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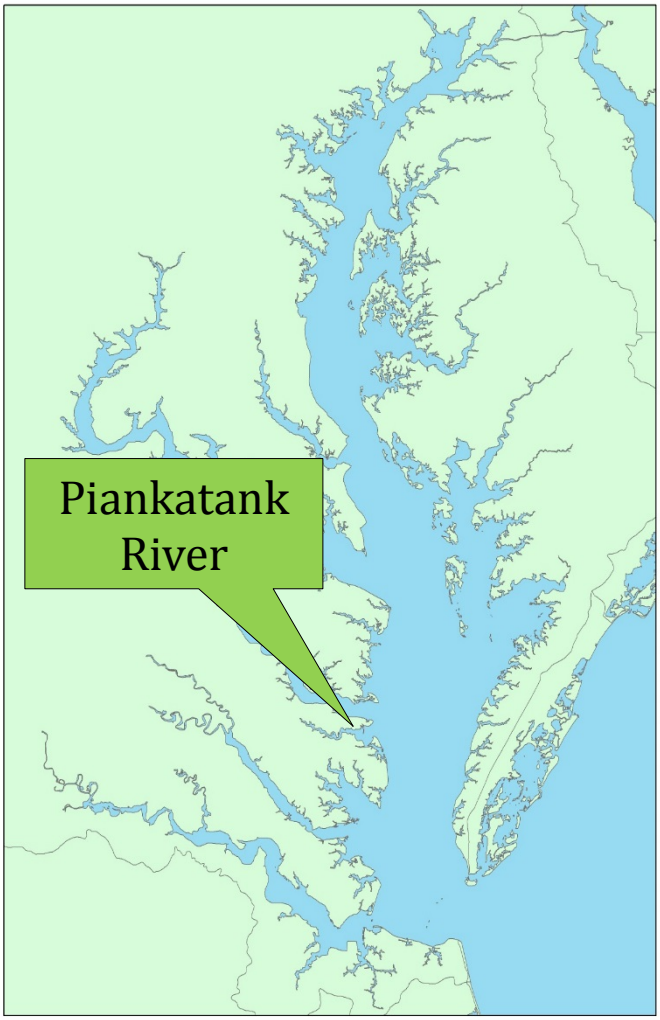
Piankatank River Oyster Restoration Tributary Plan:
A Blueprint for Restoring Oyster Populations per the Chesapeake Bay Watershed Agreement

February 2019



Drafted by the Western Shore Oyster Restoration Workgroup under the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team

The Western Shore Oyster Restoration Workgroup includes representatives from: National Oceanic Atmospheric Administration (NOAA, cochair), U.S. Army Corps of Engineers' Norfolk District (USACE, cochair), The Nature Conservancy (TNC), Chesapeake Bay Foundation (CBF), Christopher Newport University (CNU), Virginia Institute of Marine Science (VIMS), Virginia Marine Resources Commission (VMRC), Virginia Commonwealth University (VCU), and U.S. Navy.

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Executive Summary

The 2014 Chesapeake Bay Watershed Agreement[1] is the guiding directive for the work of the federal-state Chesapeake Bay Program. The Agreement established a goal to "restore native oyster habitat and populations in 10 Bay tributaries by 2025, and ensure their protection." Responsibility for achieving this goal rests with the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (GIT). For Virginia, the Sustainable Fisheries GIT convened workgroups to plan, implement, and track progress toward this goal. The Western Shore Oyster Restoration Workgroup (hereafter, the Workgroup) developed this document to explain how the river's restoration goal was established and to describe plans to achieve it.

Consistent with the Chesapeake Bay Oyster Metrics[2] success criteria, the Workgroup developed a restoration goal of 437.67 acres for the river. 203 acres of existing reefs in the river already meet the Oyster Metrics[2] density and biomass criteria, and are therefore considered 'premet' reefs (prerestored reefs (see full definition in Section II). These require no additional restoration work. Additionally, 7.24 acres of reefs were restored in the mid-1990s by the Chesapeake Bay Foundation (CBF) and Virginia Marine Resources Commission (VMRC), and between 2014 and 2018 the U.S. Army Corps of Engineers' Norfolk District (USACE), The Nature Conservancy (TNC), VMRC, Christopher Newport University (CNU), and Virginia Commonwealth University (VCU) restored 67.77 acres. Together this amounts to 75.01 acres of existing restoration projects in the River. The 'premet reefs' (203 acres) combined with the existing restoration projects (75.01 acres) equates to 287.01 acres of reefs already restored in the river. Subtracting this from the 437.67-acre goal leaves 159.66 acres that still need to be restored in the river. (Table 1).

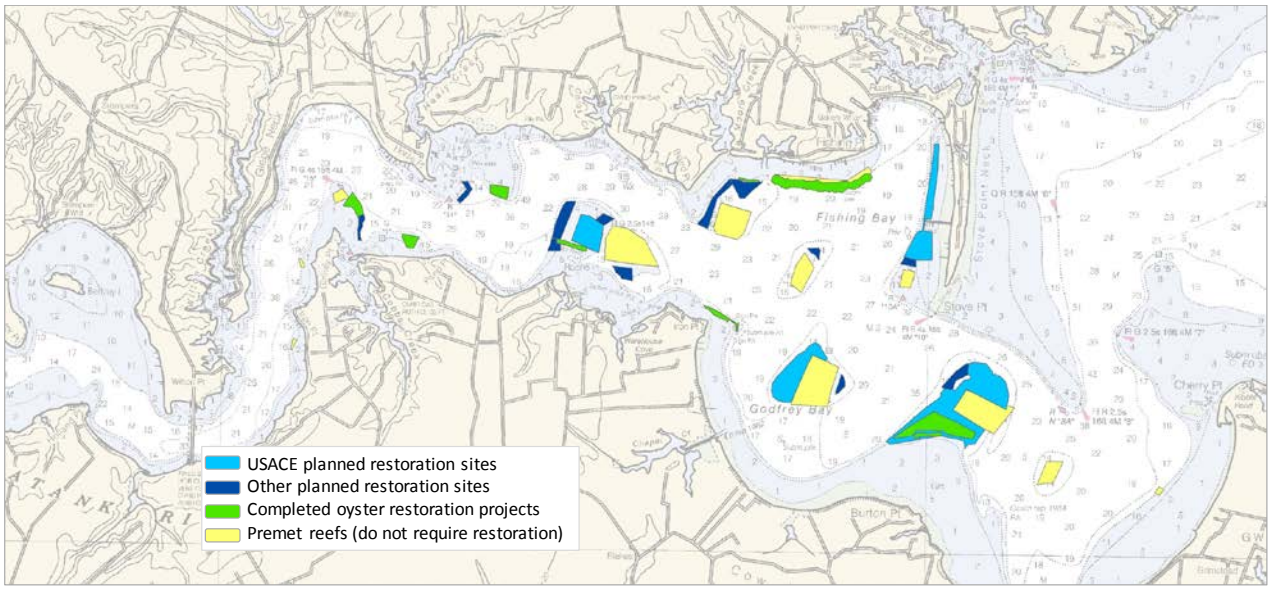
The cost estimate for completing the remaining acreage is $2.2 million to $12 million, depending on variables including construction techniques, location, materials, and other factors. It is the best professional judgement of the Workgroup that the actual cost to construct the remaining 156.66 acres will likely be closer to the middle or high end of the cost estimate. (See Section V: Cost Estimate).

Table 1: Piankatank River oyster restoration goal, existing restored area, and cost estimate

Restoration goal for the Piankatank River	437.67 acres
Already restored *(203 acres 'premet' reefs, which do not require restoration; 75.01 acres existing restoration projects)*	278.01 acres
Remaining area to be restored	159.66 acres
Cost estimate to restore remaining area	$2.2 million- $12.8 million

USACE has plans and National Environmental Policy Act (NEPA) clearance to construct 165 acres of reefs, pending funding. Other Workgroup partners may construct reefs on a subset of these areas, or on additional areas per this plan, pending funding. (Figure 1).

Figure 1: Map showing existing oyster reefs and planned restoration areas on the Piankatank River.



Section 1: Policy Drivers, Chesapeake Bay Oyster Metrics, and Western Shore Oyster Restoration Workgroup Organizational Framework

1.1 Policy Drivers

Executive Order 13508 on Chesapeake Bay Protection and Restoration[3] directs federal agencies to protect and restore oysters in the Bay. The 2014 Chesapeake Bay Watershed Agreement[1] calls for state and federal partners to "restore native oyster habitat and populations in 10 Bay tributaries by 2025, and ensure their protection." Responsibility for achieving this '10 tributaries' oyster goal rests with the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (GIT). For Virginia, the Sustainable Fisheries GIT convened two workgroups to plan, implement, and track progress toward this goal. Members of these workgroups include federal, state, and local agencies, universities, private business, and nonprofit organizations. The Western Shore Workgroup coordinates work in the Piankatank, Lower York and Great Wicomico rivers, and developed this document.

1.2 Chesapeake Bay Oyster Metrics

The Sustainable Fisheries GIT convened an Oyster Metrics panel to develop a science-based, common definition of a successfully restored tributary for the purpose of tracking progress toward the '10 tributaries' oyster goal. The panel 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 panel produced "Restoration Goals, Quantitative Metrics and Assessment Protocols for Evaluating

Success on Restored Oyster Reef Sanctuaries[2]," a report detailing these recommended success metrics (hereafter referred to as the Oyster Metrics report).

The following criteria were among those set forth in the Oyster Metrics report[2]:
1) A successfully restored reef should have:

- A minimum threshold of 15 oysters and 15 grams dry weight/square meter (m^2) covering at least 30% of the target restoration area at six years post restoration;
- Ideally, a higher, target of 50 oysters and 50 grams dry weight/square meter (m^2) covering at least 30% of the target restoration area at six years post restoration;
- Two or more oyster year classes present;
- A positive or neutral shell budget; and
- A positive or neutral postconstruction reef height and footprint.

2) A successfully restored tributary is one where:

- 50-100% of the "currently restorable oyster habitat" has oyster reefs that meet the reef-level metrics above.
- 8-16% of its historic oyster bottom has oyster reefs that meet the reef-level metrics above.

These Oyster Metrics[2] success criteria are being applied to tributary-scale oyster restoration work planned and implemented under the 2014 Chesapeake Bay Watershed Agreement '10 tributaries' oyster goal.

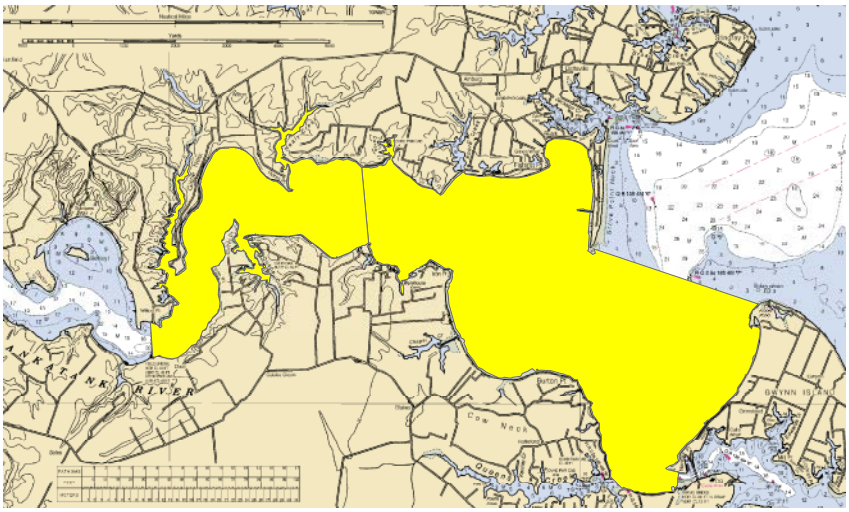
1.3 Selection of the Piankatank River as Tributary for Large-Scale Oyster Restoration under the Chesapeake Bay Watershed Agreement Oyster Outcome

Several factors led to the selection of the Piankatank River for large-scale oyster restoration under the Chesapeake Bay Watershed Agreement.

- In 2012, USACE completed the Native Oyster Restoration Master Plan[4], which evaluated 63 tributaries of the Chesapeake Bay watershed. The document prioritized rivers based on historical, physical, and biological attributes to support self-sustaining oyster populations in large-scale oyster restoration efforts. In this document, the Piankatank River was designated as a Tier One tributary, indicating it was an appropriate location for oyster restoration.
- The Piankatank River has historically exhibited very strong oyster recruitment (natural spat set).[4]
- Oyster restoration efforts have been under way in the river since the 1990s (Table 2). These were implemented by organizations including CBF, CNU, TNC, VMRC, USACE, and VCU. Where monitored, these projects have healthy oysters.
- Interest from local watershed groups was strong.
- The National Oceanic and Atmospheric Administration (NOAA), USACE, and VMRC held conversations at length to determine which tributaries in Virginia would be suitable and tenable for large-scale oyster restoration. The Piankatank River consistently was among the top candidates.

By consensus among NOAA, USACE, VMRC, and local partners, and with agreement from the Sustainable Fisheries GIT, the Piankatank River was selected for large-scale oyster restoration in Virginia under the 2014 Chesapeake Bay Watershed Agreement.

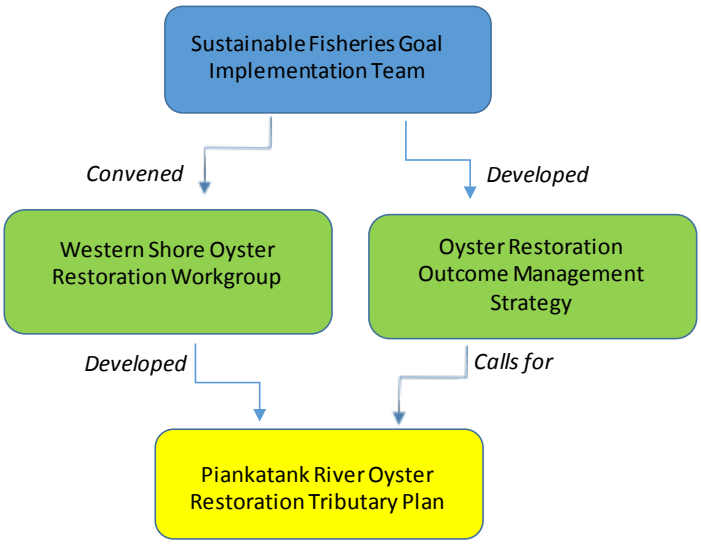
Figure 2: Subsegment (yellow area) of the Piankatank River selected for large-scale oyster restoration under the '10 tributaries' oyster restoration goal.



For the purposes of restoring the Piankatank River under the '10 tributaries' goal, the Workgroup, by consensus, defined a subsegment of the river for restoration. This boundary extends from the Twigg Bridge (Route 3) to a line between Stove Point and Cherry Point. (Fig 2 and Appendix A). In this document, the term Piankatank River refers to this subsegment of the river.

1.4 Organizational Framework

Figure 3: Organizational Framework for Large-Scale Oyster Restoration in Piankatank River under the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team.



Responsibility for achieving the Chesapeake Bay Watershed Agreement oyster restoration goal rests with the Sustainable Fisheries GIT. The Sustainable Fisheries GIT convened workgroups in Maryland and Virginia to plan and coordinate large-scale oyster restoration. Virginia's groups are the Western Shore Workgroup (working in the Piankatank, Great Wicomico, and Lower York rivers) and the Hampton Roads Workgroup (working in the Lafayette and Lynnhaven rivers). The Western Shore Workgroup (hereafter, "Workgroup") developed this plan. Like all Goal Implementation Teams under the Chesapeake Bay Program, the Sustainable Fisheries GIT crafted "management strategies" describing the steps necessary to achieve each Chesapeake Bay Watershed Agreement outcome. 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[5] calls for the Virginia workgroups to develop tributary-specific plans to restore oysters in each tributary, consistent with the Oyster Metrics success criteria. (Figure 3).

The Western Shore Workgroup (originally convened in late 2014 as the Piankatank Workgroup) developed this document. It is meant as a cohesive oyster restoration plan for the river. The Workgroup recognizes that its members may also have organization-specific oyster restoration plans and goals. This document is not meant to replace the existing plans; rather, it is meant to be inclusive of those plans and provide the overarching strategy to achieve restoration of oyster populations of the Piankatank River.

Section 2: Current Status of Piankatank River Oyster Resource

The Piankatank River is a polyhaline subestuary of the Chesapeake Bay, located in Virginia's western shore. The river bottom is managed by VMRC, and various parts are used for oyster leasing by private aquaculturists, oyster seed harvest (to be moved to private leases for grow out and eventual harvest), and sanctuary (nonharvest areas).

To develop this document, the Workgroup used new and existing data to quantify the oyster populations on existing reefs. Existing reefs (other than restoration projects) that met the Oyster Metrics[2] threshold criteria of 15 oysters per m^2 and 15 biomass per m^2 were considered already functioning a restored level. These were deemed 'premet' reefs, and counted toward the overall restoration goal in the River. A total of 203 acres in the River met the 'premet' criteria. (Figure 5). See Appendix B for detailed information on which reefs were considered 'premet' and how that determination was made.

'Premet' Reefs

Premet reefs are defined as those that already met the Oyster Metrics[2] threshold criteria for oyster biomass and density before large-scale oyster restoration started in the Piankatnak River. In other words: 'pre' restoration they 'met' the success criteria. These reefs are considered as progress toward the overall restoration goal of having 437.67 acres of reefs functioning at a restored level in the river.

The Workgroup also cataloged existing oyster restoration projects on the River. (Table 2). Older restoration projects (mid 1990s) total 7.24 acres. Between 2014 and 2018, another 67.77 acres of reefs were built by Workgroup partners with the common goal of restoring the River per the Chesapeake Bay Watershed Agreement '10 tributaries' goal. The older reefs (7.24 acres) and the newer reefs (67.77 acres) together equal 75.01 acres of existing restoration projects in the River. These 75.01 acres are counted as progress toward meeting the target of having 437.67 acres of reef functioning at a restored level in the river. (See Section III for information on how the target was developed.)

Table 2: Existing Piankatank River oyster restoration projects. These projects were present in the River prior to development of this document. They are color coded in greennn in Figure 1 (Piankatank map)

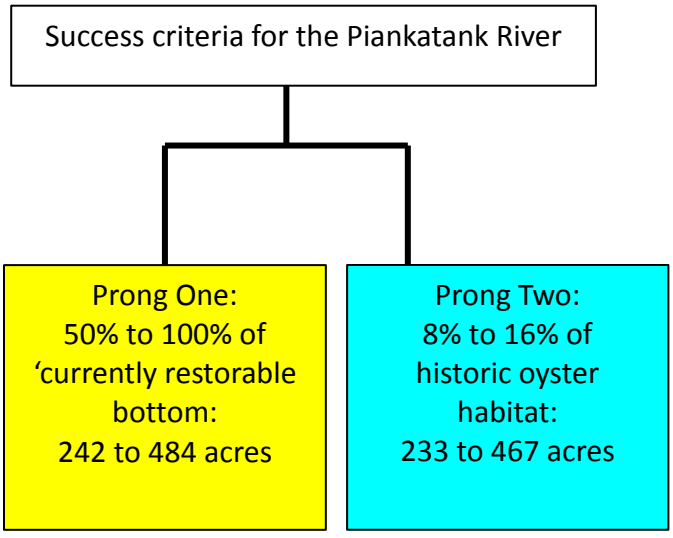
Geodatabase reef site ID	Reef Name	Acres	Year Constructed	Funded by
PR_08	Palaces Bar	3.27	1993	VMRC
PR_06	Roane Point	0.24	1995	VMRC
PR_05	Burtons Point	2.65	1995	VMRC
PR_07	Bland Point	1.08	1995	VMRC
PR_10	Iron Point Reef	3.64	2015	TNC; VMRC
PR_09	Fishing Point Reef	23.51	2014	TNC; VMRC; VCU
PR_11	Burtons Point	25.18	2017	USACE; VMRC
PR_14	Ginny Point	5.84	2018	TNC; VMRC; VCU
PR_13	Cobbs Creek	4.35	2018	TNC; VMRC; VCU
PR_12	Island Bar	5.25	2018	TNC; VMRC; VCU
Total preexisting restoration projects		**75.01**		

The information on premet reefs, past restoration projects, leased areas, and other features is available in the Piankatank River oyster restoration GIS geodatabase, www.habitat.noaa.gov/chesapeakebay/gis/Oyster_Restoration_Geodatabases/. This geodatabase is maintained by NOAA using information provided by the Workgroup.

Section 3: Oyster Restoration Target Setting

The Oyster Metrics[2] report recommends a two-pronged test to determine if a river is successfully restored (Figure 4). To meet Prong One, 50% to 100% of the 'currently restorable oyster habitat' (CROH) in the river must be covered with reefs functioning consistent with Oyster Metrics[2] reef-level success criteria. CROH is defined as *evidence-based oyster habitat*[6] within the restoration constraints determined by the Workgroup. Per the revised definition adopted by the Sustainable Fisheries GIT in 2017[6], CROH is river bottom with evidence of existing or

Figure 4: Schematic of Oyster Metrics[2] two-prong test for a successfully restored tributary, as applied to the Piankatank River. Adapted from Appendix A.



historic oyster reefs, within certain parameters determined by the Workgroup. Evidence of reefs is typically derived primarily from current-day sonar observations detecting shell river bottom, but could also include historical information, local knowledge, or other sources.

To determine CROH in the Piankatank River, the Workgroup, by consensus, used the following parameters (see Appendix A for more detail):

- River extent: The portion of the Piankatank River extending from the Twigg Bridge (Route 3) to a line between Stove Point and Cherry Point (Figure 2).
- 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 16 feet were considered restorable. The 16-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, the limits of the acoustic surveys used to create the restorable bottom analysis, and Workgroup consensus that Piankatank River reefs should be constructed subtidally to avoid oyster mortality that occurs when intertidal reefs are exposed to freezing air temperatures.
- Benthic habitat (river bottom) type: NOAA sonar survey and ground truthing data (2014) were classified using the Coastal and Marine Ecological Classification Standards[7]. Bottom suitable for oyster restoration consisted of any of the following habitat types: anthropogenic oyster rubble; sand with shell; biogenic oyster rubble; muddy sand with shell.
- Submerged Aquatic Vegetation (SAV): VIMS SAV coverage maps from 1971-2017 were examined, and 6.6 acres overlapped with potential restorable oyster habitat. These areas were removed from consideration as CROH, since SAV beds are critical habitat and constructed reefs should not interfere with potential SAV recovery.
- Water quality: In the USACE Native Oyster Restoration Master Plan[4], all tributaries (including the Piankatank) were evaluated using these criteria combined: a) summertime bottom dissolved oxygen levels from 2001-2006 (incorporating both wet and dry hydrologic years) greater than 5 mg/L; b) depth criteria of less than 20 feet; c) bottom and surface salinity greater than 5 parts per thousand. Areas that met all of these criteria were considered suitable for oyster restoration. Most of the Piankatank (6,210 acres of 7,097 acres within the Baylor polygons) was considered suitable for oyster restoration. The USACE Plan[4], which included water-quality analysis, ranked the Piankatank as a 'Tier 1' tributary for oyster restoration. There is only a single Chesapeake Bay Program water-quality monitoring station just inside the mouth of Piankatank; thus there is limited data available on water quality. The approach in this analysis is to use depth as proxy for potentially hypoxic areas.

Using the above criteria, 484 acres were classified as CROH (Figure 4 and Appendix A). Therefore, to meet Prong One of the Oyster Metrics[2] definition of a restored tributary, between 242 and 484 acres will need to be restored.

Prong Two of the Oyster Metrics[2] restored tributary test calls for restoring at least 8-16% (Figure 4) of the river's historic acreage of oyster reefs. In the Piankatank River, per the USACE Native Oyster Restoration Master Plan, 8% to 16% of historic reef acreage is estimated at 233 to 467 acres.

Since the low end of Prong Two is less than the low end of Prong One (Figure 4), restoring the acreage range defined in Prong One will also meet Prong Two. The goal range on the river therefore is defined by Prong One: between 242 and 484 acres.

The Workgroup set a target of restoring 437.67 acres in the Piankatank, which is 90.42% of CROH. This target was set by Workgroup consensus. It took into account primarily the Prong One target range, the fact that USACE has plans to construct up to 165 acres of reefs on the river, and a feasibility analysis the Workgroup developed to determine which additional areas are good candidates for oyster restoration work. Areas considered feasible for oyster restoration included were:

- In 6-16 feet of water depth
- Not on shell dominant or mud river bottom
- On hard base sediments identified by sonar
- Not within 150 feet of maintained navigation channels
- Not within 250 feet of navigational aids
- Not within 250 feet of private docks
- Not overlapping with existing reefs
- Not on or within 30 meters of oyster leases
- Not within 50 meters of VMRC oyster sampling areas
- At least 1 acre in size

See Appendix A, feasibility analysis section, for more information on the feasibility analysis.

Prior to drafting this plan, 75.01 acres of restoration projects were built in the river through the combined efforts of USACE, VMRC, TNC, CNU, VCU and CBF. In addition, the Workgroup determined that 203 acres of 'premet' reefs (see definition in Section II) in the river are already functioning at a restored level.

Subtracting the 203 aces of 'premet' reefs and 75.01 acres of existing restoration projects from the target of 437.67 acres leaves a balance of 159.66 acres remaining to be restored. (Table 3). This Plan documents where the remaining 159.66 acres will be constructed, and the estimated cost.

Table 3: Accounting of area (acres) that remains to be restored as of the drafting of this plan (end of calendar year 2018).

Restoration target	437.67 acres
Existing area functioning at a restored level *(203 acres 'premet' reefs; and* *75.01 acres of existing restoration projects)*	-278.01 acres
Remaining areas the need to be restored *(as of end 2018)*	159.66 acres

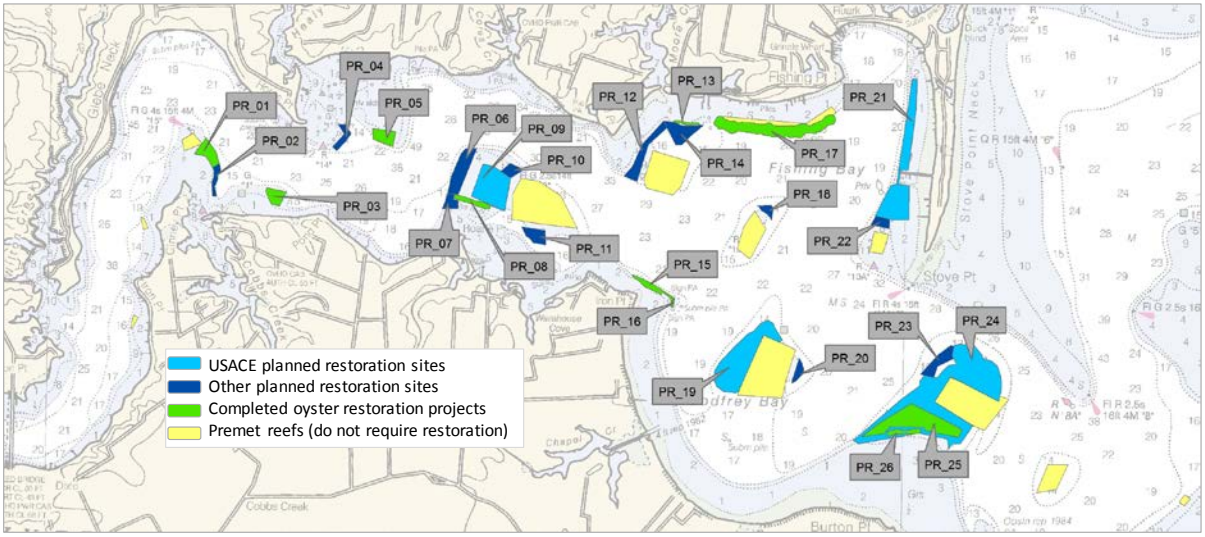
Section 4: Planned Oyster Restoration in the Piankatank River

4.1 Planned Oyster Reef Construction

The Workgroup used the above-mentioned feasibility analysis (see Appendix A for details), along with maps of planned USACE reef construction, to determine where on the river to plan construction of the required 159.66 remaining acres of reefs.

Figure 5 shows the planned reef construction areas, completed restoration projects, and premet reefs in the river. The planned restoration areas (light blue and dark blue polygons in Figure 5) represent more than the 159.66 acres that need to be constructed. Workgroup partners plan to construct reefs on a 159.66-acre subset of these areas. This allows for some of the light blue and dark blue polygons to be eliminated due to permitting concerns, future input from local citizens, adaptive management, etc.,

Figure 5: Map of planned reef construction areas, completed restoration projects, and premet reefs.



while still achieving the acreage goal. Table 4 shows the size (acreage) and status of each restoration polygon in Figure 5.

Table 4: Existing and proposed oyster restoration reefs on the Piankatank River.

Reef Number	Acres (rounded)	Status	Reef Name	Substrate	Year Constructed	Project lead
PR_01	5.84	Constructed restoration reef	Ginny Point	Stone	2018	VMRC/ TNC
PR_03	4.35	Constructed restoration reef	Cobbs Creek	Stone	2018	VMRC/ TNC
PR_05	5.25	Constructed restoration reef	Island Bar	Stone	2018	VMRC/ TNC
PR_08	3.27	Constructed restoration reef	Palaces Bar	various	1993	VMRC
PR_13	1.08	Constructed restoration reef	Bland point	various	1995	VMRC
PR_15	3.44	Constructed restoration reef	Iron Point	Concrete & Stone	2015	VMRC/ TNC
PR_16	0.24	Constructed restoration reef	Iron Poiint	various	1995	VMRC
PR_17	23.51	Constructed restoration reef	Fishing Point	Recycled Concrete	2014	VMRC/ TNC
PR_25	25.18	Constructed restoration reef	Burtons Point	A1 Riprap Stone	2017	USACE/ VMRC
PR_26	2.65	Constructed restoration reef	Burton Point	various	1995	VMRC
PR_09	21.37	USACE planned site	Reef #4	TBD	TBD	USACE/ VMRC
PR_19	33.95	USACE planned site	Reef #3	TBD	TBD	USACE/ VMRC
PR_21	30.80	USACE planned site	Reef #1	TBD	TBD	USACE/ VMRC
PR_24	76.25	USACE planned site	Reef #2	TBD	TBD	USACE/ VMRC
PR_02	2.72	Other planned site	Unnamed	TBD	TBD	TBD
PR_04	3.42	Other planned site	Unnamed	TBD	TBD	TBD
PR_06	11.12	Other planned site	Unnamed	TBD	TBD	TBD
PR_07	3.08	Other planned site	Unnamed	TBD	TBD	TBD
PR_10	3.16	Other planned site	Unnamed	TBD	TBD	TBD
PR_11	5.06	Other planned site	Unnamed	TBD	TBD	TBD
PR_12	9.21	Other planned site	Unnamed	TBD	TBD	TBD
PR_14	8.41	Other planned site	Unnamed	TBD	TBD	TBD
PR_18	2.11	Other planned site	Unnamed	TBD	TBD	TBD
PR_20	2.65	Other planned site	Unnamed	TBD	TBD	TBD
PR_22	2.84	Other planned site	Unnamed	TBD	TBD	TBD
PR_23	6.96	Other planned site	Unnamed	TBD	TBD	TBD

The general restoration technique for the planned reefs will likely be predominately placing stone or other substrate onto the target site in either a striped configuration or covering the entire site. Natural oyster recruitment is generally high in the river, and the Workgroup expects the constructed reefs will self-seed with juvenile oysters, although some spat-on-shell may be planted onto some reefs.

4.2 Implementation

Implementation of this Plan depends primarily on funding availability, as well as permitting and reef-building material availability. Workgroup partners will continue to pursue state, federal, and private funding to ensure the Piankatank River is restored consistent with Chesapeake Bay Watershed Agreement '10 tributaries' oyster outcome. Workgroup partners will continue to coordinate on reef construction, progress tracking, and Plan implementation.

Two specific projects are pending as of the drafting of this Plan:

- In spring and summer 2019, VMRC and TNC plan to construct reefs in the Piankatank River. The size of the reefs will be determined by the level of available funding (15-20 acre range is likely). These will most likely be constructed using two-inch-diameter crushed granite to cover the site approximately three inches deep. The reefs will rely primarily on natural recruitment, but VCU may add hatchery-produced spat-on-shell to the reefs. These reefs will likely be placed onto a subset of the 'other planned restoration sites' on the map in Figure 5.
- USACE has NEPA clearance and eventually plans to construct up to an additional 165 acres of reefs in the river, although there is currently no funding for project implementation. These would be constructed on the 'USACE planned restoration sites' areas on the map in Figure 5, or on a subset of these polygons.

Data relating to Plan implementation will be logged in the Piankatank GIS geodatabase maintained by NOAA at www.habitat.noaa.gov/chesapeakebay/gis/Oyster_Restoration_Geodatabases/

Since 2016, the Workgroup, along with the Hampton Roads Oyster Restoration Workgroup (coordinating restoration on the Lafayette and Lynnhaven rivers) has produced annual update documents describing Virginia progress toward the '10 tributaries' outcome. The Workgroup will continue to produce these documents annually. The 2017 version of the annual document is here: https://chesapeakebay.noaa.gov/images/stories/pdf/2017virginiaoysterrestorationupdate.pdf

Section 5: Cost Estimate

The Workgroup recognizes that restoration partners may use a variety of substrates and variations in exact technique to construct oyster reefs in the Piankatank River. The Workgroup anticipates that this will cause costs to vary due to factors including:

- Type, size, and availability of reef substrate materials used;
- Environmental compliance and permitting costs;
- Bottom composition (remnant shell reef, hard sand, hard mud, etc.) at the reef construction site;
- Hydrodynamics at the construction site;
- Number of acres constructed at once, which can affect costs for mobilization/demobilization and bulk material purchasing; and
- Physical design, including material spacing and height of the constructed reefs.

To develop a range of possible costs to construct the planned 159.66-acres of reefs, the Workgroup made these assumptions:

- Each restored reef will be constructed from shell, stone, crushed concrete, or similar material in this same cost range, or a combination;
- Reefs will primarily seed with oysters by natural oyster recruitment, so no seeding costs are included in the cost estimate;

- Costs for reef construction will be similar to those incurred when reefs were constructed on the Piankatank River from 2014 to 2018 (not adjusted for inflation or other projected cost increases). These years were chosen because prior to 2014, the last reefs constructed on the river were in the mid 1990s, and cost information is scarce and outdated. There has been steady reef construction between 2014 and 2018.
- The low end of the cost estimate range was developed using the lowest per-acre reef construction cost between 2014 and 2018. This was for the 15.44 acres of reefs built in 2018 (reefs PR_01, PR_03, and PR_05 in Figure 5). This cost was approximately $13,500 per acre. These reefs were constructed from crushed granite approximately two inches in diameter and built three inches high. The reefs were constructed on existing shell bottom with low oyster densities, taking advantage of existing reef structure in the river and therefore requiring less substrate than more expensive projects.
- The high end of the cost range was developed using the highest per-acre reef construction cost between 2014 and 2018. This was the 25-acre reef constructed in 2018 (reef PR_25 in Figure 5). The cost was approximately $80,000 per acre. This reef was built on hard sand bottom, meaning it had to be entirely reconstructed and therefore required more substrate than the less-expensive projects. It was also built in an area with high wave and tidal energy, so it had to be constructed from larger material. The reef was built 12-18 inches high, with stone substrate placed in stripes across the reef area (30 feet wide) and spaced 45 feet apart.

Using these assumptions yields a rounded cost range estimate of $2.2 million to $12.8 million to complete the remaining planned oyster reef construction on the Piankatank River (Table 5). The Workgroup notes that most of the remaining proposed reef construction areas on the Piankatank do not have existing shell remnant reefs, and therefore are not likely suitable for the lower-cost ($13,500 per acre) treatment. Therefore, it is the best professional judgement of the Workgroup that the actual cost to construct the remaining 156.66 acres will likely be closer to the middle- or high-end of the cost estimate. All dollar figures are in 2018 dollars.

Table 5: Calculations for the cost estimate for completing oyster restoration in the Piankatank River.

	Acres remaining to be constructed	Estimated cost per acre	Cost to complete planned reef construction
Low-end cost estimate	159.66	$13,500	$2,155,410
High-end cost estimate	159.66	$80,000	$12,772,800

Section 6: Public Outreach

The Western Shore Oyster Restoration Workgroup, the author of this Plan, comprises representatives from watershed groups, the scientific community, and personnel from state and federal agencies. The group represents an array of viewpoints and stakeholders, and those were incorporated into this plan. USACE also did extensive public outreach during its Environmental Assessment process for the project

Chesapeake Bay Oyster Recovery, Piankatank River, Virginia, available at https://usace.contentdm.oclc.org/digital/collection/p16021coll7/id/2815/

The VCU restoration efforts involved considerable public outreach including volunteers representing locally elected officials, state agencies, the general public, and the seafood industry. Nearly 300 hours of volunteer time from 80 volunteers has been captured from those participants. Additionally, significant press coverage in 2018 recognized the partnerships between federal, state, nongovernmental organizations and universities (TNC, VMRC, NOAA, VCU).

Section 7: Monitoring

7.1 Monitoring relative to Oyster Metrics Success Criteria

The main objective of monitoring efforts in the Piankatank River is to determine whether the restored reefs can be considered successful per the Oyster Metrics[2] standards. There are examples of appropriate sampling and analysis methodology in the Oyster Metrics[2] report itself, in the Maryland monitoring reports[8,9], and in published scientific papers on this topic.[10] According to the Oyster Metrics[2] report, biological parameters (oyster density, oyster biomass, and presence of multiple year classes), and structural parameters (reef height, reef areal extent), should be monitored three years, and again six years, postrestoration to determine reef-level success. (Table 6). The Workgroup stresses the need for consistent monitoring following protocols referenced in the Oyster Metrics[2] report to measure reef-level success, so success can be compared across all reefs under the '10 tributaries' goal.

Table 6: Reef-level success criteria for oyster restoration projects (adapted from the Oyster Metrics[2] report, and *2016 Oyster Reef Monitoring Report Analysis of Data from Large-Scale Sanctuary Oyster Restoration Projects in Maryland*[9])

Biological Metrics	Oyster density	Minimum threshold = 15 oysters per m^2 over 30% of the reef area; Target = 50 oysters per m^2 over 30% of the reef area
	Oyster biomass	Minimum threshold = 15 grams dry weight per m^2 over 30% of the reef area; Target = 50 grams dry weight per m^2 over 30% of the reef area
	Multiple year classes	Presence of at least two year-classes of oysters on the reef
	Shell budget	Stable or increasing shell budget on the reef
Structural Metrics	Reef footprint	Stable or increasing reef footprint compared to premet
	Reef height	Stable or increasing reef height compared to premet

In keeping with the Oyster Metrics[2] report, and assuming funding can be secured, these parameters (Table 6) will be monitored on the Piankatank River restored reefs, likely in partnership with scientists, nongovernmental organizations, private contractors, and government agencies. Results will be used to determine reef success and to implement adaptive management actions as necessary.

In late 2018, USACE funded VIMS and CNU to perform oyster monitoring work in the Piankatank River. The purpose is to assess the 25-acre reef constructed by USACE in 2017 relative to Oyster Metrics[2] success criteria, and to determine suitability of additional sites beyond those in Figure 5 for potential restoration. Divers and a remotely operated vehicle (ROV) will be used for the monitoring work. Anticipated completion timeframe for the data collection and assessment is spring 2019.

Further monitoring work will be done as funding allows.

7.2 Diagnostic Monitoring

In addition to monitoring to evaluate restored reefs per the Oyster Metrics[2] 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, and include water quality and oyster disease. 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 will be monitored using existing Virginia Department of Environmental Quality water-quality monitoring stations on the Piankatank River. Oyster disease information will be obtained where available from VMRC and various academic and research programs.

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10. NOAA. 2018. 2017 Oyster Reef Monitoring Report Analysis of Data from Large-Scale Sanctuary Oyster Restoration Projects in Maryland file:///C:/Users/Stephanie.westby/Downloads/2017%20Monitoring%20Report%20DRAFT%2011.2.18.pdf

Appendix A:
Piankatank River Oyster Restoration Target Setting Analysis and Feasibility Analysis

Oyster Restoration Target Setting Analysis

Drafted by the Piankatank Oyster Restoration Workgroup of the Chesapeake Bay Program Sustainable Fisheries Goal Implementation Team, June 2018.

NOTE: *this was compiled BEFORE the 15.44 acres were constructed in late summer 2018, so goal numbers here do not exactly match what is in the Plan, and the Plan represents numbers as of end 2018.*

Section 1: Overview

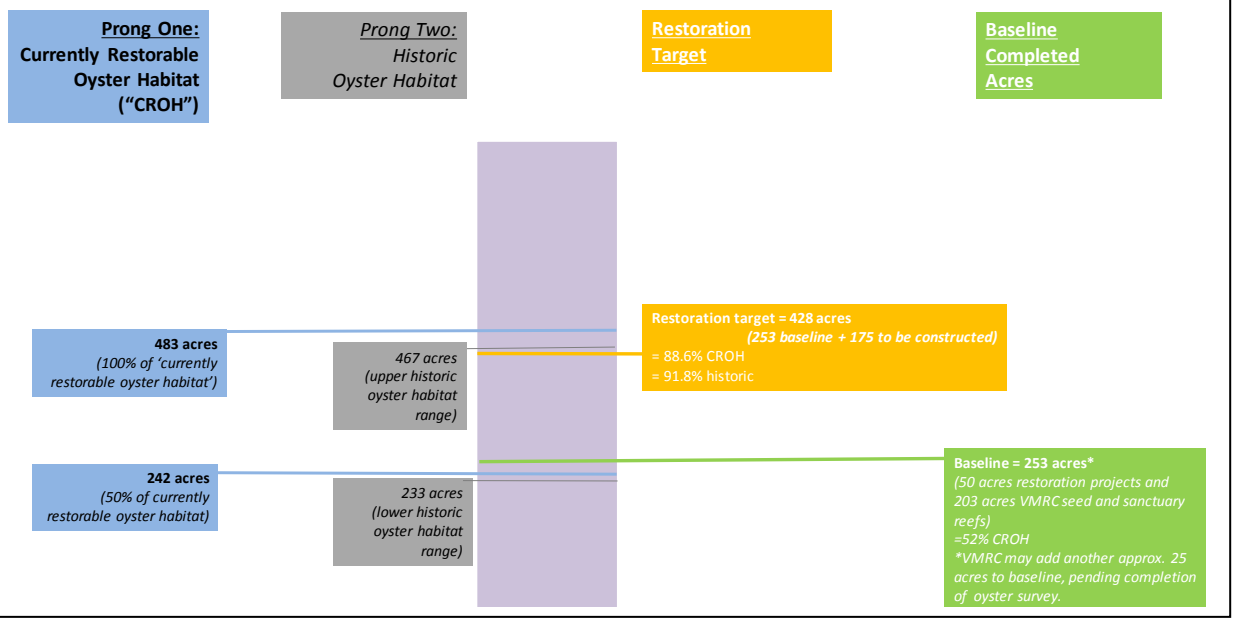
Objective

To determine the amount of currently restorable oyster habitat (utilizing the refined, evidence-based goal setting methodology adapted by the Sustainable Fisheries Goal Implementation Team on Dec. 18, 2017), and to define the amount of historic oyster habitat, that exists in the lower Piankatank River. These are needed to set a restoration target (in acres) for the river segment, consistent with the Chesapeake Bay Oyster Metrics Report (Oyster Metrics) https://www.chesapeakebay.net/channel_files/17932/oyster_restoration_success_metrics_final.pdf

This document also describes the restoration target set by the Workgroup, and the approach used to develop the target.

Results Summary:

Fig 1: Results summary. Schematic of Oyster Metrics two-prong test for a successfully restored tributary (as applied to the Lower Piankatank river segment), and the restoration target and baseline restored areas.



The Workgroup determined that the restoration target for the river is 175 acres, beyond the 253 'baseline' acres in the river that meet the Oyster Metrics success criteria. When fully restored there will be 428 acres of reefs in the river (175 new acres + 253 baseline acres), functioning per the Oyster Metrics success criteria. This equates to 88.6% percent of 'CROH' (currently restorable oyster habitat, see Section 2), and 91.6% of historic oyster habitat, as calculated per the formula in Section 3). (Fig. 1)

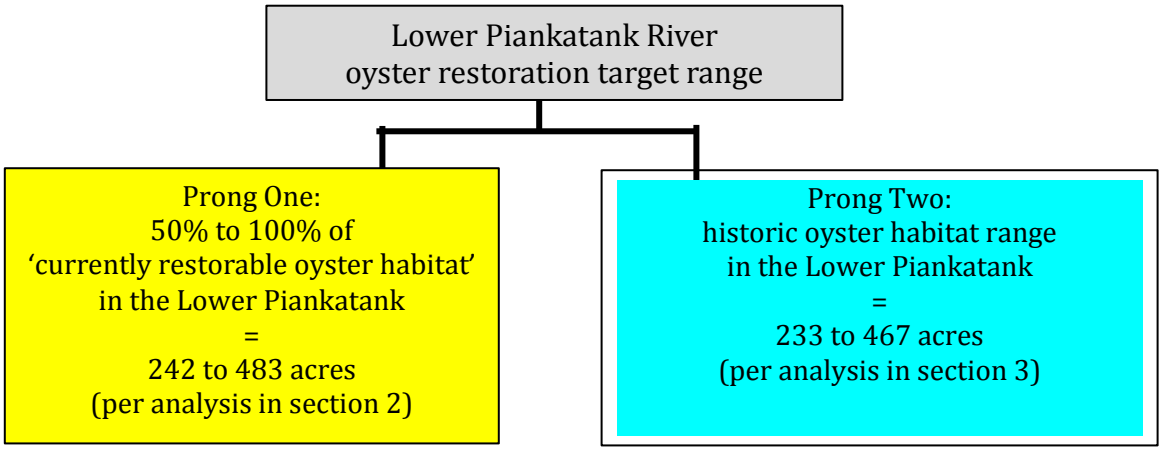
Background

The Oyster Metrics Report created a two-prong test for a restored tributary (Fig 2):

1) Prong One: 50% to 100% of 'currently restorable oyster habitat' is restored (to the reef-level success criteria). 'Currently restorable oyster habitat' is, at a minimum, areas with water quality suitable for oysters, and hard substrate with evidence of shell or oysters. We need to know how much area is restorable in the lower Piankatank, so we can determine what 50% to 100% would be.
2) Prong Two: Oyster Metrics called for restoring 8% to 16% of historic oyster habitat in the tributary, as calculated consistent with the methodology in the US Army Corps of Engineers (USACE) Native Oyster Restoration Master Plan (hereafter, Master Plan). The Piankatank Oyster Restoration Workgroup (hereafter, The Workgroup) revised this calculation for the Piankatank

River to better estimate the amount of historic oyster habitat in this river (see Section 3 for details).

Fig 2: Schematic of Oyster Metrics two-prong test for a successfully restored tributary, as applied to the Lower Piankatank river segment. References for numbers are in sections 2 and 3.



Section 2: Prong One of the Oyster Metrics Tributary-Level Success Criteria

How Prong One (50% to 100% of currently restorable oyster habitat) was defined

The Piankatank Oyster Workgroup used the following process to calculate currently restorable oyster habitat in the Lower Piankatank River segment, in order to establish a restoration target range for Prong One of the tributary-level Oyster Metrics success criteria.

Three main information sources fed the analysis:
1) Data contributed by members of the Workgroup, housed in a common GIS geodatabase (available at http://www.habitat.noaa.gov/chesapeakebay/gis/Oyster_Restoration_Geodatabases/piankatank/)

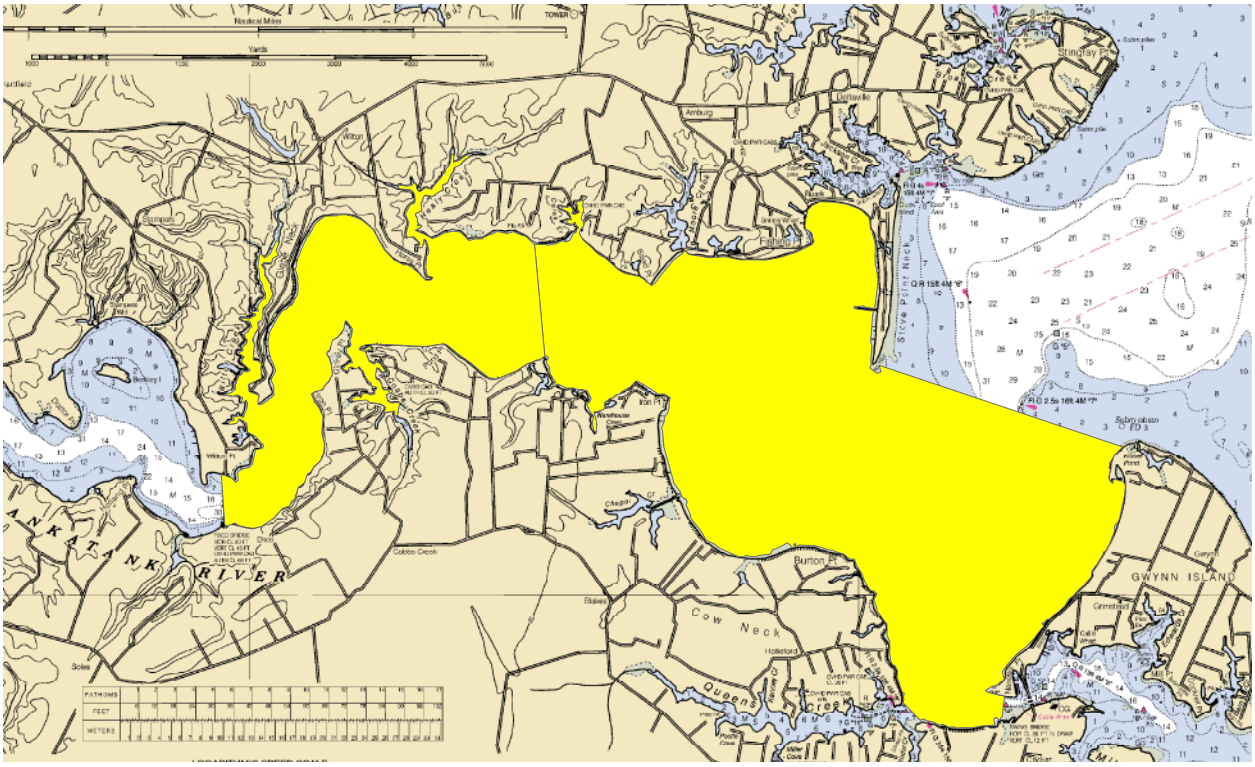
2) The 2010 report by Lipcius et al. to USACE Norfolk District, 'Ecosystem-Based Planning of Native Oyster Restoration';

3) Workgroup discussions.

Process

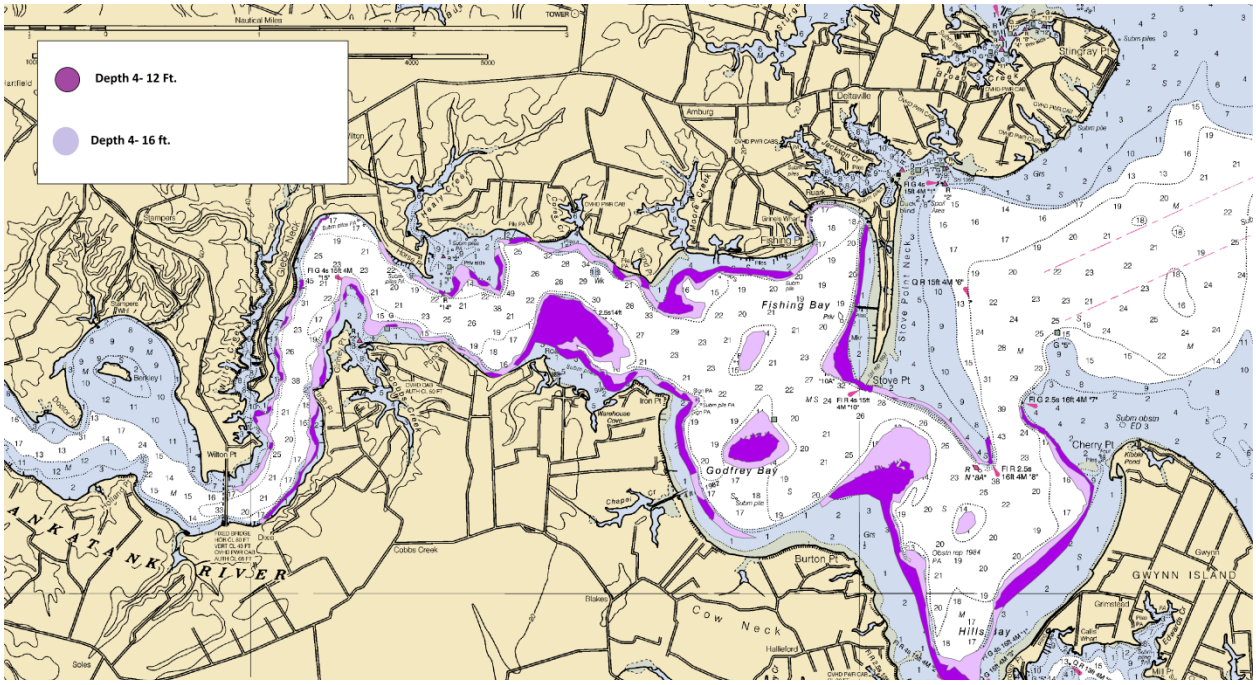
1) River segment: (Fig 3) Define geographic boundaries of the river segment within which we will target oyster restoration. Basis: Input from Workgroup; extent of potential restoration areas in Lipcius report. Result: the 'Lower Piankatank' tributary restoration project will extend from the Twigg Bridge (Route 3) to a line between Stove Point and Cherry Point.

Fig 3: Lower Piankatank river segment.



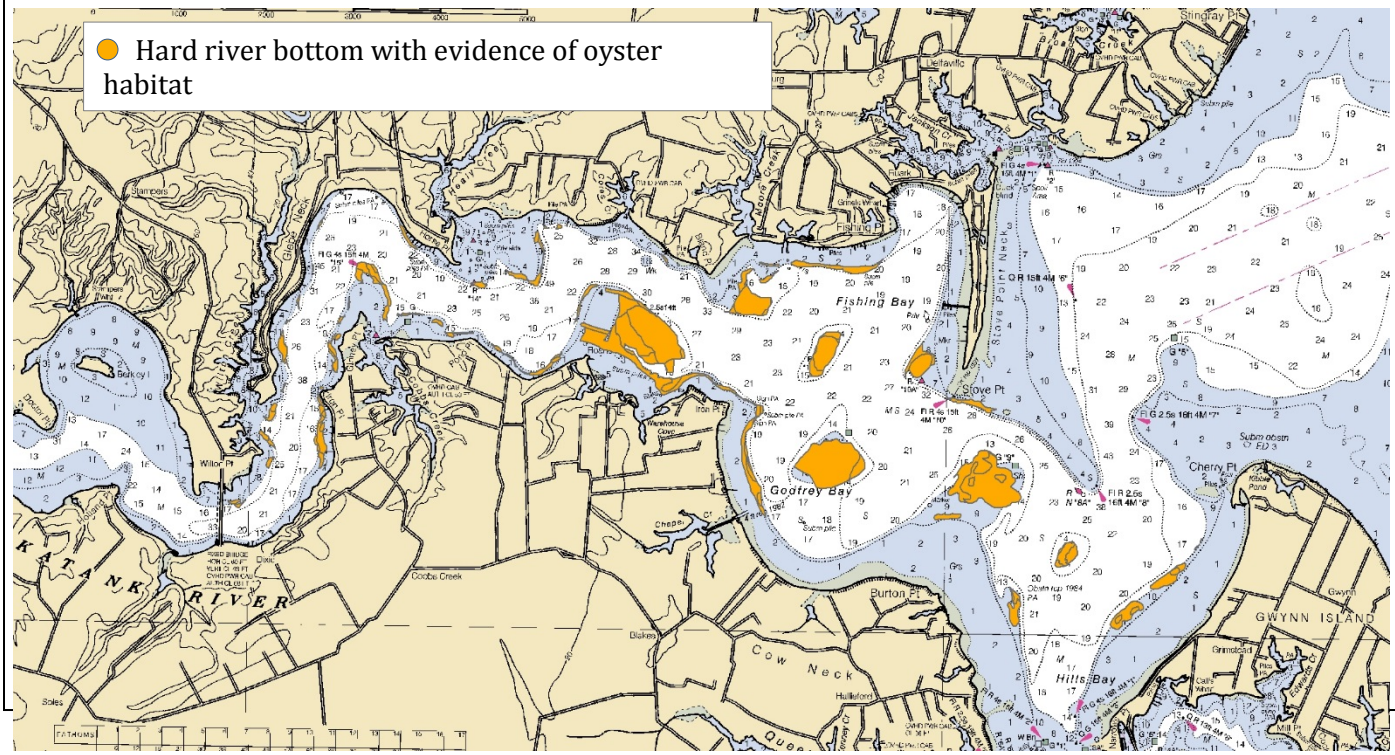
2) Depth: (Fig 4) Define depth range suitable for oyster restoration work. Basis: Workgroup discussion; shallow extent of sonar survey. Concerns about low dissolved oxygen informed the 16 ft depth cutoff; concerns about survivability of reefs exposed at extreme low tides informed the 4 ft cutoff. Result: depth interval between 4 ft and 16 ft MLW is considered suitable for restoration. The workgroup notes that depth intervals of 4-12 ft are optimal to avoid low dissolved oxygen, and recommends focusing first on suitable areas in less than 12 feet of water depth.

Fig 4: Depth intervals used to defined currently restorable oyster habitat.



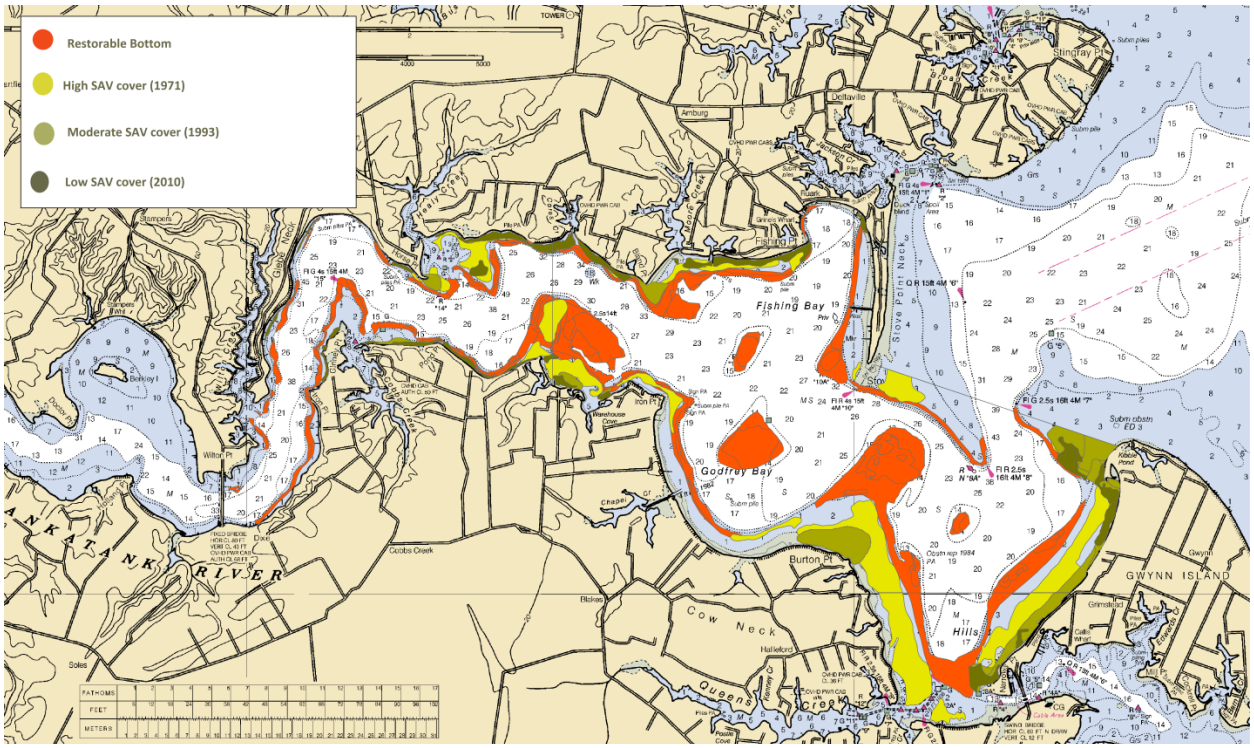
3) <u>Hard river bottom with evidence of oyster habitat:</u> (Fig 5) Define suitable (ie, hard) river bottom. Basis: NOAA sonar survey and ground truthing data (2014), using the refined, evidence-based goal setting methodology agreed to by the Sustainable Fisheries Goal Implementation Team in December 2018. Result: Habitat types considered 'suitable' include bottom consisting of any of the following: anthropogenic oyster rubble; biogenic oyster rubble; muddy sand- with evidence of shell; sand- with evidence of shell; unclassified constructed reef.

Fig 5: Evidence-based oyster habitat within the Lower Piankatank River segment



4) Submerged Aquatic Vegetation (SAV): (Fig 6) Define potential SAV habitat, and remove from restorable bottom consideration. Basis: SAV beds are critical habitat, and oyster restoration should not interfere with (and ideally would enhance) SAV habitat recovery. Oyster reefs should therefore not be constructed on potential SAV habitat. VIMS SAV maps in a high coverage (1971), moderate coverage (1993), and low coverage years (2010) were considered. Results: Using the high SAV coverage (1971) data set, 6.6 acres of SAV beds overlap with potentially restorable bottom. These 6.6 acres were removed from restorable bottom consideration. This high SAV coverage layer was compared to a layer comprised of SAV coverage from 1971- 2015, and no additional SAV areas were found outside of the 1971 year boundaries.

Fig 6: SAV habitat within the Lower Piankatank River segment



5) Water quality

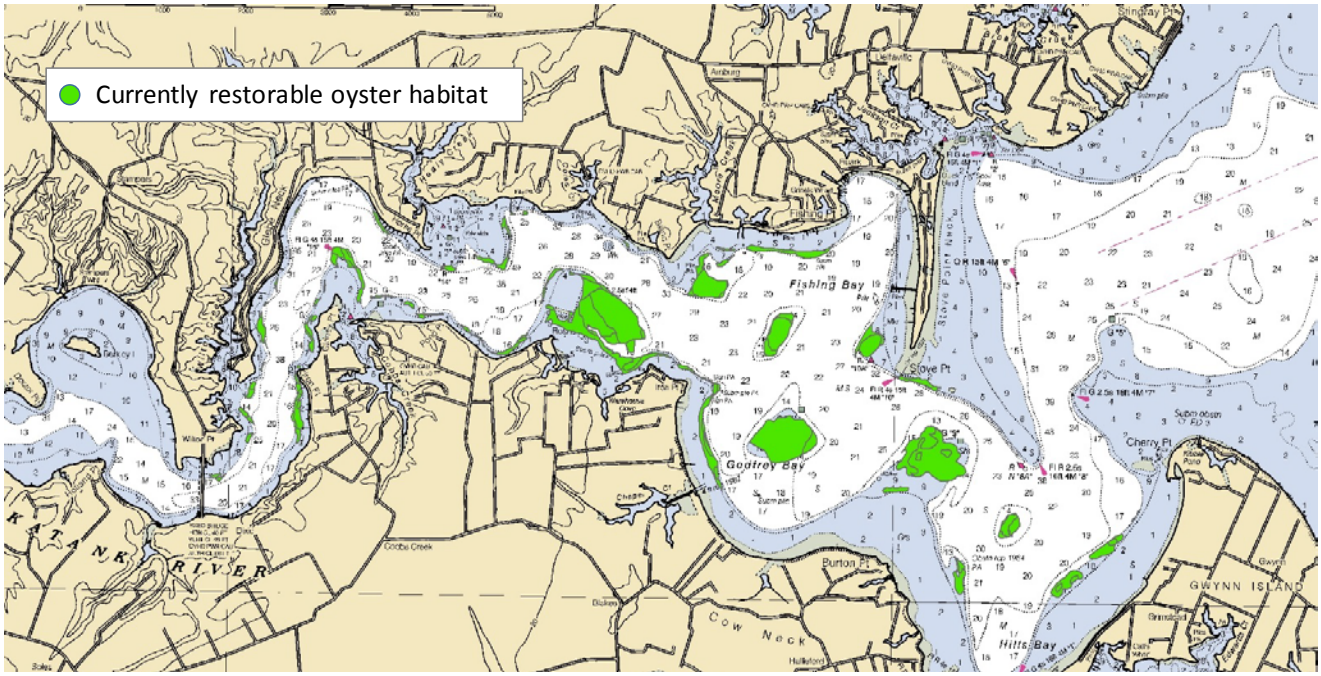
- There is a single Chesapeake Bay Program water quality monitoring station just inside mouth of Piankatank. Thus there is limited data available on water quality in the Lower Piankatank.
- The approach in this analysis is to use depth as proxy for potentially hypoxic areas.
- In the Army Corps of Engineers Native Oyster Restoration Plan, all tributaries (including the Piankatank) were evaluated using these criteria combined: a) summertime bottom dissolved oxygen levels from 2001- 2006 (incorporating both wet and dry hydrologic years) greater than 5

mg/ L; b) depth criteria of less than 20 ft; c) bottom and surface salinity greater than 5 ppt. Areas that met all of these criteria were considered 'suitable'. Most of the Piankatank (6210 acres of 7097 acres within the Baylor polygons) was considered suitable for oyster restoration. The plan ranked the Piankatank as a 'Tier 1' tributary for oyster restoration.

Results of Prong One Analysis

- 'Currently restorable oyster habitat' (Fig 7) in the Lower Piankatank tributary is defined as areas that are between 4 and 16 ft deep, have hard river bottom with evidence of oyster habitat (shell), and are outside of potential SAV beds.
- Currently restorable oyster habitat in the Lower Piankatank = 483 acres. Applying the Oyster Metrics criteria, restoring 50% to 100% of currently restorable oyster habitat would mean restoring 242 to 483 acre in the Lower Piankatank.

Fig 7: Currently resorable oyster habitat within the Lower Piankatank River segment.



Section 3: Prong Two of the Oyster Metrics Tributary-Level Success Criteria

How Prong Two (historic oyster habitat) was defined

The Workgroup used the following process to calculate determine a restoration target range for Prong Two of the tributary-level Oyster Metrics success criteria.

Process:

Original Master Plan Methodology for Calculating Historic Range:

The USACE Master Plan put forward that the acreage target within the river segment should be a minimum of 8% to 16% of historic oyster habitat. The reasoning behind this 8% to 16% calculation is in the Master Plan, Section 5.4.5, page 113, http://www.nab.usace.army.mil/Portals/63/docs/Environmental/Oysters/CB_OysterMasterPlan_Oct2012_FINAL.pdf . The Oyster Metrics Report also called for restoration work on a tributary to meet this requirement.

USACE-Norfolk District staff, as part of the Workgroup, recognized that the methodology in the Master Plan to determine historic acreage was not accurate when applied to the Piankatank River. The reasoning was because the formula in the Master Plan was based on the amount of Baylor Grounds in a given tributary. In the Piankatank River, the designated Baylor grounds encompass nearly the entire river, which likely over-estimates the amount of historic oyster habitat, even when the Master Plan correction factor is applied. To resolve this, USACE-Norfolk District staff suggested using a revised calculation to estimate the amount of historic habitat that did not rely on the Baylor survey. The Workgroup members concurred with the revised methodology.

Revised Methodology for Calculating Historic Range:

Lacking an accurate historic survey in the Piankatank River, USACE-Norfolk District staff developed a decay rate using the Moore (1910) and Haven (1981) data for the James River, then reverse applied it to the lower Piankatank River segment (Fig 7). This decay rate has been estimated at 39% (Schulte 2017). That is, 61% of the historic habitat circa the Baylor era remained as of the early 1980s. The oyster habitat found by Haven (1981) was 711.6 acres in the lower Piankatank River segment. Applying the decay rate in reverse to estimate the historical habitat acreage results in 1,166.6 acres, which is only 21.5% (not 47% as would be expected per the Master Plan formula) of the Baylor acreage in this river segment. From 1,166.6 acre historic estimate, the MPA 20% and 40% goals are applied, consistent with the Master Plan. This gives the USACE a historic restoration target range of 233.3-466.6 acres for the Piankatank River.

USACE-Norfolk District staff detailed this revised methodology and rationale in the document "*Piankatank River Restoration Goal Methodology Change",* to which the Piankatank Oyster Restoration Workgroup agreed.

The formulas for determining the historic range in the Piankatank River are therefor:
[1983 Haven survey acreage] * [inverse decay rate] * [20%] = lower historic range
[1983 Haven survey acreage] * [inverse decay rate] * [40%] = upper historic range

Applying these formulas yields:
[711.6] * [1.61] * [.2] = 233 acres (rounded)
[711.6] * [1.61] * [.4] = 467 acres (rounded)

Section 4: Analysis of Baseline areas already meeting Oyster Metrics density and biomass success criteria

The Workgroup recognizes that 253 acres in the Piankatank River can be considered 'baseline' restored areas toward the Lower Piankatank River restoration target (Fig 1). These are comprised of 50 acres of restoration projects, and 203 acres of seed and sanctuary reefs maintained by the Virginia Marine Resources Commission (VMRC). Of the 203 acres of VMRC reefs, 164 are seed harvest reefs, and 39 are sanctuary reefs.

The 50 acres of existing oyster restoration projects includes the 2017 U.S. Army Corps of Engineers reef construction and Virginia Commonwealth University reef seeding, combined with reefs built by The Nature Conservancy in 2014 and 2015.

In 2017, the Workgroup analyzed VMRC and VIMS oyster population data from 2011- 2016 (from Virginia Oyster Stock Assessment and Replenishment Archive [VOSARA], http://cmap2.vims.edu/VOSARA/viewer/VOSARA.html) and determined that 203 acres in the Piankatank River already meet the Oyster Metrics density and biomass definition for restored reefs. These 203 acres are managed by VMRC as either sanctuaries, or as seed reefs (where carefully monitored removal of seed oysters is allowed in selected years, and is placed onto private leases for grow out and harvest). VMRC ensures that seed reefs have shell added immediately post-harvest and targets additional areas for shell planting after reviewing annual stock assessment findings.

The 253 acres of 'baseline' restored areas count toward the restoration target (Fig 1). The Workgroup notes that VMRC is currently analyzing another 50 acres of VMRC reefs, and anticipates that some of these reefs will similarly meet the Oyster Metrics density and biomass criteria for successfully restored reefs. Additionally, VIMS staff are surveying other areas in the river that may also meet the 'baseline' criteria. Thus, the baseline number may rise upon completion of these analyses.

Section 5: Oyster Restoration Target Setting on the Lower Piankatank River

Prong One (50% to 100% of currently restorable oyster habitat, equal to 242 to 483 acres is higher than Prong Two (historic oyster habitat range, equal to 233 to 467 acres). Meeting Prong One (242 to 483 acres), therefore, will automatically also meet Prong Two, which is lower. The restoration target for the river should be set using Prong One, between 242 and 483 acres.

The Piankatank workgroup recognized that the *minimum threshold* for considering the river successfully restored is when 242 acres in the river meet the reef-level success criteria, per Oyster Metrics. At this point, the river can be considered *minimally restored*.

Fig 8: Summary of oyster restoration target.

Piankatank River Oyster Restoration Target

River is Minimally Restored: 242 acres
River is Fully Restored: 428 acres.

To reach the target of 428 acres, 175 acres will need to be restored, in addition to the existing 253 acres of 'baseline' reefs that already meet the Oyster Metrics success criteria.
This 428 acres equates to:

- 88.6% of CROH
- 91.6% of historic

The *restoration target* for the river should be set between 242 and 483 acres. By consensus, the Piankatank Oyster Workgroup determined that the *restoration target* will be achieved when an additional 175 acres of reefs have been constructed. Added to the 'baseline' existing 253 acres of reefs of the river, this equates to a total of 428 acres. At this point, the river can be considered *fully restored*. The 175-additional-acre restoration target was set by Workgroup consensus, based on the following:

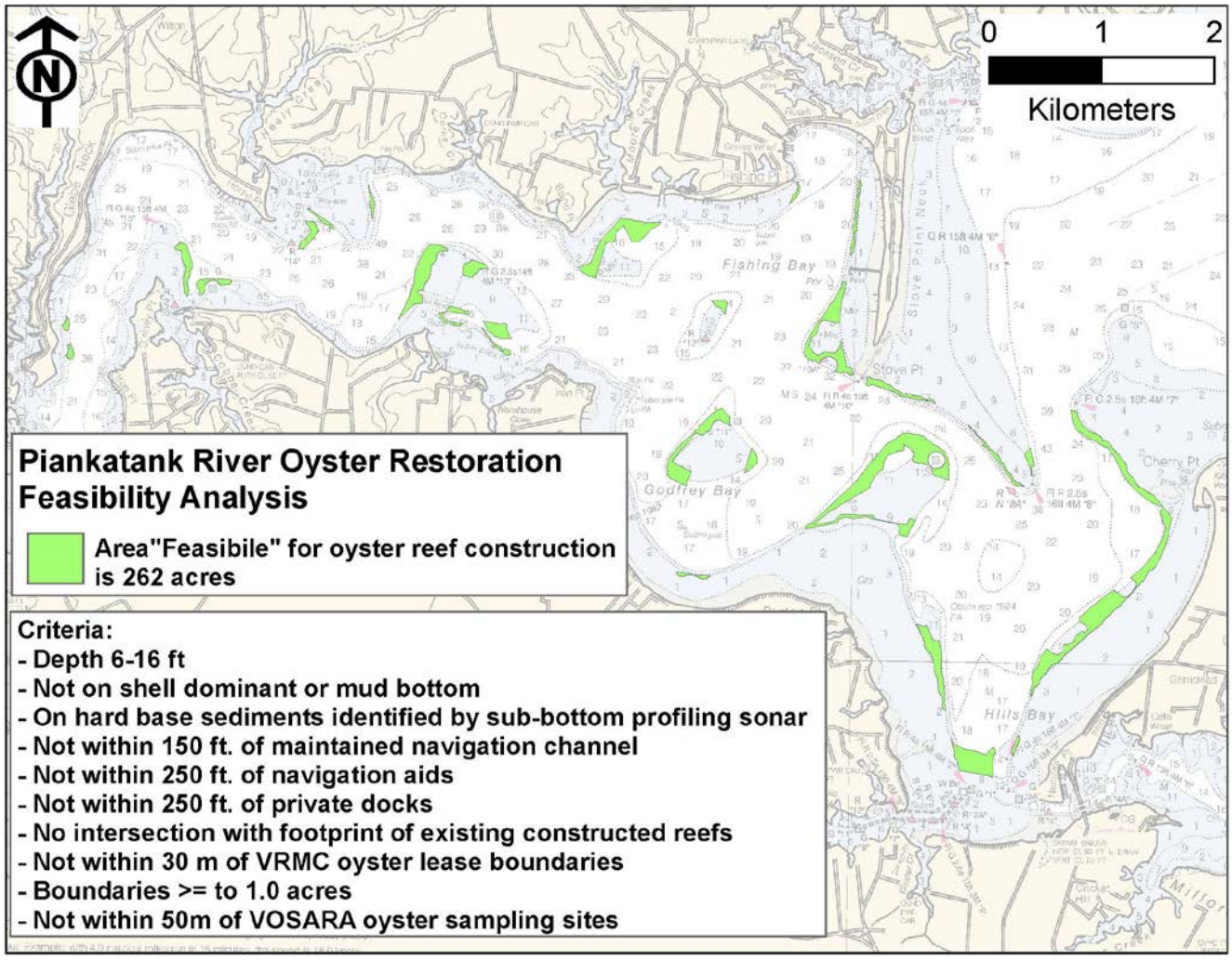
- Existing 'baseline' reefs in the river are a combination of seed reefs (164 acres), VMRC sanctuary reefs (39 acres), and restoration projects (50 acres). Any additional reef acreage constructed in the future will be sanctuary reef. Constructing at least 75 acres of reefs (all sanctuary) beyond the 'baseline' existing reefs will result in a ratio of 1:1 sanctuary: seed reefs in the river. The Workgroup agreed it is appealing to honor, at a minimum, this 1:1 ratio. Therefore, setting a goal of at least 75 acres was desirable to ensure that 1:1 ratio. Setting a higher target and constructing more sanctuary reefs would result in a higher ratio (more sanctuary reefs relative to the acreage of seed reefs), which was supported by the Workgroup. Although the seed: sanctuary ratio concept informed discussions on restoration target setting for the river, partners agreed that this ratio is not meant as a requirement for considering the river restored. For example, if VMRC constructs additional seed reefs, this should not affect the restoration target for the river. (That is, the construction of additional seed reefs by VMRC is not discouraged, but the emphasis of new construction should be for sanctuary reefs).
- The Workgroup projected that a reasonable (if optimistic) average reef construction rate is 25 acres per year. Honoring the Chesapeake Bay Agreement '10 tribs by 2025' oyster goal time period, and averaging 25 acres per year between 2019 and 2025, it is reasonable to strive to construct 175 acres within the goal time horizon.
- Based on a 'feasibility analysis' performed by the team (Fig. 9) there is sufficient available acreage on the river (away from docks, leases, navigation aids, etc) to construct far more than

175 acres. The 175 acre target allows for a sub-set of the feasible areas to be constructed, while leaving other areas unconstructed to minimize user conflicts. (Fig 10).

- The U.S. Army Corps of Engineers, Norfolk District (USACE) in partnership with the Virginia Marine Resources Commission (VMRC), the nonfederal sponsor for the project for the Chesapeake Bay Oyster Recovery, Piankatank River Project, plans to construct an additional 165 acres of reefs at the Piankatank River. In the process of planning the project, the USACE evaluated and analyzed available data, developed site selection criteria, and conducted public outreach. The public outreach consisted of multiple public coordination meetings, coordination with the Piankatank Oyster Recovery Team, the Virginia Institute of Marine Science, and a 30-day public review of the Environmental Assessment. As part of the planning process, information from the Master Plan and data from site-specific findings of the Piankatank Oyster Restoration Workgroup was gathered to facilitate the restoration site selection process. Based on existing data, the following were used as site selection criteria in the planning efforts: (a) size of the restoration site; (b) NOAA bathymetry data and bottom substrate composition; (c) shoaling patterns; (d) distance from navigation channels, heavy boat traffic, private docks, and piers, (e) the presence absence of an existing reef, (f) distance from submerged aquatic vegetation beds, (g) historical reef data, (h) potential for larval retention; and (i) potential for sanctuary status. Based on this planning effort, approximately 190 acres of restoration reefs were proposed for construction in the Piankatank River. To date, the USACE in partnership with the VMRC and The Nature Conservancy has constructed 49.3 acres in the Piankatank River as part of the Chesapeake Bay Oyster Recovery, Piankatank River Project. In summary, the USACE in partnership with the VMRC plans to construct an additional total 165 acres of reefs in the Piankatank River.

- Setting a Piankatank Restoration goal close to that the planned construction acreage described in the Chesapeake Bay Oyster Recovery, Piankatank River Project leverages off the substantive restoration already planned by USACE and VMRC in this tributary. The 175 acre proposed target allows for full implementation of the Chesapeake Bay Oyster Recovery, Piankatank River Project planned by USACE and VMRC, plus an additional 10 acres which could be constructed by other partner organizations.

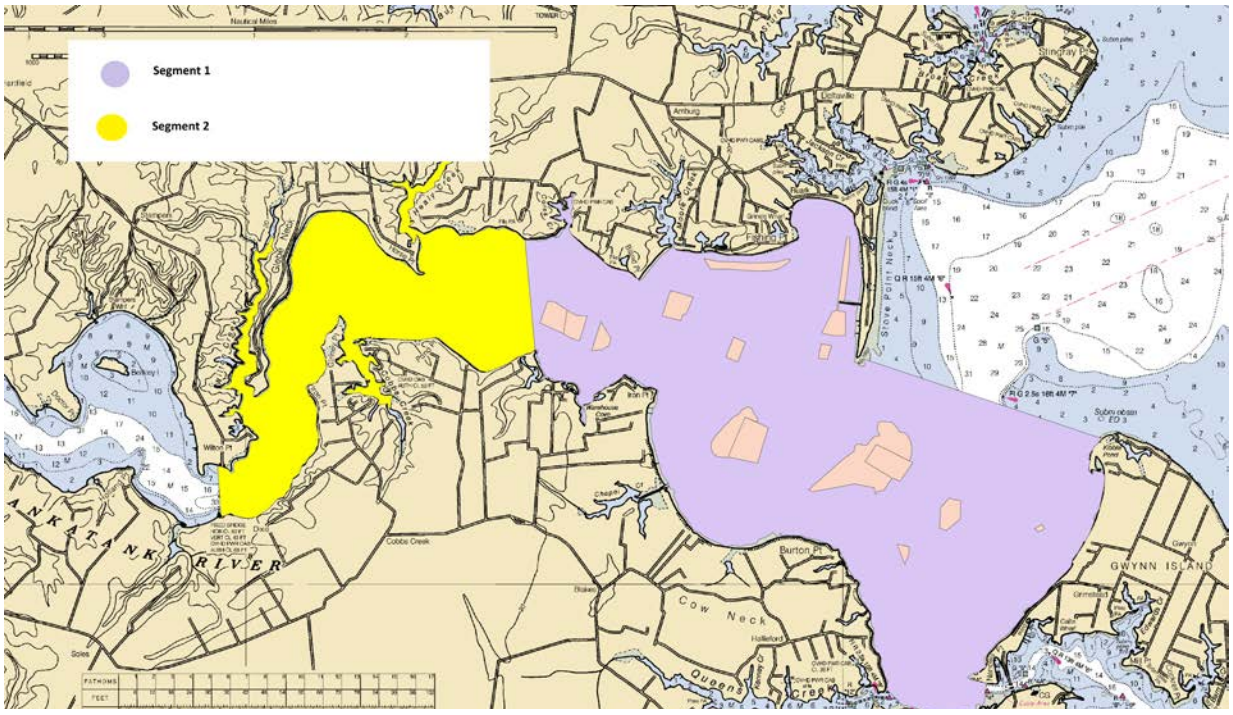
Fig 9: Lower Piankatank River feasibility analysis. Drafted by David Bruce, NOAA Chesapeake Bay Office, May 2018. Used by the Piankatank Oyster Restoration Workgroup to determine areas on the river where reef construction would likely be able to proceed, excluding areas such as leases, docks, buffers around navigation aids, etc.



Section 6: Suggested Next Steps

- Further refine the restorable bottom areas into a tributary plan or 'blueprint'. This lay out which areas are suitable for reef construction, determine which restoration type is best suited for each polygon, and lay out cost estimates for completion.
- Focus on the downstream-most portion of the Lower Piankatank (Segment 1; Fig 9) . Basis: incorporates all currently planned restoration projects, and includes optimal area for reef restoration from Lipcius report.
- Complete oyster population survey / analysis to determine which additional areas (if any) already meet the reef-level oyster density and biomass metric, and can be considered 'baseline' toward the restoration target.
- Workgroup recommends generally using substrate without hatchery-produced seed in Segment #1, due to the expectation of high natural recruitment in this area. Segment #2 may require the addition of hatchery-produced seed.

Fig 9: Segments 1 and 2 within the Lower Piankatank River segment.



Appendix B:
Analysis of 'Premet' Areas in the Piankatank River

Appendix B: Analysis of 'Premet' Areas in the Piankatank River

Note this Appendix is in two parts:
Part I: Piankatank River, Virginia: Oyster Abundance at VOSARA Sites Relative to GIT Metrics 8/15/2017
Part II: Piankatank River, Virginia: 2017 Oyster Abundance at Shell Plantings Adjacent to VOSARA Sites 6/26/2018

These two parts together describe the process for and results of two analyses used to determine which areas on the Piankatank River met the Oyster Metrics oyster density and biomass success criteria prior to restoration. These areas are considered to be functioning at a restored level, and do not require restoration. Throughout the Piankatank River Oyster Restoration Tributary Plan, these are referred to as 'premet' reefs.

Appendix B Part I:

Piankatank River, Virginia

Oyster Abundance at VOSARA Sites Relative to GIT Metrics

8/15/2017

Objectives

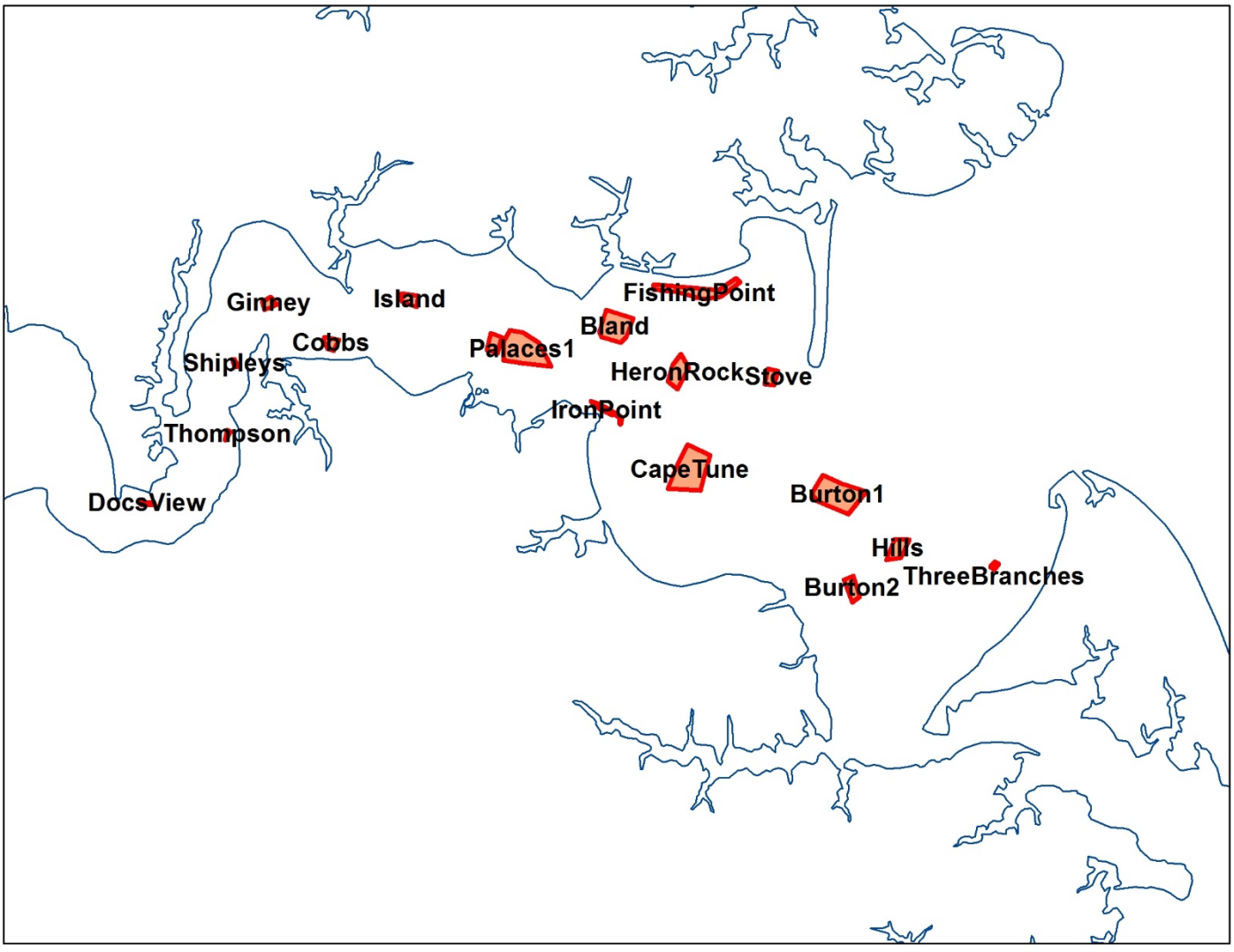
Eighteen oyster reefs are sampled by the VOSARA program (the Virginia Oyster Stock Assessment and Replenishment Archive) in the Piankatank River. In this exercise, 2011-2016 patent tong sample data were interpolated to determine the proportion of area at the 18 sites that met the 15 and 50 oyster density (number/m^2) and biomass (grams dry wt. /m^2) threshold and target restoration success metrics. The 18 reef boundaries are in the process of being refined to better match the actual distribution of shell bottom as identified by sidescan sonar. Some patent tong samples, included in this analysis, and from within the

reef boundaries, were not taken from shelled bottom; this was determined by sonar and corroborated by the lack of live oysters and oyster shell in sample contents. This analysis uses the all patent tong samples collected 2011-2016 to estimate abundance and considers the current VOSARA polygons as the reef boundaries with acknowledgement of errors relative to ground conditions. During the interval 2006-2016, 15 of 18 sites were planted with shell least once and 5 were open to oyster seed harvest.

Summary

1) At 16 of 18 locations, 30 percent or greater of the area had interpolated oyster densities greater or equal to 15/meter^2. 218.8 acres (16 sites) of 227.5 acres (18 sites) or 96% of total site area met the success threshold metric for density.
2) At 13 of 18 locations, 30 percent or greater of the area had interpolated oyster densities greater or equal to 50/meter^2. 201.9 acres (13 sites) of 227.5 acres (18 sites) or 89% of total site area met the success target metric for density.
3) At 16 of 18 locations, 30 percent or greater of the area had interpolated oyster biomass greater or equal to 15 g dry weight/meter squared. 201.9 acres (16 sites) of 227.5 acres (18 sites) or 89% of total site area met the success threshold metric for biomass.
4) At 4 of 18 locations, 30 percent or greater of the area had interpolated oyster biomass greater or equal to 50 g dry weight/meter^2. 13.5 acres (4 sites) of 227.5 acres (18 sites) or 6% of total site area met the success target metric for biomass.

Index



Results

Density Metric: Number Oysters Per Square Meter - Interpolated

Location	Area (acres)	Area sq. meters	Tot. Area of interpolated grid (no. 1x1 m grid cells)	Sum grid cells (meters sq.) with density value < 15	Sum grid cells (meters sq.) with density value > = 15	Sum grid cells (meters sq.) with density value > = 50	Percent area with density value < 15	Percent area with density value >= 15	Perce area with densit value >= 50
Bland	25.0	101055.2	101057	7069	93988	81531	7.0	93.0	80
BurtonA	39.0	157929.0	157934	77454	80480	58137	49.0	51.0	36
BurtonB	7.6	30778.2	30777	25185	5592	14	81.8	18.2	0
CapeTune	41.4	167546.3	167545	4199	163346	137297	2.5	97.5	81
Cobbs	4.3	17519.7	17517	5004	12513	7149	28.6	71.4	40
DocsView	1.1	4535.2	4517	3322	1195	226	73.5	26.5	5
FishingPoint	20.8	84078.5	88782	6501	82281	61334	7.3	92.6	69
Ginney	3.6	14375.6	14381	1999	12382	11763	13.9	86.1	81
HeronRock	13.3	53850.1	53849	12159	41690	29903	22.6	77.4	55
Hills	9.4	38219.9	38215	20082	18133	5891	52.6	47.4	15
IronPoint	3.6	14740.4	14744	628	14116	13595	4.3	95.7	92
Island	5.3	21253.0	21252	6081	15171	10643	28.6	71.4	50
PalacesA	38.5	155843.7	156151	2971	153180	137821	1.9	98.1	88
PalacesB	6.7	26955.2	27406	12894	14512	228	47.0	53.0	0
Shipleys	0.8	3112.2	3106	1462	1644	916	47.1	52.9	29
Stove	5.2	21110.7	21110	4302	16808	13607	20.4	79.6	64

Thompson	0.8	3108.2	3102	1583	1519	944	51.0	49.0	30
ThreeBranches	1.1	4541.0	4541	516	4025	3090	11.4	88.6	68
Sum	227.5								

above or equal to the 30% areal threshold:

below the 30% areal threshold:

Summary:

5) At 16 out of 18 locations, 30 percent of the area had interpolated oyster densities greater or equal to 15/meter squared
6) At 13 out of 18 locations, 30 percent of the area had interpolated oyster densities greater or equal to 50/meter squared

Density Metric: Dry Biomass (g) Per Square Meter - Interpolated

Location	Area (acres)	Area sq. meters	Tot. Area of interpolated grid (no. 1x1 m grid cells)	Sum grid cells (meters sq.) with density value < 15	Sum grid cells (meters sq.) with density value > = 15	Sum grid cells (meters sq.) with density value > = 50	Percent area with density value < 15	Percent area with density value >= 15	Pe ar wi de va >=
Bland	25.0	101055.2	101057	15842	85215	23498	15.7	84.3	
BurtonA	39.0	157929.0	157934	96990	60944	11221	61.4	38.6	
BurtonB	7.6	30778.2	30777	27920	2857	0	90.7	9.3	
CapeTune	41.4	167546.3	167545	28733	138812	29109	17.1	82.9	
Cobbs	4.3	17519.7	17517	10865	6652	1946	62.0	38.0	
DocsView	1.1	4535.2	4517	4145	372	27	91.8	8.2	
FishingPoint	20.8	84078.5	84241	25439	58802	20095	30.2	69.8	
Ginney	3.6	14375.6	14381	2573	11808	8832	17.9	82.1	
HeronRock	13.3	53850.1	53849	17817	36032	10148	33.1	66.9	
Hills	9.4	38219.9	38215	29264	8951	225	76.6	23.4	
IronPoint	3.6	14740.4	14744	1653	13091	7832	11.2	88.8	
Island	5.3	21253.0	21252	9670	11582	4229	45.5	54.5	
PalacesA	38.5	155843.7	156151	28397	127754	20314	18.2	81.8	
PalacesB	6.7	26955.2	27406	22682	4724	0	82.8	17.2	

Shipleys	0.8	3112.2	3106	2077	1029	2	66.9	33.1
Stove	5.2	21110.7	21110	6148	14962	6957	29.1	70.9
Thompson	0.8	3108.2	3102	2398	704	7	77.3	22.7
ThreeBranches	1.1	4541.0	4541	865	3676	1952	19.0	81.0
Sum	227.5							

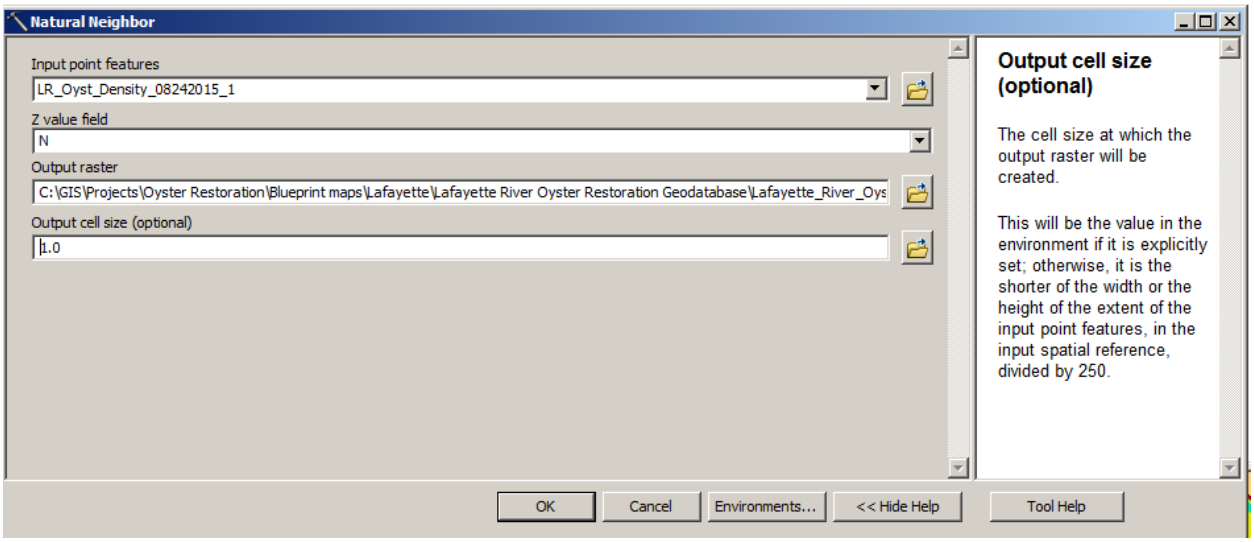
above the 30% areal threshold:
below the 30% areal threshold:

Summary:

1) At 13 out of 18 locations, 30 percent of the area had interpolated oyster biomass greater or equal to 15 g dry weight/meter squared.
2) At 4 out of 18 locations, 30 percent of the area had interpolated oyster biomass greater or equal to 50 g dry weight /meter squared

Interpolation Methods

1) 50 meter buffer polygons were created around each of the VOSARA site boundaries
2) Generalized polygons were created from the 50m buffer using a 50m generalization distance (Douglass-Poiker algorithm in ET Geowizards GIS Extension).
3) Dummy points located at the vertices of the generalized polygons, were added to the patent tong sampling data, and were assigned values of zero. This was done to ensure that the oyster density interpolations extended beyond the outermost patent tong sampling points and covered the entire site polygon



4) Patent tong oyster density and biomass data were interpolated with the Natural Neighbor method (above). The output grid had 1x1 m cell dimensions.

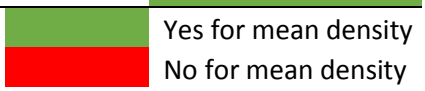
5) Density and biomass grid cells were converted to points and clipped with the site boundary polygon. For each of the 18 sites, density and biomass values were binned into the following intervals: < 15.0, 15.0-49.9,>= 50.0. The results are summarized in pages 2 and 3.

VOSARA Patent Tong Summary Stats 2011-2016 (sample data - not interpolated)

Number Per Square Meter

Location	Mean Density	Median	Standard Error	Min	Max	N (number samples)	Meets Threshold (>=15)	Meets Target (>= 50)
Bland	117.8	97.5	11.8	0	338	60		

BurtonA	71.4	33	14.8	0	603	57	
BurtonB	9.5	0.5	2.4	0	55	42	
CapeTune	121.8	103	11.3	0	350	60	
Cobbs	71.3	33	20.0	0	753	43	
DocsView	9.5	0	3.7	0	124	42	
FishingPoint	118.7	60	22.4	0	570	46	
Ginney	175.2	179	23.0	0	546	42	
HeronRock	75.7	69	11.6	0	363	42	
Hills	31.8	4	9.0	0	279	43	
IronPoint	207.9	227.5	46.4	0	460	14	
Island	85.0	43	16.4	0	374	42	
PalacesA	151.5	122.5	16.7	0	668	60	
PalacesB	18.9	12.5	3.0	0	79	42	
Shipleys	23.6	0.5	7.5	0	258	42	
Stove	135.4	88.5	22.1	0	546	42	
Thompson	19.8	0	9.6	0	368	42	
ThreeBranches	83.8	55.5	15.9	0	420	42	



Summary:

1) At 16 out of 18 locations, mean oyster density, from 14-60 samples (N), was greater or equal to 15/meter squared.
2) At 16 out of 18 locations, mean oyster density, from 14-60 samples (N), was greater or equal to 50/meter squared.

VOSARA Patent Tong Summary Stats 2011-2016 (sample data - not interpolated)

Biomass (g dry wt.) Per Square Meter

Location	Mean Biomass	Median	Standard Error	Min	Max	n (number samples)	Meets Threshold (>=15)	Meets Target (>= 50)
Bland	38.8	31.7	4.0	0	136.2	60		
BurtonA	24.4	16.2	3.4	0	124.7	57		
BurtonB	6.1	0.65	1.7	0	41.8	42		
CapeTune	36.9	29.85	3.8	0	125.4	60		
Cobbs	24.5	10.2	5.7	0	184.7	43		
DocsView	3.3	0	1.7	0	67.7	42		
FishingPoint	36.8	25.5	6.4	0	179.6	46		
Ginney	58.1	53.2	7.0	0	185.8	42		
HeronRock	32.8	27.55	5.0	0	149.1	42		
Hills	11.3	0.6	3.0	0	85.1	43		
IronPoint	55.9	33.55	19.6	0	263	14		
Island	26.4	7.7	5.7	0	142.1	42		
PalacesA	34.3	28.2	3.4	0	111	60		
PalacesB	7.2	6.6	1.1	0	29.3	42		
Shipleys	7.5	0.15	2.2	0	51.7	42		
Stove	45.2	39.75	5.9	0	142	42		
Thompson	4.9	0	2.0	0	57.7	42		
ThreeBranches	43.4	20.5	7.8	0	187.2	42		

Yes for mean biomass

No for mean biomass

Summary:

1) At 12 out of 18 locations, mean oyster biomass, from 14-60 samples (N), was greater or equal to 15 g dry weight/meter squared.
2) At 2 out of 18 locations, mean oyster biomass, from 14-60 samples (N), was greater or equal to 50 g dry weight /meter squared.

Summary of Survey and Management Activity at VOSARA Sites 2006-2016

		Management Activity		
Location	Patent Tong Surveys	Year	Fishery Status	Shell Planting
BLAND POINT	2006-2016	2006-2007	Closed	No
BLAND POINT	2006-2016	2008-2015	Seed Harvest	Yes
BLAND POINT	2006-2016	2016	Closed	No
BURTON POINT A	2006-2016	2006	Closed	Yes
BURTON POINT A	2006-2016	2007-2008	Closed	No
BURTON POINT A	2006-2016	2009-2010	Closed	Yes
BURTON POINT A	2006-2016	2011	Closed	No
BURTON POINT A	2006-2016	2012	Closed	Yes
BURTON POINT A	2006-2016	2013	Closed	No
BURTON POINT A	2006-2016	2014	Closed	No
BURTON POINT A	2006-2016	2015	Closed	No
BURTON POINT A	2006-2016	2016	Closed	No
BURTON POINT B	2006-2016	2006-2016	Closed	No
CAPE TOON	2006-2016	2006-2007	Closed	No
CAPE TOON	2006-2016	2008-2010	Closed	Yes
CAPE TOON	2006-2016	2011	Closed	No
CAPE TOON	2006-2016	2012	Closed	Yes
CAPE TOON	2006-2016	2013	Closed	No
CAPE TOON	2006-2016	2014-2016	Seed Harvest	Yes
COBBS CREEK	2011-2016	2011	Closed	No
COBBS CREEK	2011-2016	2012	Closed	Yes
COBBS CREEK	2011-2016	2013-16	Closed	No
DOC'S VIEW	2011-2016	2011	Closed	No
DOC'S VIEW	2011-2016	2012	Closed	Yes
DOC'S VIEW	2011-2016	2013-2016	Closed	No
2014 FISHING POINT REEF	2014-2016	2014	Closed	Yes
2014 FISHING POINT REEF	2014-2016	2015-2016	Closed	No
GINNEY POINT	2006-2016	2006-2010	Closed	No
GINNEY POINT	2006-2016	2011	Closed	Yes
GINNEY POINT	2006-2016	2012-2016	Closed	No
HERON ROCK	2006-2016	2006	Closed	No
HERON ROCK	2006-2016	2007	Closed	No
HERON ROCK	2006-2016	2008	Seed Harvest	Yes

HERON ROCK	2006-2016	2009-2016	Seed Harvest	No
HILLS BAY	2011-2016	2011	Closed	No
HILLS BAY	2011-2016	2012	Closed	Yes
HILLS BAY	2011-2016	2013-2016	Closed	No
2015 IRON POINT REEF	2015-2016	2015-2016	Closed	No
ISLAND BAR	2011-2016	2011	Closed	Yes
ISLAND BAR	2011-2016	2012-2016	Closed	No

		Management Activity		
Location	Patent Tong Surveys	Year	Fishery Status	Shell Planting
PALACE BAR A	2006-2016	2006-2007	Closed	No
PALACE BAR A	2006-2016	2008	Seed Harvest	Yes
PALACE BAR A	2006-2016	2009	Seed Harvest	No
PALACE BAR A	2006-2016	2010-2016	Seed Harvest	Yes
PALACE BAR B	2006-2016	2006-2007	Closed	No
PALACE BAR B	2006-2016	2008-2016	Seed Harvest	No
SHIPLEY'S EDGE	2011-2016	2011	Closed	No
SHIPLEY'S EDGE	2011-2016	2012	Closed	Yes
SHIPLEY'S EDGE	2011-2016	2013-2016	Closed	No
STOVE POINT	2006-2016	2006-2008	Closed	No
STOVE POINT	2006-2016	2009	Closed	Yes
STOVE POINT	2006-2016	2010-2011	Closed	No
STOVE POINT	2006-2016	2012	Closed	Yes
STOVE POINT	2006-2016	2013-2016	Closed	No
THOMPSON'S	2011-2016	2011	Closed	No
THOMPSON'S	2011-2016	2012	Closed	Yes
THOMPSON'S	2011-2016	2013-2016	Closed	No
THREE BRANCHES	2011-2016	2011	Closed	No
THREE BRANCHES	2011-2016	2012	Closed	Yes
THREE BRANCHES	2011-2016	2013-2016	Closed	No

Appendix B Part II:

Piankatank River, Virginia

2017 Oyster Abundance at Shell Plantings Adjacent to VOSARA Sites

6/26/2018

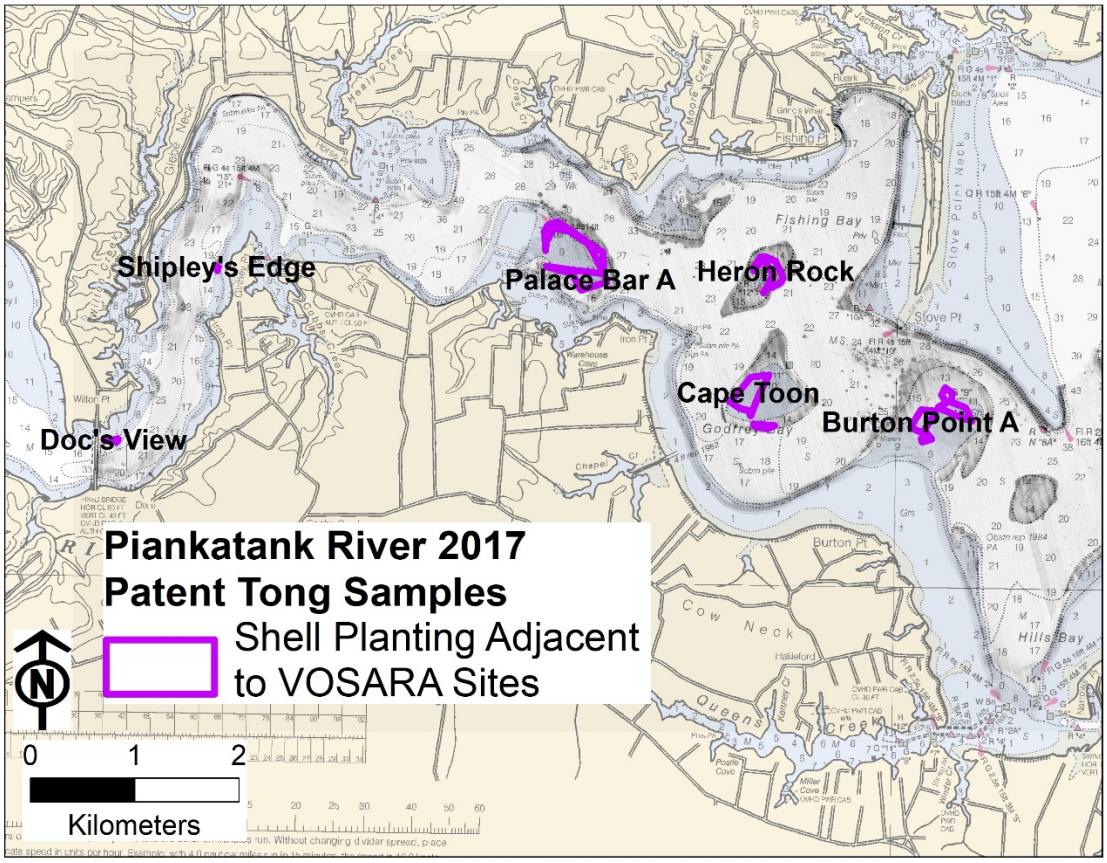
Objectives

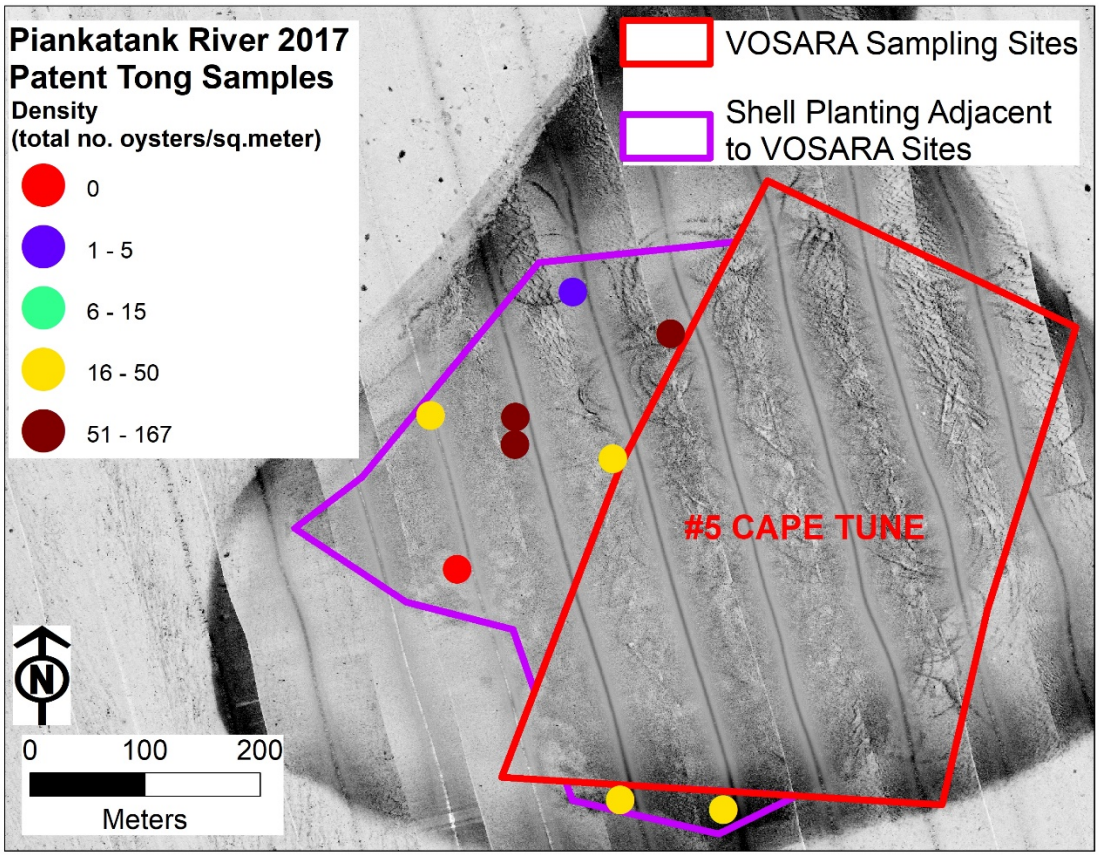
Eight shell planting sites were sampled in 2017 by the VOSARA program using patent tongs. These sites were located adjacent to a subset of the 18 annually sampled VOSARA sites and were identified from sidescan sonar surveys conducted in 2012 and 2014.

In this exercise, patent tong sample data were interpolated to determine the proportion of area at the 8 sites that met the 15 and 50 oyster density (number/m^2) and biomass (grams dry wt. /m^2) threshold and target restoration success metrics.

Summary

7) At 5 of 8 locations, 30 percent or greater of the area had interpolated oyster densities greater or equal to 15/meter^2. 24.5 acres (from 5 sites) of 61.4 acres (8 sites) or 39.9% of total site area met the success threshold metric for density (>=15/ meter^2).
8) None of the 8 locations had interpolated oyster densities greater or equal to the target density (>=50/meter^2).
9) At 1 of 8 locations, 30 percent or greater of the area had interpolated oyster biomass greater or equal to 15 g dry weight/ meter^2. 2.6 acres (1 site) of 61.4 acres (8 sites) or 4% of total site area met the success threshold metric for biomass (>=15/ meter^2).
10) None of the 8 locations had interpolated oyster biomass greater or equal to the target density (>=50/meter^2).


Shipley's Edge
Palace Bar A
Heron Rock
Cape Toon
Burton Point A
Doc's View
Piankatank River 2017
Patent Tong Samples
Shell Planting Adjacent to VOSARA Sites
N
0 1 2
Kilometers



Results

Density Metric: Number Oysters Per Square Meter - Interpolated

Location	Area (acres)	Area sq. meters	Tot. Area of interpolated grid (no. 1x1 m grid cells)	Sum grid cells (meters sq.) with density value < 15	Sum grid cells (meters sq.) with density value > = 15	Sum grid cells (meters sq.) with density value > = 50	Percent area with density value < 15	Percent area with density value >= 15	Percent area with density value >= 50
Burton Pt. A #1	8.14	32948.8	32958	32958	0	0	100.0	0.0	0.0
Burton Pt. A #2	8.85	35824.9	35830	35830	0	0	100.0	0.0	0.0
Cape Tune #1	15.8	63882.1	63878	20646	43232	8905	32.3	67.7	13.9
Cape Tune #2	1.2	4738.7	4737	701	4036	0	14.8	85.2	0.0
Docs View	0.3	1401.3	1402	1402	0	0	100.0	0.0	0.0
Heron Rock	7.2	29333.5	29335	13884	15451	8003	47.3	52.7	27.3
Palace Bar A	19.7	79760.3	79761	43960	35801	537	55.1	44.9	0.7
Shipleys Edge	0.2	632.9	632	257	375	131	40.7	59.3	20.7
Sum Area	61.39	248522.5							

above or equal to the 30% areal threshold:

below the 30% areal threshold:

Summary:

11) At 5 out of 8 locations, at least 30 percent of site area had interpolated oyster densities greater or equal to 15/ meter^2.

12) None of the 8 locations, had interpolated oyster densities greater or equal to 50/ meter^2.

Density Metric: Oyster Biomass (g DWT) Per Square Meter - Interpolated

Location	Area (acres)	Area sq. meters	Tot. Area of interpolated grid (no. 1x1 m grid cells)	Sum grid cells (meters sq.) with biomass value < 15	Sum grid cells (meters sq.) with biomass value > = 15	Sum grid cells (meters sq.) with biomass value > = 50	Percent area with biomass value < 15	Percent area with biomass value >= 15	Percen area with biomas value > 50
Burton Pt. A #1	8.14	32948.8	32958	32958	0	0	100.0	0.0	0.0
Burton Pt. A #2	8.85	35824.9	35842	35842	0	0	100.0	0.0	0.0
Cape Tune #1	15.8	63882.1	63878	48774	15104	0	76.4	23.6	0.0
Cape Tune #2	1.2	4738.7	4737	4737	0	0	100.0	0.0	0.0
Docs View	0.3	1401.3	1402	1402	0	0	100.0	0.0	0.0
Heron Rock	7.2	29333.5	29335	18713	10622	761	63.8	36.2	2.6
Palace Bar A	19.7	79760.3	79761	65833	13928	0	82.5	17.5	0.0
Shipleys Edge	0.2	632.9	632	445	187	0	70.4	29.6	0.0
Sum Area	61.39	248522.5							

above or equal to the 30% areal threshold:

below the 30% areal threshold:

Summary:

3) At 1 of 8 locations, at least 30 percent of site area had interpolated oyster biomass greater or equal to 15 g dry weight/ meter^2.

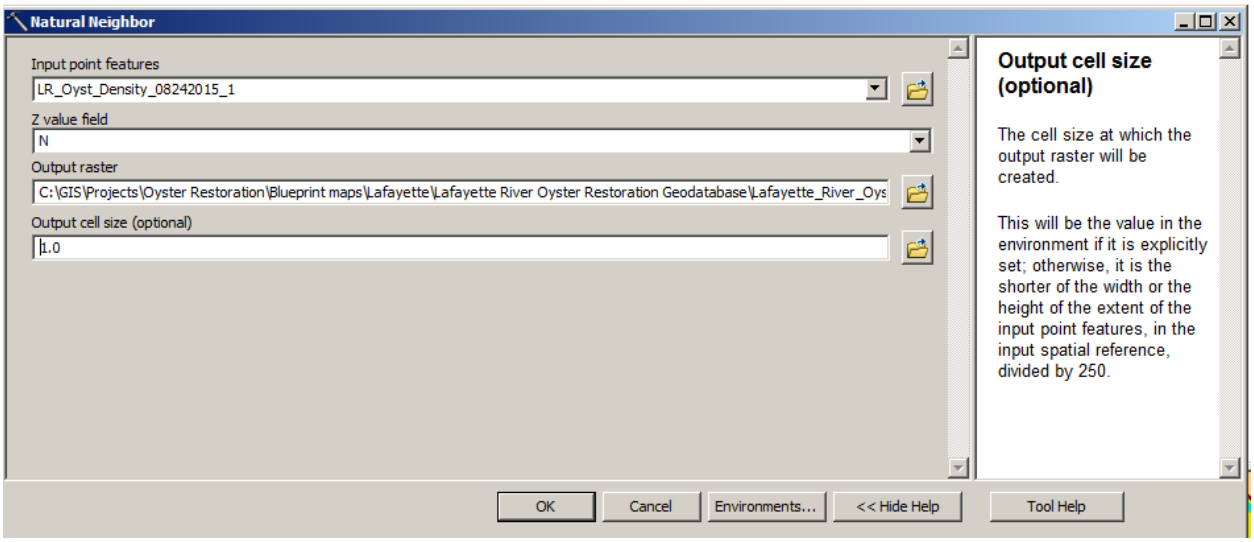
4) None of the 8 locations had interpolated oyster biomass greater or equal to 50 g dry weight / meter^2.

Interpolation Methods

6) 50 meter buffer polygons were created around each of the site boundaries

7) Generalized (simplified) polygons were created from the 50m buffer using a 50m generalization distance

8) Dummy points located at the vertices of the generalized polygons, were added to the patent tong sampling data, and were assigned values of zero. This was done to ensure that the oyster density interpolations extended beyond the outermost patent tong sampling points and covered the entire site polygon



9) Patent tong oyster density and biomass data were interpolated with the Natural Neighbor method (above). The output grid had 1x1 m cell dimensions.

10) Density and biomass grid cells were converted to points and clipped with the site boundary polygon. For each of the 8 sites, density and biomass values were binned into the following intervals: < 15.0, 15.0-49.9,>= 50.0. The results are summarized in pages 4 and 5.

VOSARA Patent Tong Summary Stats 2017 (sample data - not interpolated)

Number Per Square Meter

Location	Acres	Sq. Meters	Mean Density	Median	Standard Error	Min	Max	n	Meets Threshold (Mean >=15)	Meets Target (Mean >= 50)
Burton Point A1	8.1	32948.8	1.1	0.0	1.1	0	8	7	No	No
Burton Point A2	8.9	35824.9	0.4	0.0	0.4	0	3	7	No	No
Cape Toon 1	15.8	63882.1	41.3	39.0	13.0	0	84	7	Yes	No
Cape Toon 2	1.2	4738.7	26.5	26.5	4.5	22	31	2	Yes	No
Doc's View	0.3	1401.3	2.3	0.0	1.3	0	8	7	No	No
Heron Rock	7.2	29333.5	50.6	39.0	21.9	0	167	7	Yes	Yes
Palace Bar A	19.7	79760.3	21.2	8.0	7.4	0	53	9	Yes	No
Shipley's Edge	0.2	632.9	28.8	21.0	14.3	0	72	5	Yes	No

Summary:

3) At 5 of 8 locations, mean oyster density, from 2-9 samples (n), was greater or equal to 15/ meter^2.
4) At 1 of 8 locations, mean oyster density, from 7 samples (n), was greater or equal to 50/ meter^2.

VOSARA Patent Tong Summary Stats 2017 (sample data - not interpolated)

Biomass (g dry wt.) Per Square Meter

Location	Acres	Sq. Meters	Mean Biomass	Median	Standard Error	Min	Max	n	Meets Threshold (Mean >=15)	Meets Target (Mean >= 50)
Burton Point A1	8.1	32948.8	0.6	0.0	0.6	0.0	4.4	7	No	No
Burton Point A2	8.9	35824.9	0.3	0.0	0.3	0.0	1.9	7	No	No
Cape Toon 1	15.8	63882.1	14.2	13.5	4.0	0.0	28.3	7	No	No
Cape Toon 2	1.2	4738.7	13.2	13.2	0.3	12.9	13.4	2	No	No
Doc's View	0.3	1401.3	0.7	0.0	0.4	0.0	2.3	7	No	No
Heron Rock	7.2	29333.5	19.8	17.4	8.7	0.0	67.1	7	Yes	No
Palace Bar A	19.7	79760.3	8.9	5.2	3.2	0.0	22.5	9	No	No
Shipley's Edge	0.2	632.9	9.6	8.4	4.9	0.0	26.4	5	No	No

Summary:

3) At 1 out of 8 locations, mean oyster biomass, from 7 samples (n), was greater or equal to 15 g dry weight/ meter^2.
4) At none of the locations mean oyster biomass was greater or equal to 50 g dry weight / meter^2.

Appendix C:
Piankatank River Restoration Goal Estimation Methodology Change White Paper

Piankatank River Restoration Goal Methodology Change

Produced by USACE- Norfolk District for the
Western Shore Oyster Restoration Workgroup

Background:

The Piankatank River is a Tier 1 tributary currently selected for large-scale restoration in Virginia, having been earlier prioritized by the USACE (2012) in its Bay-wide oyster restoration Master Plan. Establishing a goal agreeable to multiple federal and state agencies (and NGOs) is a significant challenge. The initial means to establish a restoration goal for the Piankatank by the USACE is based on taking a certain percentage (from 8-16%) of the Baylor (Public Oyster) grounds delineated in the area (USACE 2012). This percentage was based on a few underlying assumptions:

1. Within a given Baylor ground, significantly less than 100% of it consisted of oyster habitat (shell, shell/sand, and shell/mud) with the remainder being open bottom that never supported oyster reefs. This discrepancy is due to the fact that Baylor grounds were delineated in such a way that oyster habitat tends to be very irregular in shape and distribution within any given river, and was enclosed within straight-line polygons roughly approximate in shape to the network of oyster habitat.
2. The USACE adopted a goal of restoring from 20-40% of this assumed acreage, in keeping with Marine Protected Area size recommendations from the literature as cited in the USACE Master Plan (USACE 2012).
3. The result meant taking from 8-16% of a given Baylor Ground as a restoration target.

The USACE Oyster Restoration Master Plan was written with these underlying assumptions when goals for various sub-estuaries and tributary rivers were established.

Habitat Estimation Methodology Details from USACE (2012):

In the James River, Moore (1910) found that actual oyster habitat comprised approximately 47% of the Baylor Grounds (Baylor 1895). This river, like the Piankatank, was a hand tong area, not open to wide-scale dredging as oyster habitat was in the Bay mainstem of Virginia. Dredging causes significantly more damage and habitat loss than tonging (Schulte 2017). Due to this, the USACE (2012) plan considered the Moore (1910) survey data as the best example of what might have been present in a riverine system historically. Relative to the desired MPA %, it was then determined that to restore 20-40% of the Moore (1910) acreage, which equates to a goal of 8-16% of the actual Baylor Ground acreage being restored. This goal was to allow for a large enough sanctuary reef network to increase recruitment in the region hydrodynamically connected to the reef network, allow for multiple use of oyster habitat outside the

sanctuary network (seed and/or market oyster production), and large enough to improve local water quality as well as other regional benefits, such as improved secondary production, and enhancing other fisheries (fin as well as blue crab). Both the Great Wicomico and Piankatank Rivers show evidence of recruitment enhancement due to large-scale restoration efforts (Schulte and Burke 2014) though significantly more restoration work remains to be done to ensure these trends continue and are improved.

The Issue:

When the Piankatank River was delineated by Baylor, instead of roughly enclosing areas of the river that held reefs as he had done in most other areas, Baylor simply delineated almost the entire river, from the North to South bank, as one large Baylor Ground. The result is that we believe the percentage of oyster habitat/Baylor ground in the Piankatank River is much lower than 47% relative to the size of the Baylor Grounds in the area.

Considering the most recent survey that included extensive an extensive examination of the bottom to determine the actual extent of oyster habitat in Virginia (Haven et al. 1981), 711.6 acres of oyster habitat were found in the area defined as the Piankatank River by the interagency oyster restoration team that covers 5,426 acres (Figure 1). This habitat is 13.1% of the defined area, the assumption in the USACE (2012) plan is that there was originally 2,387.4 acres of oyster habitat in this region. Further, NOAA discovered approximately 918 acres of current and former oyster habitat in this region, which is 16.9% (far from 47%) of the associated Baylor Ground area. There is no evidence to support the estimate of 2,387.4 acres amount of oyster reefs in the river historically, and considering the river-wide polygon Baylor delineated, it seems to be an overestimation. The oyster habitat currently present, as well as former habitat as noted by NOAA, was located in the river where such habitat is typically expected to be. The extensive deeper bottom in the Piankatank likely never held oyster habitat, and NOAA generally found none, either current or former, in these deeper waters. We believe that by using the original USACE (2012) method, the goal defined by the USACE will be too high.

Proposed Solution for the Piankatank:

Due to the difference in delineation of Baylor Grounds in the Piankatank River relative to the James River, it would be best if we instead used the historic reef acreage to estimate our goal, not the Baylor Ground polygons. However, we do not have a historic survey that accurately bottom maps the true extent of oyster habitat in the Piankatank as we do for the James River. But, we do have a decay rate we can estimate using the Moore (1910) and Haven (1981) data for the James River that we could apply in reverse to the Haven (1981) Piankatank oyster habitat acreage. This would allow us to estimate what the original acreage likely was in our Piankatank River restoration area. This decay rate has been estimated at 39% (Schulte 2017), that is, 61% of the historic habitat circa the Baylor era remained as of the early 1980s. The oyster habitat found by Haven (1981) was 711.6 acres in the restoration polygon as defined by the interagency oyster restoration team. Applying the decay rate in reverse to estimate the historical habitat acreage, we get 1,166.6 acres, which is only 21.5% (not 47% as would be expected) of the Baylor acreage in this region. This number is also reasonably close to the approximately 918 acres

that NOAA identified in this same area as either having shell present or once had shell on the surface (buried shell). We then apply the MPA 20 and 40% goals to this historical estimate, which gives the USACE a restoration target of 233.3-466.6 acres for the Piankatank River. This goal is what the USACE, Norfolk District, recommends for the Prong 2 goal of the Lower Piankatank Oyster Restoration Target.

This goal is also quite compatible with the Prong 1 goal, which is to restore 50-100% of the currently restorable oyster habitat in the lower Piankatank River, which is 242-483 acres.

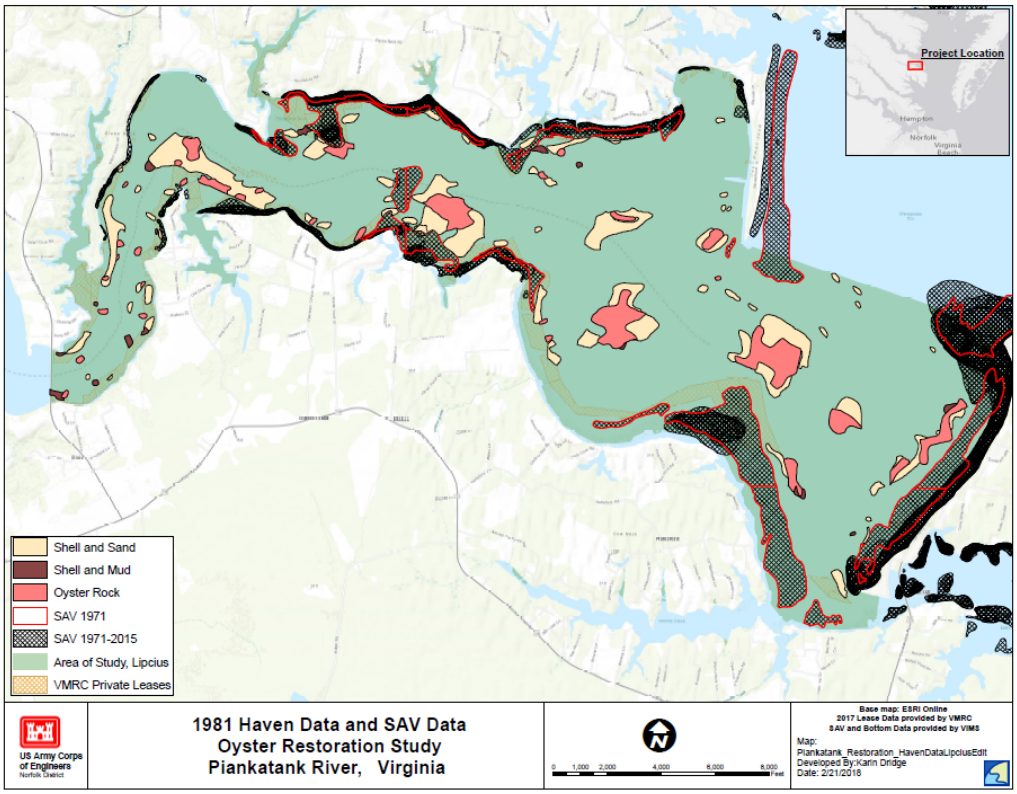


Figure 1. Haven et al. (1981) oyster habitat data, and SAV data.

Appendix C References

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