River, and reflects partial subsidy of material transportation by CSX railroad. This is an averaged cost between Florida shell and granite; costs for other materials may vary.

Table 10: Substrate Cost Analysis

Reef Treatment	Area to Be Treated (acres)	Substrate Required per Treatment Type (at 1,201 cubic yards per acre)	Substrate Cost (at $60.33 per cubic yard)
Substrate & Seed	260	312,260	18,838,646
Seed Only	137	0	0
Seed Only (initial density = 50+ oysters per m2)	43	0	0
Total for Tributary Plan	**440**	**312,260**	**18,838,646**

Monitoring

The primary objective of the monitoring described herein is to determine whether or not the restoration work meets the definition of a “restored tributary” per the oyster metrics report. In addition, a set of “diagnostic” parameters are recommended. These are basic water quality and biological parameters which can help determine the cause of success or failure of the restoration work. The extent of the monitoring is consistent with the scope of this document and the oyster metrics report. Cost estimates are approximate; they will likely evolve as monitoring progresses.

Monitoring of Oyster Metrics Success Goals

The principle goal of monitoring efforts in Little Choptank River is to determine if the restored reefs can be considered “successful” per the oyster metrics standards. According to the oyster metrics report, evaluation of reef-level restoration success requires the determination of four parameters:

(1) structure of the restored reef (reef spatial extent, reef height, and shell budget),
(2) population density (as individual abundance and biomass),

(3) an estimate of total reef population (including biomass and number of individuals), and
(4) the number of age classes present on the reef.

In keeping with the oyster metrics report, these parameters will be measured as the basic monitoring protocol for the Little Choptank oyster sanctuary under this plan, likely in partnership with academics, researchers, non-governmental organizations, private contractors, and other agencies. Table 11 describes in detail the recommended parameters to be monitored to evaluate progress towards the restoration goals.

Pre-restoration data on reef extent were collected by Maryland Geological Survey and NOAA using sonar, video, and grab samples. Baseline data on oyster population density were collected by Versar and Dr. Ken Paynter of the University of Maryland Paynter Labs, with NOAA funding, and by DNR. These data were used to estimate baseline oyster population size and densities in the Little Choptank oyster sanctuary. Future monitoring results will be compared to these baseline data to determine the success of restoration efforts, and whether or not adaptive management actions are necessary. Table 13 lists estimated costs for monitoring per the oyster metrics success goals.

Diagnostic Monitoring

In addition to monitoring to evaluate the success or failure of restoration projects per the oyster metrics standards, 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 basic water quality, disease, and physiologic factors that affect oyster health and reef structure persistence. Understanding these parameters alongside metrics of restoration success will allow practitioners to understand not only whether or not the project succeeded, but why. Table 12 lists the recommended diagnostic parameters.

Due to the large scope of monitoring, some of these factors will be measured only at "sentinel sites" within the Little Choptank oyster sanctuary. Sentinel sites are fixed sites that are monitored at appropriate intervals. Collecting data on these recommended diagnostic monitoring parameters will likely require partnering with academic institutions, non-governmental organizations (NGOs), and other state and federal agencies. Table 11 shows suggested diagnostic monitoring activities and estimated costs of these activities.

Table 11: Suggested Restoration Success Monitoring Activities

Parameter	Sentinel Site Monitoring*	All Site Monitoring**	Method of Measurement	Units/Performance Metric	Estimated Cost (assumes a 6-year monitoring timeline)
Population- Density	x	x	quadrat sampling or patent tong	number of oysters/m^2	These three parameters are collected simultaneously; cost to monitor sentinel sites annually for 6 years = $33,000 ($11,000 per year). The cost to monitor each of 440 acres in years 3 and 6 = $512,720 ($580 per acre per monitoring event).
Population-Biomass	x	x	regression	g wet or dry weight/m^2	
Size-Frequency Distribution (multiple age classes)	x	x	quadrat sampling or patent tong	(length, number)	
Spatset	x		quadrat sampling or patent tong	(spat/m^2) Evidence of successful recruitment during at least two recruitment periods	No additional cost (this data is collected as part of DNR's existing annual fall oyster survey)
Reef Height		x	sidescan or multibeam sonar/seismic profiling	(cm) Positive or neutral change in reef height from original structure	No additional cost (These three parameters are monitored as part of NOAA's existing program; the value of NOAA's data collection is $80,000 over 6 years).
Reef Area		x	sidescan or multibeam sonar/seismic profiling	(m^2)	
Reef Patchiness		x	sidescan or multibeam sonar/seismic profiling	Percent of reef with hard substrate and/or 15 oysters m^2; target is >30%	
Shell Volume -- black/brown (shell budget)		x	patent tong or quadrat sampling (if possible)	increase in brown shell/black shell ratio	No additional cost
Total Additional Cost over 6 Years (rounded)					**$546,000**

*Assumes three 10-acre sentinel sites, monitored annually; **pre- and post-construction, years 3 and 6

Table 12: Suggested Diagnostic Monitoring Activities

Parameter	Priority	Frequency	Number of Sites	Method of Measurement	Units/ Performance Metric	Estimated Cost
Dissolved Oxygen	High	Every 30 minutes	3 sentinel sites	Data logger	mg/L	$147,000 over 6 years, including equipment and labor
Temperature	High	Every 30 minutes	3 sentinel sites	Data logger	°C	
Salinity (Conductivity)	High	Every 30 minutes	3 sentinel sites	Data logger	PSU	
pH	Medium	Every 30 minutes	3 sentinel sites	Data logger	$-\log[H^+]$	
Total Algae (Chlorophyll a)	Medium	Every 30 minutes	3 sentinel sites	Data logger	µg/l	
Turbidity	Medium	Every 30 minutes	3 sentinel sites	Data logger	NTU	
Alkalinity	Medium	Monthly	3 sentinel sites	Titration	mg/L of $CaCO_3$	$100 for test kits; data can be collected when sensors are changed
Disease (Dermo, MSX)	High	Annually in fall	2	Histology	Prevalence, intensity	No additional cost (included with DNR's fall survey unless additional sites are added)
Predation	Low	Annually in fall	Signs of predation will be assessed during populations surveys.	Shell examination	N/A	No additional cost
Poaching	High	Constant	All	MLEIN	N/A	No additional cost (part of DNR's existing MLEIN program)
Sedimentation Rate	High	Pre- and post-construction, years 3 and 6	3 sentinel sites	Sonar	cm/year	No additional cost (sedimentation rates can be estimated as part of NOAA's existing program)
Total Additional Cost over 6 Years (rounded)						**$147,000**

Table 13 summarizes the costs of the suggested restoration success and diagnostic monitoring activities for the Little Choptank oyster sanctuary.

Table 13: Summary of Monitoring Costs

Monitoring per Oyster Metrics Success Standards*	**$546,000**
Diagnostic Monitoring*	**$147,000**
Total Cost	**$693,000**

* This reflects the cost to monitor beyond what is already funded as part of ongoing federal, state and NGO programs.

Monitoring Protocols

More information is provided below for some of the monitoring identified in the restoration success monitoring table. Note that data on some of these parameters are already collected by agencies and or partners. The tables above list costs beyond what is already being monitored.

Post-Planting Monitoring – Spat Growth and Mortality

Growth and mortality of seed plantings are monitored 4 to 8 weeks after planting by collecting spat on shell. The 4 to 8-week window has been found to be the most effective in assessing these parameters. Focusing on a narrower window in time has proven difficult with weather and other variables affecting the opportunities to sample. Using the planting vessel's track lines as a target, divers collect hatchery shells from each survey location. Divers place a 0.3-meter x 0.3-meter quadrat on the bottom and collect all shells contained within the quadrat. Divers attempt to collect at least six quadrat samples at each site. When shell densities are too low for quadrat sampling, such that the diver could not find shell in areas with few track lines, the diver will instead haphazardly collect 50 to 100 shells from throughout the bar.

Each shell is examined for live spat, boxes, scars, and gapers. Additionally, the first 50 live spat observed in each sample are measured for shell height and, each shell is inspected for the presence of *Stylochus*. Shells are counted in the field, without magnification. The assumption is that live spat are visible at 4-8 weeks old. All shells are returned to the bar when sampling is complete. The number of spat per shell is multiplied by the total amount of shell planted on each bar to calculate the amount of spat detected on the bar by the post-planting monitoring survey. Spat survival is then calculated as the percentage of spat planted that was detected by the survey.

Environmental and biological factors such as dissolved oxygen, bottom quality, and salinity, are collected to investigate their relationship to growth; survival analyses are conducted to correlate various environmental and biological factors with growth and survival.

Oyster Population Surveys

Patent tong surveys are conducted on target reefs to assess restored oyster population dynamics including reef-level population estimates, oyster size frequency and disease dynamics, as well as spatial patterns of oyster and shell densities across a given reef.

A grid of 25-meter x 25-meter cells is overlaid onto the planted area using spatial tools in ArcGIS and each grid cell is sampled with hydraulic patent tongs. Number and size (mm) of live and dead (box) oysters are recorded at each grab. In addition, shell score (the amount of shell substrate collected in each tong grab) is quantified on a scale of 0 to 5[4]. The density of oysters at each point is calculated based on the grab area of the tongs (between 1 and 2 square meters depending on the vessel used) and a population estimate is generated using this density data. The total biomass of oysters at each reef is estimated according to Liddell (2007). The density of oysters and shell score at each patent tong survey point is spatially referenced using GIS. These spatial data allow for shell score and density plots to be generated to illustrate the spatial distribution of shell and oysters at each site. All oysters and shells, except those collected for disease sampling, are returned to the reef.

Reefs targeted for patent tong surveys are all reefs planted 3 and 6 years prior, in order to facilitate the consistent sampling of each reef. Sentinel reefs are targeted to act as long-term monitoring sites. These reefs are sampled every year (rather than every 3 years). This allows for the analysis of temporal trends in oyster population and disease levels, as well as how the spatial distribution of oyster density and shell base changes with time.

The dynamic nature of the conditions in the Chesapeake Bay and the ever-changing body of information on oysters and restoration in general require a flexible monitoring plan paired with controlled experiments to maximize restoration success and efficiency. Additionally, the productive collaboration of all agencies involved in Chesapeake Bay restoration has greatly helped with the success of restoration. The coordination of the efforts of the Maryland Geological Survey, NOAA Chesapeake Bay Office, ORP, and the Paynter Labs has allowed for the implementation of the most up-to-date data on the suitability of areas for planting. This coordination is critical to the success of oyster restoration.

[4] Oyster Recovery Partnership's tong fullness scale: 0=no shell in the tongs; 1= 1/5 full; 2= 2/5 full; 3= 3/5 full; 4= 4/5 full, 5= totally full. These values are for total volume of shell within the patent tongs.

Control Sites

Control sites (untreated areas) have been designated to allow comparison between restored reefs and untreated reefs within the Little Choptank. These are areas that are otherwise suitable for restoration, but will receive neither substrate nor seed. (See Blueprint Map for control sites location.) Six control sites were designated, selected to include sites that span the length of the target restoration area within the sanctuary (upstream, midstream, and downstream). Of these, three sites were otherwise suitable for seed-only treatment, and three were otherwise suitable for substrate treatment. From among the candidates that met the upstream/ midstream/ downstream and treatment type criteria, these particular sites were selected because they were the most isolated from other restoration polygons.

Research

The purpose of this plan is to lay out the reef construction and seed plantings needed for Little Choptank oyster sanctuary to meet the definition of a restored tributary under the implementation strategy for Executive Order 13508. The monitoring section describes the monitoring needed to determine whether the reefs in Little Choptank sanctuary are, in fact, successfully restored per the goals defined in the oyster metrics report, and potential causes of success and/or failure. The workgroup also recognizes that the large-scale oyster restoration described in this plan provides unique opportunities for critical research. Examples of relevant research areas are listed in the Harris Creek Oyster Restoration Tributary Plan (Maryland Interagency Oyster Restoration Workgroup of the Sustainable Fisheries Goal Implementation Team, 2013)
http://www.chesapeakebay.noaa.gov/images/stories/habitats/harriscreekblueprint1.13.pdf

The hope is that having this tributary plan will allow researchers, agencies and funders to understand the intended restoration work slated for Little Choptank oyster sanctuary, and to determine if it may constitute a suitable study site for research. In fact, it may be possible to actually design reefs to facilitate certain studies by having agencies and researchers work collaboratively. The ideal approach to large-scale, tributary-based restoration is to maximize the gain in both restored reefs as well as knowledge about successful restoration strategies. The interest in optimizing learning from the effort may need to be tempered, though, with the realities of limited resources in a difficult economic climate.

Cost Analysis for Little Choptank River Tributary Plan

The total estimated cost for implementing this plan, including monitoring, is $29,000,000. Of that, approximately $18,839,000 is for substrate (including material purchase and substrate placement), and $9,382,500 is for hatchery-produced seed (including planting). The remaining $693,000 is for monitoring. Table 13 summarizes the plan implementation cost (details of the seed costs are in Table 7; details of substrate costs are in Table 9; details of monitoring costs are in Table 12).

This estimate assumes a cost of $5,000 per million planted oyster seed (ORP, July 2013), and approximately $73,000 per acre to purchase and place substrate averaging 9 inches high. (approximately $60.00 per cubic yard, DNR, September 2014). This cost is based on a substrate mixture of rock and fossil shell; costs could be different for other materials, such as recycled concrete, reclaimed oyster shell, or other substrates, should they become available.

Table 14: Summary of Total Costs

1.9 Billion Seed	**$9,382,500**
314,600 Cubic Yards Substrate	**$18,839,000**
Monitoring	**$693,000**
Total Cost (rounded)	**$29,000,000**

Implementation of the Little Choptank River Tributary Plan

The time frame for implementation of the Little Choptank oyster restoration tributary plan depends primarily on funding. The estimated cost for implementation and monitoring is $28.56 million. DNR's 2014 contract funded the construction of 114 acres of substrate. (These constitute all of the areas in the river that, per this plan, require substrate, and can be constructed under existing permits). In late 2013, DNR applied for a permit modification to be able to construct the remaining reefs; as of publication of this document, that permit has not been granted. NOAA anticipates being able to provide some funding in future years toward implementation of the Little Choptank tributary plan. Construction and seeding will continue as funding allows.

Project completion is also dependent upon oyster seed production and performance of the restoration actions. Current and anticipated seed production capacity from the University of Maryland's Horn Point facility is likely sufficient to supply the project over several years. The Horn Point hatchery currently produces, and ORP plants, about 500 million spat-on-shell annually; the hatchery has plans to expand to 1 billion annually over the next few years. At current capacity, the 1.876-billion seed demand for Little Choptank oyster sanctuary could be met within 3 to 5 years from initial implementation time, possibly sooner if capacity increases. However, other restoration projects, oyster gardening programs, aquaculture, and public re-seeding of the wild fishery grounds require seed from this partnership as well, so not all of the Horn Point hatchery's annual production would go to the Little Choptank initiative. A natural spat set on the river could significantly reduce anticipated costs, seed needs, and the time frame in which restoration can be achieved.

Substrate for new reef construction may be a limiting factor. The amount of substrate needed to restore Little Choptank oyster sanctuary is estimated at 314,600 cubic yards. This could be any combination of oyster shell, clam shell, fossil shell, or alternative substrates such as crushed concrete, or rock. Reef balls can also be used for additional three-dimensionality. Oyster shell is a natural material, and relatively inexpensive if it can be found locally. However, it is currently in extremely short supply, and demand is high from both the restoration and aquaculture sectors. Also, shell can break apart into very small fragments ('fines') with multiple handlings resulting in reduced interstitial spaces. Further, oyster shell provides no protection from illegal harvesting/poaching. It may be possible to reclaim old shell from past unsuccessful restoration efforts, but it remains unclear how much of this shell is potentially recoverable and at what expense. Rock and concrete are readily available, and may help deter poaching. However, these materials are costly, and concerns exist about possible interference with other fisheries (e.g., trotlines for crab harvest). Reef balls are a good citizen outreach activity, and may help deter poaching. However, reef balls are costly as well, and concerns exist about possible interference with trotlines.

Permits are another key component for implementation. Currently, Section 10 permit restrictions limit placement of substrate to areas where a clearance of 8 feet of water depth will remain overtop of the reef post construction. Assuming a maximum of 1 foot of substrate is placed, 9 feet of water depth or greater is needed to maintain the 8-foot clearance. The analyses performed for the tributary plan show that in order to meet the restoration target, shallower areas need to be restored. DNR would require a permit modification to construct reefs with less than 8 feet of navigational clearance. DNR has applied for this permit.

Adaptive Management and Project Tracking

The Little Choptank River Oyster Restoration Tributary 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. The original document will be posted on the websites of the NOAA Chesapeake Bay Office and DNR. 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.

NOAA, USACE-Baltimore District and DNR will produce annual updates describing progress that has been made on restoring the oyster population in Little Choptank oyster sanctuary. These reports will be produced annually by February for the previous calendar year. The reports will include: an accounting of the seed and substrate planted, a map showing the location of the seed and substrate plantings for the year, a summary of any major issues encountered by the project, a discussion of any adaptations made to the original plan, and planned work for the next year. These annual updates will be posted on the websites of the NOAA Chesapeake Bay Office and DNR.

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