# MONITORING AND EVALUATING THE SUCCESS OF THE ST. MARY'S OYSTER REEF PROJECT

by

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## Acknowledgments and Disclaimer


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# 1 Abstract

Oysters are a keystone species in the Chesapeake Bay ecosystem that reduce pollutants, including sediment, nitrogen, and phosphorous, through filtration. The goal of the St. Mary's River Oyster Reef Project was to restore a five-acre oyster reef within the St. Mary's River Shellfish Sanctuary. After nearly a decade of restoration, this study aims to evaluate the success of these restoration efforts. A pilot monitoring and evaluation program was conducted in 2017, and this study's methods build upon the pilot and its methods. In this study, we assessed the success of the reef project using four major criteria as defined by the 2014 Chesapeake Bay Agreement: percent coverage, oyster density, oyster biomass, and presence of multiple year classes. Sampling was conducted during August 2022 and April 2023. The St. Mary's River Oyster Reef Project met and exceeded the target values for all four criteria, indicating that restoration efforts have been successful thus far; calculated values for oyster density, oyster biomass, and percent coverage were all at least twice the target value. The data collected in this study can be utilized to target areas in the reef for future restoration efforts.

# 2 Definitions

For the purposes of this study, the following terms are defined in the following ways.

**Spat-** Post-settlement juvenile oysters; defined as oysters less than 10 mm in all portions of this study with the exception of Figure 6.

**Hard Substrate**- Concrete rubble or reef balls added to the reef in previous restoration efforts

**Flat Bottom**- A sampling area without hard substrate

**Reef Ball-** A concrete structure designed to provide suitable substrate for reef formation

**Percent Coverage-** Percentage of the project area containing oysters

**Oyster Density-** Number of oysters per square meter

**Oyster Biomass-** Estimated oyster tissue dry weight (g) per square meter

**Year Class-** Classification used to determine oyster age groups in relation to the year they were spawned

# 3 Introduction

The St. Mary's River is a tributary of the lower Potomac River with a drainage area of about 45,000 acres and a protected area exceeding 1,300 acres (Maryland Department of the Environment [MDE], 2014). The river is listed as "impaired" under section 303d of the Clean Water Act due to low pH in first through fourth order streams, the presence of fecal coliform, and high nitrogen and phosphorus (Maryland Department of Natural Resources [MD DNR], 2012). Human activities in the watershed, such as increasing development and overfishing, present environmental challenges, including nutrient pollution and depletion of natural stock.

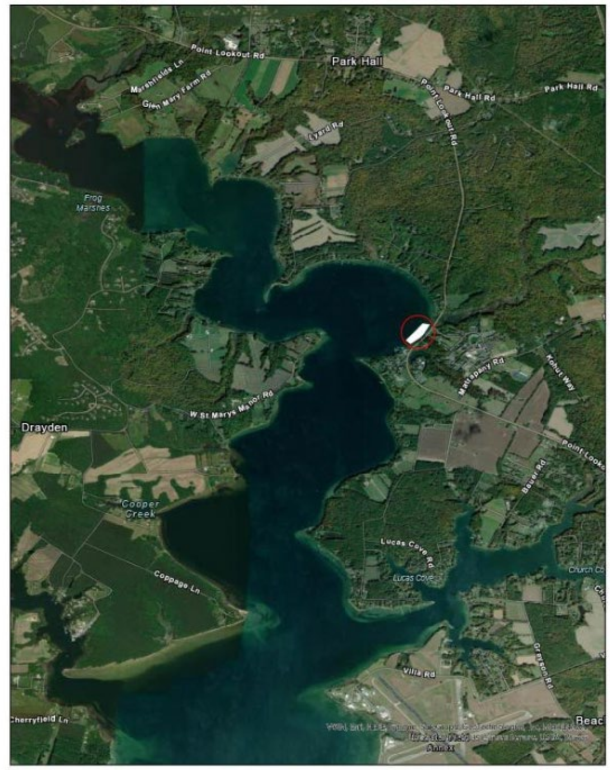


**Figure 1.** Map of the St. Mary's Oyster Reef Project location in the St. Mary's River.

However, the St. Mary's River is listed as a Tier 1 tributary, indicating its suitability for oyster restoration (U.S. Army Corps of Engineers [USACE], 2012). The once-prevalent Eastern oyster (*Crassostrea virginica*) provides a variety of ecosystem services, including water filtration, nutrient uptake, and substrate and refuge for other organisms, making oyster restoration highly beneficial to the river ecosystem. The St. Mary's Oyster Reef Project, the restored five-acre site addressed in this report, is adjacent to St. Mary's College of Maryland (SMCM) and is located in an area commonly referred to as Horseshoe Bend (Figure 1). The project was established in 2014 by the St. Mary's River Watershed Association (SMRWA) and SMCM. Its goals included restoring a healthy oyster reef in the St. Mary's River Shellfish Sanctuary.

The St. Mary's Oyster Reef Project has two distinct areas. Initially, the southern area was planted with only oyster shells and spat (flat bottom), and on the northern end, hard substrate (concrete rubble and reef balls) covers the bottom. However, in 2018, SMRWA began adding reef balls to the southern area. The northern end constitutes about 60% of the restoration area, and the southern end constitutes the remaining 40%. Over the past ten years, 8,000 bushels of spat-on-shell, 2,326 reef balls, and 250 tons of concrete rubble have been added to the restoration area. The intent of the St. Mary's River Watershed Association (SMRWA) in this study is to evaluate the success of the oyster sanctuary thus far and to determine areas to target with future restoration efforts.

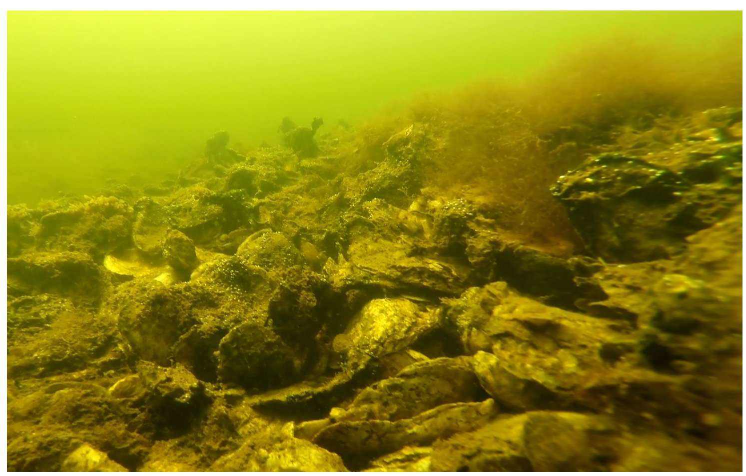

**Photo 1.** Oysters on the restored five-acre reef site.

In 2012, SMRWA applied for a Maryland Army Corps of Engineers wetlands permit to authorize the use of Horseshoe Bend for alternate substrates for oyster reefs. In 2013, SMRWA began restoring the reef with alternate substrates. The restoration was initially funded using a National Fish and Wildlife Federation Small Watershed Grant, and over the years other funders, including Boeing, Patagonia, Dominion Charitable Foundation, Cove Point Natural Heritage Trust, the Chesapeake Bay Trust, the Rotary Club International, and several other partners, have supported this project.

After four years of restoration, in the summer of 2017, SMRWA and SMCM partnered to conduct a pilot survey to evaluate the success of the five-acre reef project. SMCM students measured the oyster density, biomass, and age structure on 17 hard substrate sites within the five-acre reef site. Additional restoration has occurred on the five-acre reef site since, and we anticipated that at least four acres will now meet restoration criteria.

**Criteria and Goals**

The goal of this study is to evaluate the success of oyster restoration in the five-acre project site. We examined four different metrics outlined by the Oyster Metrics Workgroup (2011; Table 1).

**Table 1.** Summary of restoration success criteria as defined by the 2011 Oyster Metrics Workgroup.

| Metric | 1. Percent Coverage | 2. Oyster Density | 3. Oyster Biomass | 4. Presence of multiple year class of live oysters |
|---|---|---|---|---|
| **Minimum** | **None** | **15** oysters/$m^2$ covering at least **30%** of the target restoration | **15** grams dry weight/$m^2$ covering at least **30%** of the target restoration | **-** |
| **Target** | **30%** coverage with spat-on-shell, hard substrates | **50** oysters/$m^2$ covering at least **30%** of the target restoration | **50** grams dry weight/$m^2$ covering at least **30%** of the target restoration | **2** year classes present |

# 4 Materials and Methods

### Preliminary Methods Determination

In the 2017 study, we found that scraping oysters off hard substrate caused some mortality. To avoid this mortality, we conducted preliminary oyster density measurements on hard substrate to determine whether we could accurately determine oyster density by counting the oysters in situ. A diver utilizing a surface air compressor visually counted oysters within a 0.25 $m^2$ quadrat placed on a reef ball or concrete substrate. The observed number of oysters was reported to a data recorder on the boat. After in situ counts, the oysters within the quadrat were scraped off and counted aboard the boat. The process was repeated for five separate sites. In total, five oysters were killed during the scraping. An average of 91 more oysters (per $m^2$) were counted with the retrieval method than with the visual method (Figure 2). Therefore, we concluded that retrieval methods would be necessary for accurate assessment of oyster reef density on hard substrate.

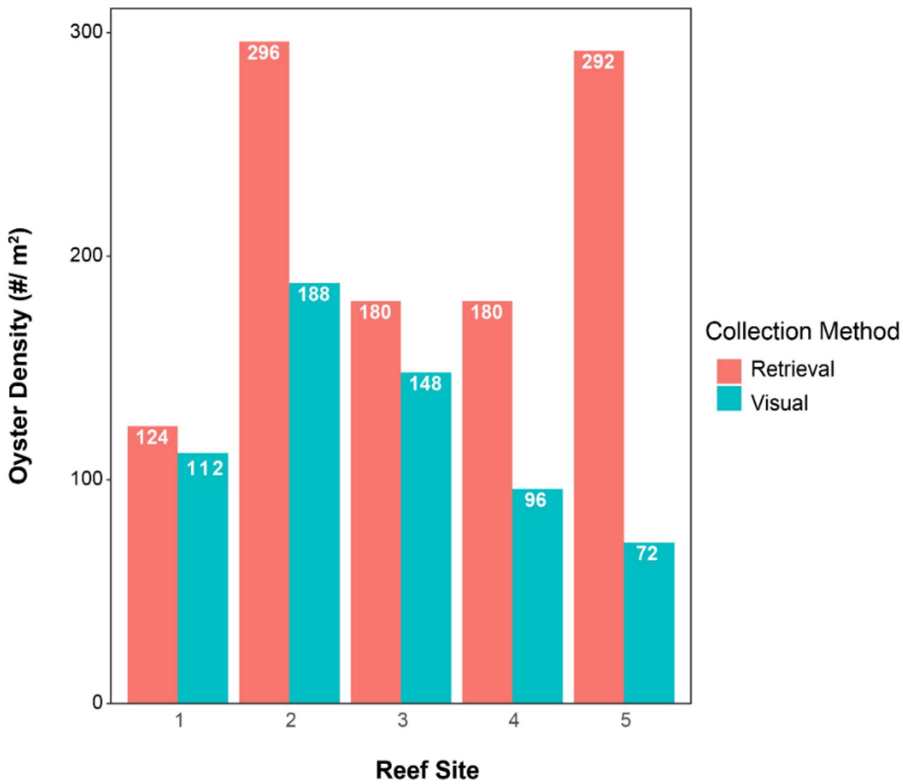


**Figure 2**. Comparison of oyster density counts (#/$m^2$) using in situ methods (visual) and retrieval methods. On average there were 91 less oysters/$m^2$ when assessed visually than when assessed using the retrieval method.

**Oyster Density**

We utilized a random selection method to determine sites for oyster density sampling. The five-acre restoration area was divided into 3x3 meter grids using QGIS 3.28.1-1. This grid was converted into polygons, and we obtained the centroid of each polygon using the geometry functions in QGIS. Then, we randomly selected 5% of the centroids to serve as our study sites for density measurements.

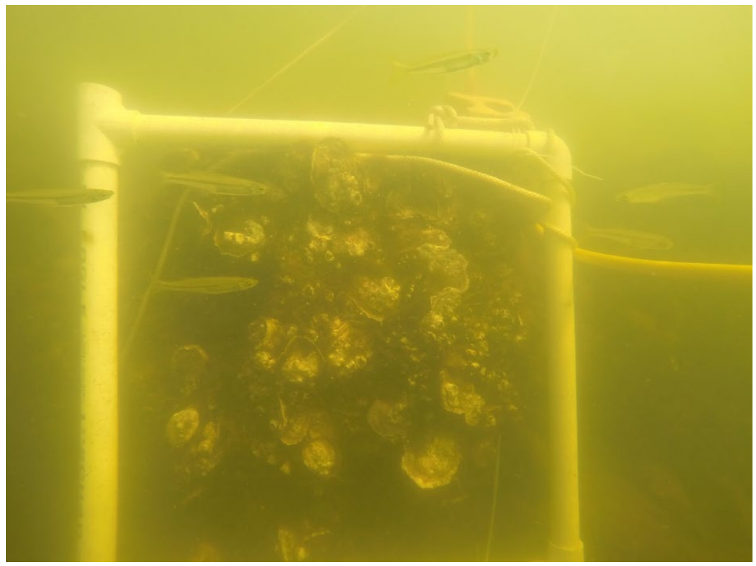

**Photo 2.** Quadrat (0.25 $m^2$) deployed underwater on a reef ball.

A Garmin GPSMap276Cx was used to locate the sampling site (point in the center of the 3x3 m grid). Once we were within 9 m of the sampling site (our GPS's accuracy), we threw a 0.25 $m^2$ quadrat and a basket for collecting oyster shells overboard (Photo 2). On flat bottom sites, the primary sampler traveled to the quadrat and basket and placed oysters present within the quadrat up to six inches off the sediment's surface into the basket. On hard substrate sites, the primary sampler scraped the oysters within the quadrat from the hard substrate and placed them in the basket. The basket was brought to the surface and the number of live and dead oysters over 10 mm were counted and recorded (Photo 3). Our procedures regarding spat (oysters less than 10 mm) will be discussed later. In 2022, sampling took place between August 9th and 23rd, and in 2023, sampling took place between April 5th and 26th.

The number of live and dead oysters collected from within the 0.25 $m^2$ quadrate were multiplied by four to determine the number of oysters per $m^2$. Any observations made by the samplers, including oxygenation of sediment and growth patterns of oysters, were also recorded.

**Photo 3.** Oysters retrieved for density measurements.

**Estimating spat counts in density measurements**

We chose to exclude oysters under 10 mm from our field counting for oyster density for two reasons. The first is that in 2022, sampling was conducted in late summer. Oysters in the Chesapeake Bay generally spawn annually from May to

August (Maryland Fish Facts: Shellfish - Eastern Oyster, n.d.). Therefore, the oysters that were less than 10 mm during the summer of 2022 sampling were presumably from the summer spawn of 2022. In 2023, sampling was conducted in the spring, and therefore, we did not capture the summer 2023 spawn in our samples. Our results would not have been comparable between years, so we did not count spat during density measurements to ensure sampling was consistent across seasons. The second reason is that during age structure analysis, we found a large number of oysters less than 10 mm. With limited funding and staff time, we decided to estimate the number of spat post-sampling rather than count each individually. We estimated the average number of spat per oyster shell from our age structure measurements and multiplied by the number of adult oysters per $m^2$ to determine total spat per $m^2$. The number of live adult oysters per $m^2$ and the estimated spat per $m^2$ were added to estimate live oysters per $m^2$.

**Age Structure**

Bagget et al. (2014) recommend a sample size of 250 oysters per reef for oyster size-frequency distributions. We initially sampled 250 total oysters across both hard substrate (n=100) and flat bottom (n=150) and separated them into 5 mm bin size classes. Age structures had different distributions between hard substrate and flat bottom, so we increased our sample size to 500 total oysters—250 from hard substrate and 250 from flat bottom. Oysters were retrieved from ten sampling locations (Figure 3). The number of spat (<10 mm) were counted on each oyster, and all other oysters were measured to the nearest mm. The oysters were separated into 5 mm size bins and into spat, small, and market size bins. All oysters were measured in August 2022.

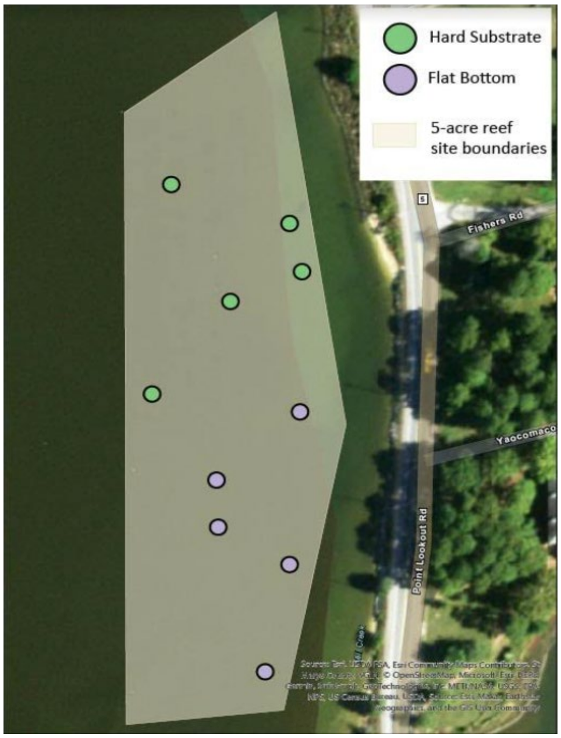


**Figure 3.** Map of sampling locations for age structure across the five-acre reef.

## Biomass

We estimated oyster biomass using the following allometric formula from Jordan et al. (2002). Jordan et al (2002) measured 450 oysters from 45 sites (10 oysters per site) in the Maryland portion of the Chesapeake Bay for both size (mm) and dry weight (g). They compared the dry tissue weight (g) to the shell height (mm) and developed the following formula (Equation 1):

$$\log_{10}(dry\ tissue\ weight) = 2.06[\log_{10}(shell\ height)] - 3.76 \qquad \textbf{Equation 1}$$

We used the length of oysters (>10 mm) to estimate their biomass using Equation 1. Then, we averaged the biomasses (n=500) for these oysters. We multiplied the average biomass by the live adult oyster (>10 mm) density (per $m^2$) for each density measurement. This calculation provided an approximation of the biomass (dry tissue wt [g]) per $m^2$ at each site where density was calculated.

### Percent Coverage

Percent coverage was calculated using the total number of sites sampled for oyster density. The number of sites with zero live or dead oysters was divided by the total number of sites to determine the percentage of sites with zero oysters. Similar methods were used to determine the percentage of sites with greater than zero and greater than fifty oysters per $m^2$.

## 5 Results

### Age Structure

A total of 500 live oysters greater than 10 mm were measured to the nearest mm. We counted 502 spat (oysters less than 10 mm) that settled on the 250 oysters measured on hard substrate and 560 spat that settled on the 250 oysters measured on flat bottom. Age structure among oysters retrieved from flat bottom was more evenly distributed than oysters retrieved from hard substrate (Figure 4 and Figure 5). The distribution of oyster sizes on hard substrate skewed right: more oysters were from smaller size bins. On flat bottom, the highest number of oysters fell within the 96-100 mm size bin (n = 18; Figure 4). The mean oyster shell height fell within the 75-80 mm size bin. On hard substrate, the highest number of oysters fell within the 41-45 mm (n=25) and 46-50 mm (n=25) size bins (Figure 5). The average oyster fell within the 65-70 mm size bin. Oysters under 20 mm and over 145 mm were present at both sites. NOAA Fisheries defines three-year classes in their 2021 Maryland Oyster Monitoring Report: spat (<40 mm), small (40-75 mm), and market (>75 mm). Oysters in all three year classes were present on both hard substrate and flat bottom. The fewest oysters (n=95) were present in the small year class on flat bottom, and the most oysters (n=647) were present in the spat year class on hard substrate (Figure 6).

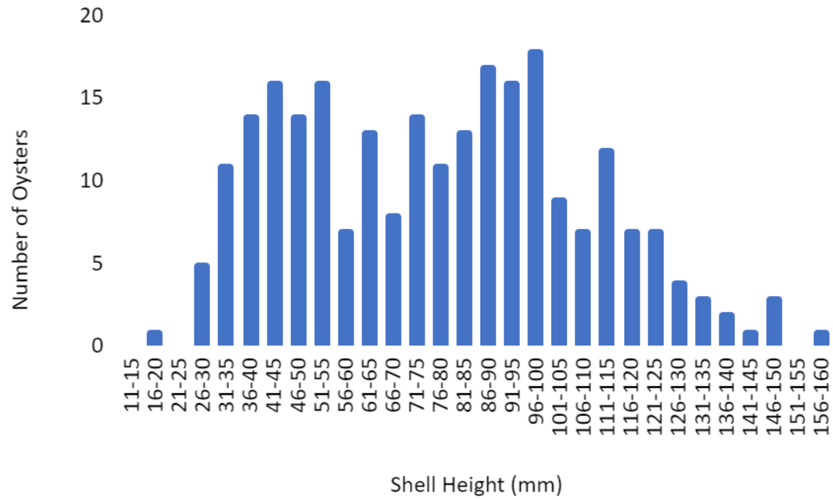


**Figure 4**. Size distribution (shell height in mm) of oysters (n=250) in adult 5 mm bin size classes on flat bottom.

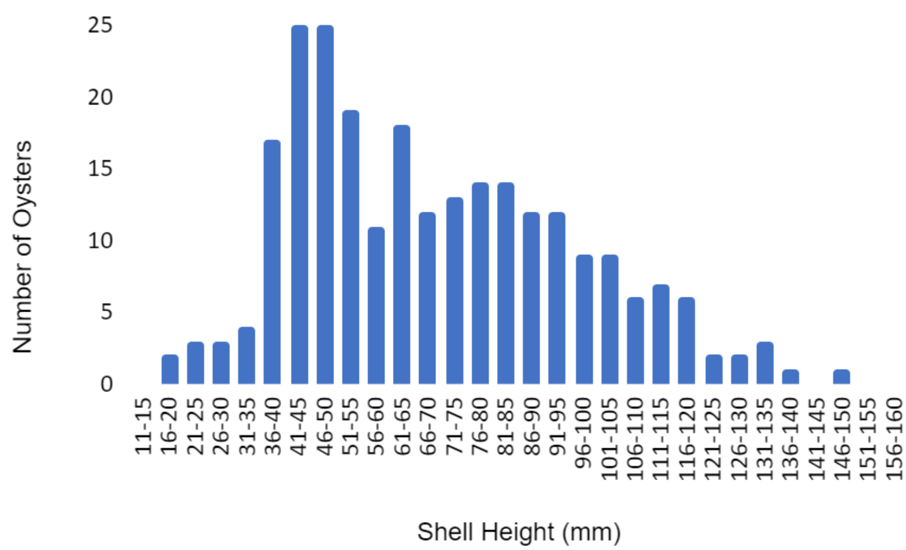


**Figure 5.** Size distribution (shell height in mm) of oysters (n= 250) in adult 5 mm bin size classes on hard substrate.

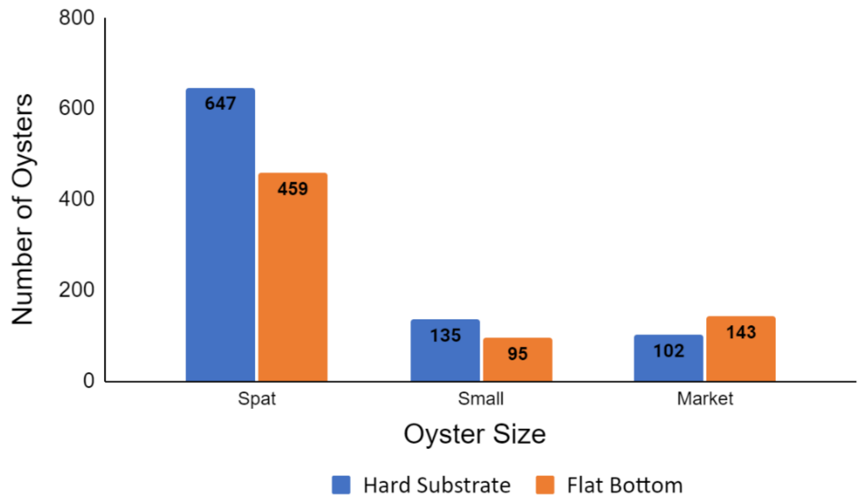


**Figure 6.** Size distribution (shell height in mm) of oysters (n=1,581) in year classes as defined by NOAA Fisheries on hard substrate and flat bottom. This graph includes oysters less than 10 mm.

## Oyster Density

Of the randomly selected centroids used for sampling oyster density, all but one were located on flat bottom; the remaining site was located on a reef ball. A total of 122 locations were sampled—58 in August 2022 and 64 in April 2023. Oyster density varied across these sites (Figure 7). Across all bottom types there were an average of 75 adult live oysters/$m^2$ and 10 adult dead oysters/$m^2$. Using the estimated average spat per oyster (2.2 spat per oyster on flat bottom and 2.0 spat per oyster on a hard substrate), we calculated a total of 165.3 spat per $m^2$, resulting in an average of 240.7 live oysters per $m^2$ (Figure 8). These numbers varied across bottom type. For example, density on shell bottom was over twice as high as both mud and sand bottoms (shell: 486.4 oysters per $m^2$, mud: 221.9 oysters per $m^2$, sand: 196.7 oysters per $m^2$). Shell bottom sites had the smallest sample size (n=7) and mud had the largest (n=56).

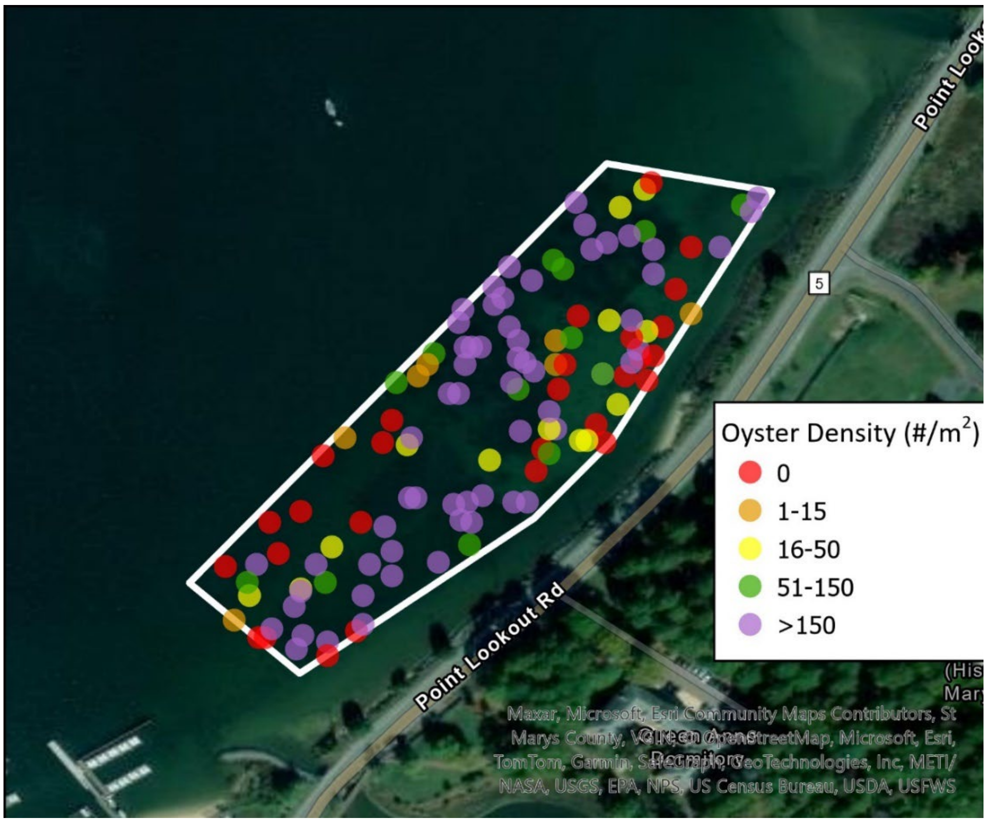


**Figure 7.** Map of the oyster density (oysters/$m^2$) at each of the 122 density sampling sites.

No live oysters were found at twenty-eight (23.0%) of the 122 density sampling sites. The remaining 77.0 % of sites had greater than zero oysters per $m^2$. Of the sample sites, 60.7 % had greater than 50 oysters per $m^2$, which is more than twice the target value of 30 % coverage.

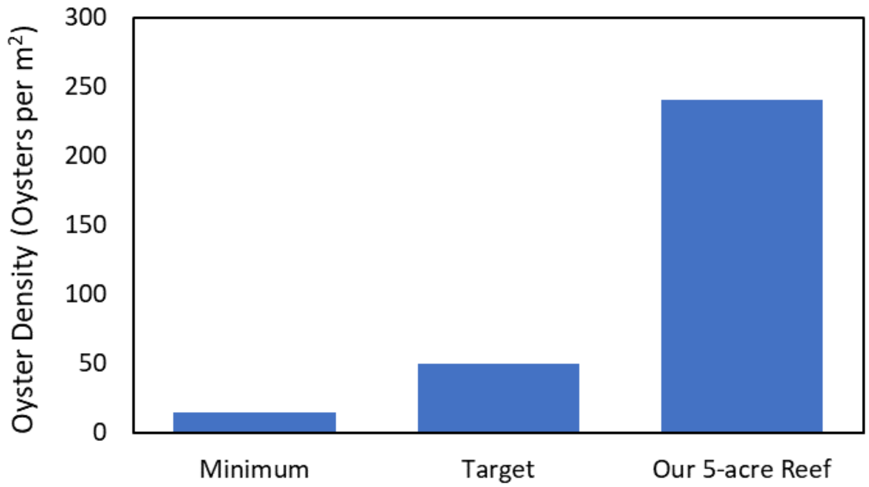


**Figure 8.** Comparison of the minimum, target, and calculated average oyster densities (oysters/m$^2$) for the St. Mary's River oyster restoration area.

**Biomass**

Using the formula from Jordan et al (2002) and our age structure measurements, we calculated an average biomass per adult oyster (> 10 mm) of 1.4 g. After multiplying by the oyster density measurements, we found an average biomass of 107.0 g/m$^2$ across all study sites (Figure 9). Because biomass calculations were derived from the oyster density results, the data are similar for these two metrics. The same 28 sites with no live oysters also had no biomass, and the 65 sites with greater than 50 adult oysters/m$^2$ also had greater than 50 g/m$^2$. A total of 53.28 % of the study sites had greater than 50 g/m$^2$, which is almost twice the target value of 30 % coverage.

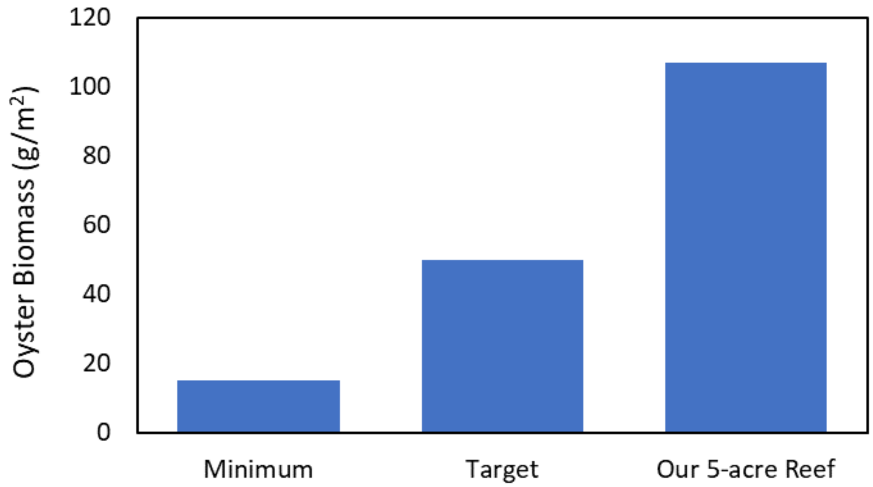


**Figure 9.** Comparison of the minimum, target, and calculated average oyster biomass values (g/$m^2$) for the St. Mary’s River oyster restoration area.

## 6 Discussion

In this study, the success of the St. Mary’s River oyster reef restoration project was evaluated using four criteria as outlined by the Oyster Metrics Workgroup (2011) and specified by the 2014 Bay Agreement. The first criterion utilized to determine oyster reef success was percent coverage. The target value was the presence of oysters over 30 % of the reef area. We calculated the presence of oysters over 77.05 % of the reef area, indicating that the first criterion of success was met in the St. Mary's River oyster restoration area.

The second criterion is oyster density, with a minimum density of 15 oysters/$m^2$ covering at least 30 % of the target restoration area and a target density of

50 oysters/m$^2$ covering at least 30 % of the target restoration. Oyster density metrics traditionally include first year settlement (spat), but due to the large amount of spat (2.0 per oyster on the reef ball and 2.2 per oyster on the shell bottom) and differing sampling times, we did not include spat in our density counts. Spat were instead estimated using the average spat per shell and used to determine total oysters per m$^2$. Across all bottom types surveyed there were an average of 240.7 oysters/m$^2$, which is over four times the target density. We calculated that 60.7 % of sites had an oyster density greater than 50 oysters/m$^2$. Therefore, the second criterion has also been met.

Oyster density is a commonly measured indicator of restoration success and can be highly variable between reefs and regions. A 2019 assessment of two restored oyster reefs in Loxahatchee River Estuary, Florida recorded a density of 1,182 and 446 oysters/m$^2$ (Metz, 2021). Another reef in Pensacola East Bay, Florida has an average density of 55 oysters/m$^2$ one year post-restoration (The Nature Conservancy, 2023), demonstrating the variation in density among restored reefs in the same region. The oyster density and biomass in the St. Mary's River restoration area is similar to other restored reefs in the Chesapeake Bay. In 2017, oyster density on restored reefs in Virginia's Great Wicomico, Lynnhaven, and Lafayette Rivers averaged between 98.83 and 308.51 oysters/m$^2$, and biomass averaged between 53.91 and 75.14 g/m$^2$ (Bruce et al., 2021). Density and biomass in the St. Mary's River (240.7 oysters/m$^2$ and 107.0 g/m$^2$) indicate that our five-acre reef is performing well within the context of Chesapeake Bay restored oyster reefs, especially in regards to biomass.

Restoration activity, particularly type of added alternative substrate materials, also impacts resultant oyster density. A restoration project in the Tappan Zee region of the Hudson River reported a high average oyster density (1,976 oysters/m$^2$) two years post-construction (AKRF Inc. et al., 2021), which is also substantially higher than the density measured in this study. However, the Tappan Zee reefs were restored entirely with hard substrate types—reef balls and gabions—while the St. Mary's Oyster Reef Project was partially restored by adding spat-on-shell to flat bottom. The density measuring site in the St. Mary's River located on a reef ball had the highest density of all the sites (1,320 oysters/m$^2$), which is the most comparable to the density in the Tappan Zee reefs. This indicates that hard substrate types allow for higher oyster densities, potentially by providing greater surface area for colonization. Although only one of the randomly selected density sampling sites was located on hard substrate, our five-acre reef still exceeded the target threshold for density. The average density would likely be higher had more measurements been taken from hard substrate.

The third criterion by which we evaluated reef success involves biomass, with a minimum of 15 grams dry weight/m$^2$ covering at least 30 % of the target restoration, and a target of 50 grams dry weight/m$^2$ covering at least 30 % of the target restoration. We found that the average biomass of the reef was 107.0 g/m$^2$ and that 53.3 % of the reef had an approximate biomass greater than 50 g/m$^2$, indicating that this criterion has been met.

The fourth criterion regarding reef success used in this study was the presence of multiple year classes. Baggett et al. (2014) recommend grouping oysters into 5 mm bin size classes for analysis, allowing for small variations in age groupings to be visible. These groupings revealed that on hard substrate a higher percentage of oysters are smaller and belong to younger age classes (Figure 5). These age classes differ from year classes, which allow for the distinction between oysters spawned in different years. Year classes are based on the average oyster growth rate of approximately 25-40 mm per year for the first few years of life (Levinton et al., 2013). Year classes were defined by NOAA Fisheries in their 2021 Maryland Oyster Monitoring Report as market (>76 mm), small (40-75 mm), and spat (<40 mm). In the St. Mary's oyster reef, at least 95 oysters were present in each year class on both hard substrate and flat bottom. Therefore, multiple year classes were present, and this criterion has been met.

# 7 Conclusions and Further Study

Based on our evaluation of the St. Mary's River oyster reef, all four target criteria (percent coverage, oyster density, oyster biomass, and presence of multiple year classes) have been met and exceeded in the restoration area. We can use these data to identify areas performing with less success and target them for future restoration efforts.

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