# Paynter Lab Annual Summary 2011

## Submitted to the Oyster Recovery Partnership

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# Executive Summary

The Paynter Laboratory at the University of Maryland conducted monitoring activities of restored oyster populations in Maryland in 2011. These activities include monitoring the effectiveness of bar rehabilitation, pre-planting ground-truthing (GT), post-planting monitoring (PPM), patent tong surveying, and research. Bar rehabilitation moves buried shell from areas throughout the bay to areas targeted for restoration and our monitoring of these sites helps determine the effectiveness of the rehabilitation effort. GT involves the assessment of bottom quality prior to planting spat-on-shell by the Oyster Recovery Partnership (ORP). PPM consists of sampling newly planted spat within four to eight weeks after planting to determine survivorship and growth rates. Patent tong surveys are conducted to estimate the number and density of oysters on various bars as well as to sample the oysters for size and *Perkinsus marinus* prevalence. Most of the research we conducted this year was in collaboration with scientists from the Horn Point Laboratory, University of Maryland Center for Environmental Science (UMCES). With the help of the UMCES staff we continued the study assessing the egg quality of oysters from four different sites as well as conducted our first comprehensive spat survival study. Finally, a survey of the oyster populations in Harris Creek and the Little Choptank River was conducted to understand the effectiveness of bottom imaging tools, assess the standing oyster population as well as determine the extent of the existing shell base in both tributaries. Full reports of the spat survival study as well as intensive patent tong surveys in Harris Creek and the Little Choptank River will be forthcoming soon and separate from this report.

Our bar rehabilitation assessment this year (Section II) did not indicate that bottom quality drastically improved with rehabilitation. However, these data were limited in power because scheduling constraints only allowed for two bars to be monitored before and after rehabilitation. Therefore, we believe that our data are incomplete and the trends from only two bars cannot be interpreted as patterns for all rehabilitation efforts.

Similar to the method employed in 2010, side scan sonar (SSS) was used for guidance when selecting sites to GT (Section III). Again, our GT effort was highly effective in improving our efficiency in location suitable bottom for planting. We assessed 25 bars and identified acceptable planting areas within most bars.

PPM (Section IV) showed that the mean survivorship of spat planted was about 27%, which was much higher than the average survivorship of spat in previous years (see Table 1). Thirteen sites at 12 bars were sampled and survival ranged from 0.4 to 89.4%. We believe this success is directly related to the dedication of ORP staff (Steve Allen) to direct plantings to areas of harder, more shelled bottom targets than in years past. This was accomplished largely by the use of acoustic data and diver GT. Although it was a very wet year and therefore salinities were unusually low (see Table 2), adjustments were made to plant oysters in areas with acceptable salinities and not impacted by the deluge of silt and debris caused by Hurricane Irene and Tropical Storm Lee.

Table 1. Plantings and survival. Values show the total sites and spat planted for each year (2008-2011) as well as the mean spat per shell and percent survival base on post-planting surveys.

| Sample Year | Sample Locations | Sites Planted | Total Acreage Planted | Total Spat Planted (Millions) | Means per Year: Initial Spat per Shell | Survey Spat per Shell | Shell Height (mm) | % Survival | Spat Detected on PPM Survey (Millions) |
|---|---|---|---|---|---|---|---|---|---|
| 2008 | 20 | 27 | 215.64 | 369.95 | 30.23 | 3.94 | 14.94 | 17.0 | 62.89 |
| 2009 | 19 | 56 | 408.82 | 761.96 | 17.9 | 3.4 | 11.45 | 12.0 | 91.44 |
| 2010 | 13 | 16 | 99.56 | 373.76 | 14.86 | 2.03 | 20.13 | 12.8 | 47.84 |
| 2011 | 12 | 13 | 93.53 | 514.95 | 16.51 | 4.36 | 20.07 | 27.0 | 139.04 |

Table 2. Mean annual salinity (ppt) at each of six regions sampled in 2011. Data are included for 2009 and 2010 where appropriate.

| River | Annual Salinity (ppt): 2009 | 2010 | 2011 |
|---|---|---|---|
| Chester | 10.8 | 10.5 | 6.6 |
| Choptank | 15.6 | 11.9 | 8.8 |
| Eastern Bay | 12.9 | 13.7 | 9.7 |
| Harris Creek | - | - | 7 |
| Little Choptank | 12.7 | - | 8.2 |
| Severn | 11.5 | 8.7 | 5.6 |

Patent tong surveys (Section V) were conducted to estimate population abundances, assess shell base, estimate oyster size and biomass, and collect oysters to test for *Perkinsus marinus*, the parasite that causes Dermo disease. Twelve bars were surveyed with oyster densities ranging from 0.1 to 4.3 oysters/m$^2$ (see Table 3). As shown in Table 3, restored bars between 3 and 5 years of age show relatively low numbers compared to a calculated expected population size (Expected = (planted – 90%) – (remaining*.15) for each year). Table 3 does not include all bars tonged in 2011, only those that have not been harvested or over-planted and thus have a known estimate of total initial spat planted without removal to harvest. Most populations are less than 10% of the expected abundance, suggesting there remain unknown sources of loss. That said, patent tong surveys conducted in Fall 2011 showed 2011 plantings in Harris Creek at 25 oysters/m$^2$, well above the minimum of 15 oysters/m$^2$ set recently by a NOAA/DNR/VMRC led effort to define metrics of success.

Table 3. Oyster populations, density and biomass on restored bars surveyed using patent tongs in 2011.

| River | Bar Name | Planting Year | Spat Planted | Expected 2011 Population (Oysters) | Population Estimate (Oysters) | % of Expected | Bar Oyster Density (#/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|---|---|---|---|
| Chester | Blunt | 2008 | 21,040,000 | 1,520,140 | 38,674 | 2.5 | 0.4 | 0.7 |
| | Drum Point | 2007 | 2,310,000 | 141,863 | 15,539 | 11 | 0.6 | 3.0 |
| | Strong Bay | 2005 | 44,880,000 | 1,991,349 | 99,772 | 5 | 1.8 | 2.6 |
| | Strong Bay | 2008 | 15,120,000 | 1,092,420 | 83,909 | 7.7 | 2 | 0.2 |
| | Willow Bottom | 2007 | 7,680,000 | 471,648 | 3,108 | 0.7 | 0.1 | 1.2 |
| Choptank | Bolingbroke Sand | 2008 | 10,720,000 | 774,520 | 103,649 | 13.4 | 1.5 | 1.8 |
| | Green Marsh | 2008 | 11,970,000 | 864,833 | 205,745 | 23.8 | 4.3 | 7.6 |
| Magothy | Ulmstead Point | 2006 | 1,350,000 | 70,471 | 41,782 | 59.3 | 3.7 | 7.0 |
| Miles | Old Orchard | 2008 | 9,670,000 | 698,658 | 2,451 | 0.4 | 0.1 | 0.1 |
| Severn | Chinks Point | 2008 | 11,500,000 | 830,875 | 107,044 | 12.9 | 3.9 | 4.8 |
| Upper Bay | Six Foot Knoll | 2008 | 13,600,000 | 982,600 | 51,450 | 5.2 | 1.2 | 1.3 |

Long term monitoring (Section VI) of Coppers Hill, Drum Point, Ulmstead Point and Willow Bottom bars revealed that the two bars that showed the highest oyster abundance and biomass in 2010 were harvested. Coppers Hill, was opened for harvest so such a decline was expected (Figure 1). However, Ulmstead Point is in the Magothy River and, as a sanctuary, should have been protected from harvest. The steep reduction in abundance and biomass can only be explained by large-scale removal, burial or other mechanisms that would make them irretrievable to patent tong sampling since the number of boxes found at the site do not account for the missing oysters. Because we have followed these four bars from planting through harvestable age, we will be switching the long term monitoring effort to different bars in 2012.

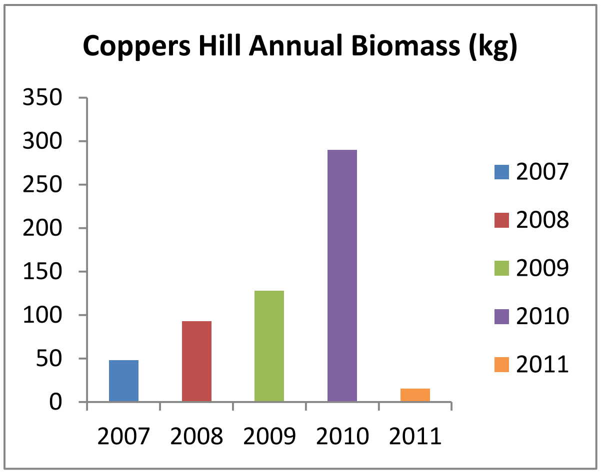



Figure 1. Coppers Hill Annual Biomass. The annual biomass (kg) is shown at Coppers Hill, a bar in the Chester River, calculated based on patent tong survey results from 2007-2011.

The research and analyses of the data from 2011 and years past indicate that although we are making progress in understanding the dynamics of restored oyster populations, there are still many unanswered questions and challenges. Although the survival of spat was drastically higher in 2011 than in previous years, questions remain regarding the primary factors affecting spat survival. In collaboration with researchers at the Horn Point Laboratory oyster hatchery, we are beginning to understand how spat size and bottom type affect the survival of spat four to eight weeks post-planting. The data from our experiment indicate that spat size as well as bottom type will dramatically affect spat survival; the larger the spat and the more shell on the bottom, the higher the survival. Data from a comprehensive patent tong survey of Harris Creek (a full report of this survey will be presented to the ORP in a separate report) show that more oysters are found where more shell exists (see Figure 2), further underscoring the importance of a shell base for oyster survival.

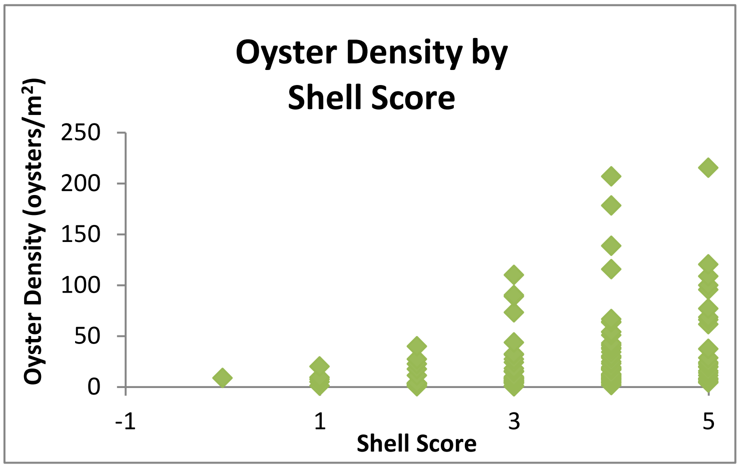
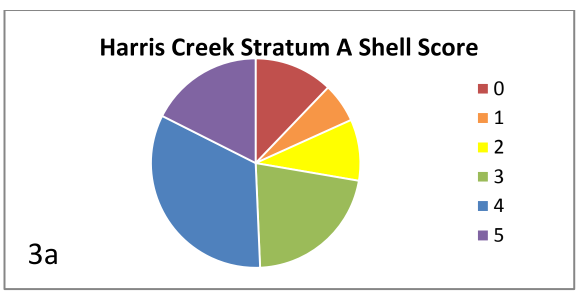



Figure 2. Oyster density by shell score at planted areas in Harris Creek. Data show the density of live oysters surveyed during post-planting surveys relative to the shell score quantified at each site during patent tong surveys.

However, a greater challenge to restoration is the lack of a consistent shell base on which planted spat will best survive. Data from the patent tong survey of Harris Creek indicate that even on bottom that, according to side scan sonar, is supposed to be the best oyster habitat, we find much less shell than expected. In Harris Creek, the small areas considered best and planted in 2011 (Stratum A), were 75% covered with shell scores of 3 to 5 (Figure 3a). Using sidescan sonar and QTL acoustic tools, Maryland Geologic Survey and NOAA's NCBO staff classified the bottom of Harris Creek into three strata of essentially mud, shell mixed with mud or sand, or shell. Unfortunately, when we look at the proportion of shells scores on the "best" stratum as identified by sonar (Stratum B, Figure 3b), the picture gets much more grim. Stratum B shows that the number of 3 to 5 shell score grabs is only about 10%.



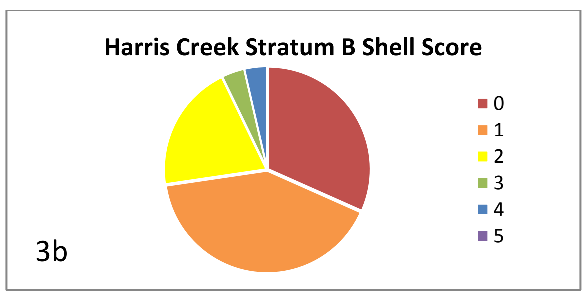




Figure 3. Relative shell score values in Strata A and B at Harris Creek. Data presented show shell score as measured during patent tong surveys in Harris Creek in Stratum A (a), which was the planted stratum, and Stratum B (b), the area identified by side-scan sonar as "best bottom" aside from planted bottom.

Throughout 2011, data from laboratory research and field surveys were presented in fora outside of project reports to the ORP. Some of our work on the predation of mud crabs on spat was published in the Journal of Shellfish Research (Volume 30, Number 2, Pages 1-6). Other work was presented at meetings including six papers at the National Shellfisheries Association meeting in Baltimore, MD and one paper at the International Conference on Shellfish Restoration in Stirling, Scotland.

In summary, this report describes our findings in detail and presents data and analyses that provide a pathway to adaptive management in oyster restoration. Each project is presented below in distinct sections, as well as a summary of our time in the field and laboratory work related to/funded by the ORP.

## Table of Contents

## Section I: Annual Summary

### Field Summary

- Experimental Work:
  - Predator exclusion experiment trial
    - Conducted 6/1/11
    - Purpose: to determine which predators most affect spat survival (and improve upon previous year's methods).
    - Treatments: Open cage, ¼" mesh cage, fine mesh cage.
    - To test effectiveness of new cage design, three cages were deployed for one week at Oak Grove Marina, each containing a known number of store-bought shrimp as bait attached to oyster shells tied to each cage.
    - After one week, all cages remained intact and varying degrees of predation were observed.
    - Additional cages were constructed to be used in future (2012) experiment.
  - Spat size and bottom type study
    - Conducted 7/15, 7/21, 7/22, 8/1, 9/13/11
    - Purpose: To investigate the effect of spat size at time of planting and bottom type on early spat survival.
    - 12 PVC quads were deployed in LaTrappe Creek, each split in half to contain 150 shells with spat in either half (150 with spat over 10 mm, 150 with spat under 10 mm). 4 quads were placed on each substrate type (sand, mud, and shell).
    - Spat-on-shell were sampled on the day of planting, one and five weeks post-planting.
    - Preliminary data shows that spat size had little effect while bottom type significantly influence spat survival.
  - Oyster reproductive senescence experiment
    - See Section VII.
    - Conducted 6/14 and 6/15/11
    - Purpose: to determine the effect of oyster age on relative fecundity and egg quality.
    - 200 oysters were collected from 4 locations: Dobbins (12y), Chest Neck Point (5y), Shoal Creek (10y) and States Bank (4y).
    - Animals were collected during the fall of 2010, and overwintered at the Horn Point Laboratory oyster hatchery to eliminate and site-related effects/

        - About 100 oysters from each site were mass-spawned, with 121 females over the 4 sites successfully spawning.
        - Egg count, shell height (mm), total mass (g), wet tissue mass (g) and dermo prevalence were collected for each individual on spawning day.
        - Eggs from each spawning female were individually collected for lipid analysis.
- Pre-planting ground-truthing survey
    - See Sections II and III.
    - Similar to 2010, 2011 data show that diver surveys of different bottom types confirm bottom typing suggested by the side-scan sonar data.
    - These results again underscore the importance of complete side-scan sonar coverage for all ground-truthing surveys.
- Post-planting monitoring survey
    - See Section IV.
    - Average 2011 spat survival was 27%, which was higher than 2010 survival (12.8%).
    - 2011 data do not suggest a trend with initial number of spat on shell and survival of spat 4-8 weeks post-planting.
    - 2011 data also do not suggest a trend with the density of shells (with spat) and spat survival.
    - These results indicate that other factors are affecting spat survival among sites, and other factors such as predation and bottom type will be tested in 2012 (expanding the predator-exclusion trial and repeating the bottom type study).
- Patent-tong survey of sanctuaries and managed reserves
    - See Sections V and VI.
    - 13 bars were monitored in the regular 2011 patent tong season.
    - Generally, disease prevalence and intensity were low.
    - Population estimates were generated from the patent tong survey data for each bar surveyed, as well as density and shell score plots.
    - Coppers Hill, Drum Point, Ulmstead Point, and Willow Bottom bars have been surveyed since 2007 (see Section IV).
    - The long-term data from those bars indicate that the patent tong survey accurately records post-planting oyster population dynamics on undisturbed bars.
    - Additionally, in November and December 2011, tributary-wide patent-tong surveys of Harris Creek and the Little Choptank Rivers were conducted in collaboration with Mike Wilberg (UM-CBL). The aim of these surveys is to classify bottom-type relative to available side-scan data as well as estimate the oyster population in each tributary.

- *Perkinsus marinus* (Dermo) monitoring
    - Table 1.1 compares dermo prevalence and intensity from 2008-2011.
        - Although sites were not consistent between years, these data show that 2011 had the highest prevalence and intensity of any year surveyed, but all years were relatively low and not different from each other.
        - Despite record low salinities in 2011, dermo prevalence and intensity were not significantly different from the other years.
    - Figure 1.1 shows the sites where dermo was sampled in 2011 by infection prevalence. Larger, darker circles indicate increasing dermo prevalence. More dermo infections were observed in the Little Choptank River than any other tributary, with most other sites at less than 60% infection.
    - Figure 1.2 shows the sites where dermo was sampled in 2011 by weighted intensity (0-5 scale, 0=no infection, 5=very heavy infection). In general, dermo infection intensity increased as sampling sites moved southward, likely following an increase in salinity.
    - See Table 1.2 below for a summary of the 2011 data.
        - Intensity scores highlighted in gray represent values greater than 1. Such values, while low, may indicate sites potentially at risk of greater infection.
    - Mean prevalence was 40.8% and mean intensity was 0.43 out of a possible 5.
    - These data suggest that Dermo was not high in surveyed bars in 2011 and was probably not a large factor in oyster survival.

Table 1.1. Mean *Perkinsus marinus* prevalence and intensity from 2008-2011, with mean salinity per year.

| Year | Mean Prevalence (%) | SEM | Range | Mean Intensity | SEM | Range | Mean Salinity (‰) |
|---|---|---|---|---|---|---|---|
| 2008 | 29.98 | 5.28 | 0 - 93 | 0.28 | 0.09 | 0 - 2.07 | N/A |
| 2009 | 26.07 | 4.23 | 0 - 90 | 0.32 | 0.09 | 0 - 1.77 | 12.3 |
| 2010 | 35.86 | 4.72 | 0 - 100 | 0.41 | 0.09 | 0 - 2.53 | 11.3 |
| 2011 | 40.8 | 6.03 | 0 – 100 | 0.43 | 0.10 | 0 – 1.67 | 6.6 |

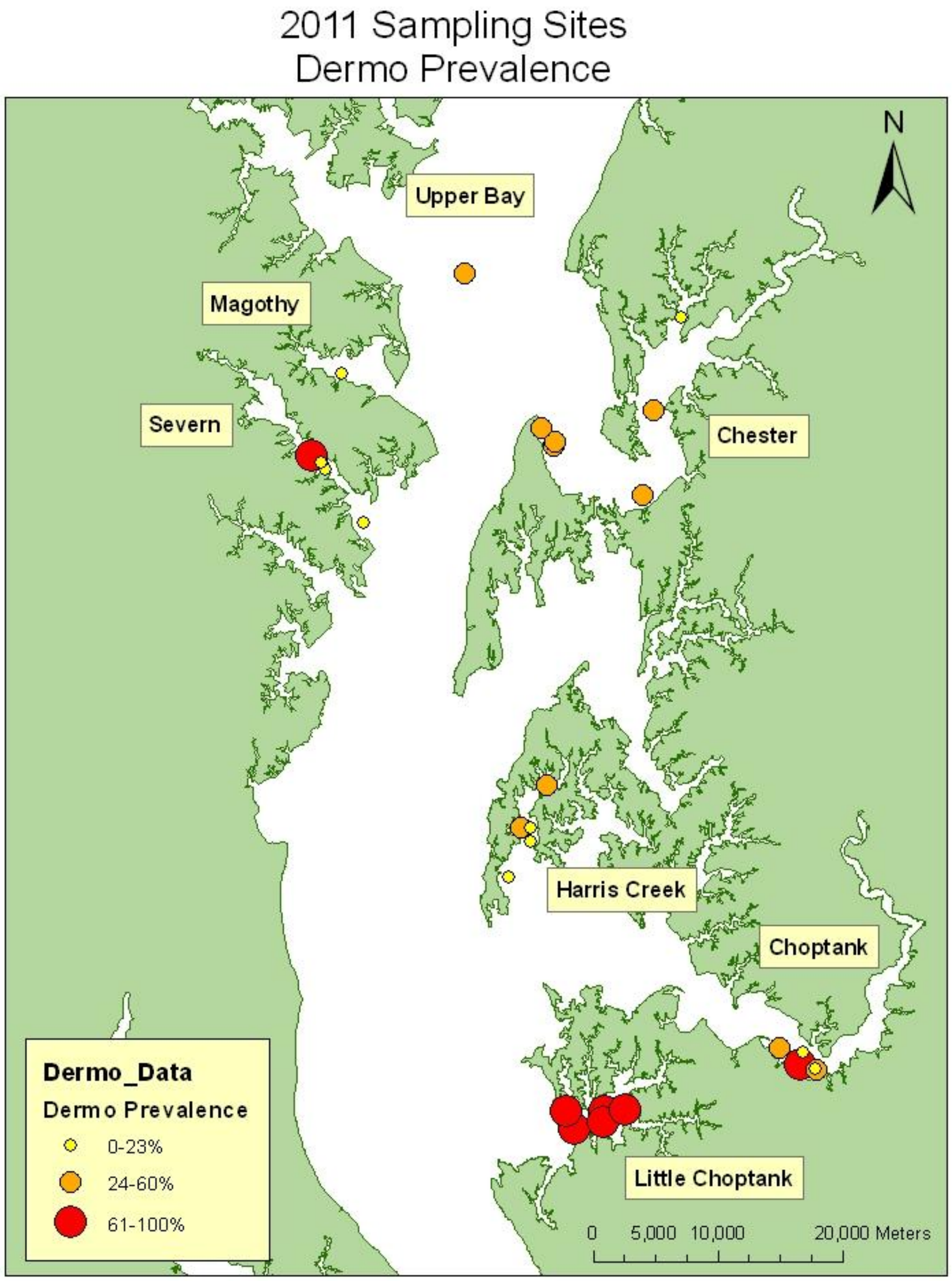



Figure 1.1. *Perkinsus marinus* prevalence by site sampled in 2011. Darker, larger circles indicate increasing dermo prevalence. More animals were infected with dermo in the Little Choptank River than any other tributary.

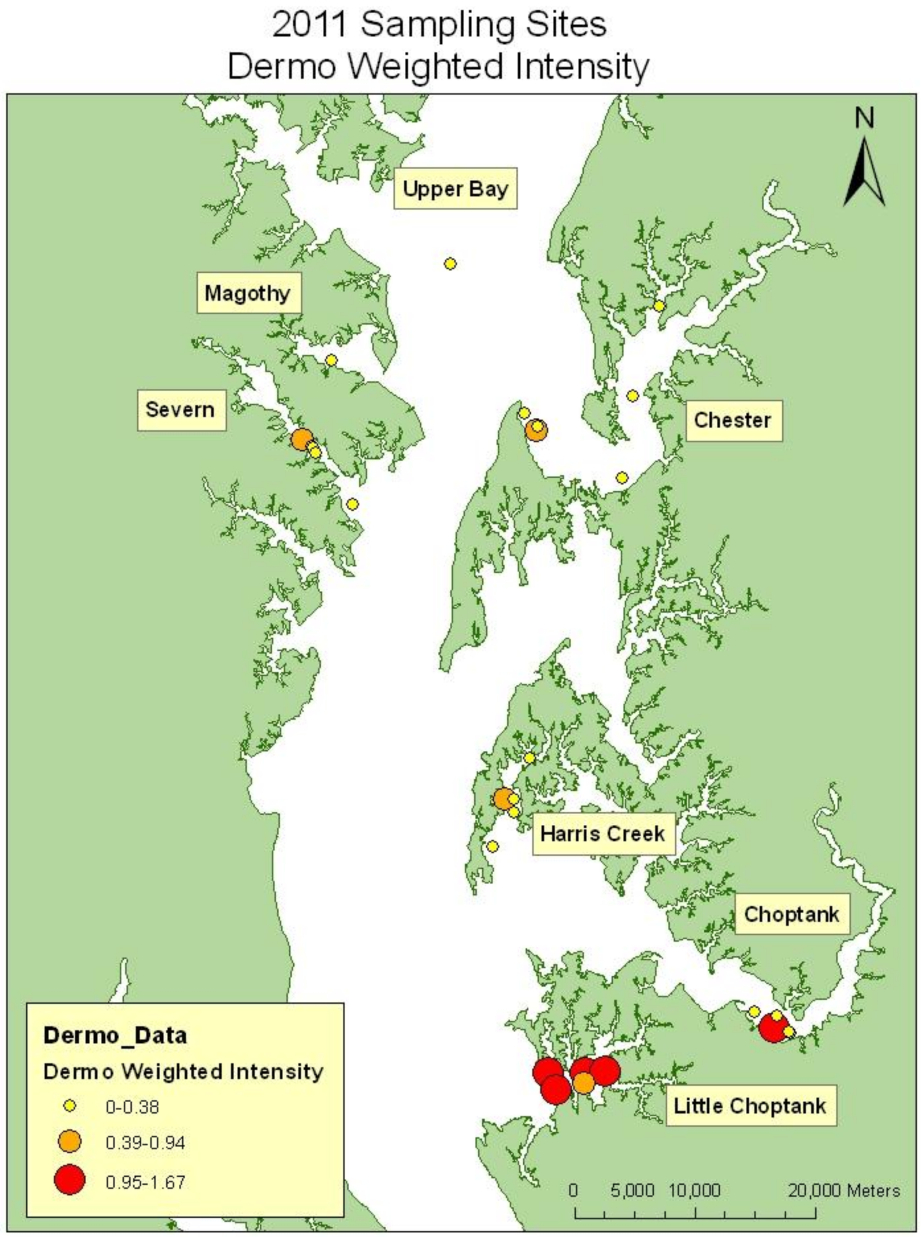



Figure 1.2. *Perkinsus marinus* weighted infection intensity by site sampled in 2011. Darker, larger circles indicate increasing dermo weighted infection intensity. Samples were measured on a 0-5 scale with 0 indicating no dermo infection and 5 indicating very heavy infection. In general, dermo infection intensity increased as sampling sites moved southward, likely following an increase in salinity.

Table 1.2. 2011 *Perkinsus marinus* prevalence and intensity by site within each tributary. Data are further designated by section of river/region, with the following abbreviations: L= lower, M= middle, U= upper.

| River/Region | Section | Bar Name | Plant Year | Date Collected (2011) | How Collected | Average Shell Height (mm) | Average Total Weight (g) | Average Shell Weight (g) | Dermo Prevalence (%) | Dermo Weighted Intensity |
|---|---|---|---|---|---|---|---|---|---|---|
| Chester River | L | Blunt | 2008 | 12-Sep | Dive | 95.3 | 161.5 | 133.7 | 32.26 | 0.05 |
| | L | Strong Bay | 2005a | 20-Sep | Tong | 112.5 | 244.1 | 207.2 | 60 | 0.51 |
| | L | Strong Bay | 2005e | 11-Oct | Tong | 125.0 | 217.9 | 162.3 | 58.62 | 0.29 |
| | L | Strong Bay | 2008 | 17-Oct | Tong | 104.4 | 166.2 | 137.6 | 60 | 0.22 |
| | U | Coppers Hill | 2007/2008 | 9-Sep | Tong | 92.3 | 135.5 | 113.3 | 50 | 0.38 |
| | U | Drum Point | 2007 | 1-Sep | Tong | 99.1 | 185.9 | 154.5 | 23.33 | 0.04 |
| Choptank River | M | Green Marsh | 2008 | 11-Oct | Tong | 105.5 | 131.6 | 103.8 | 56.67 | 0.22 |
| | U | Bolingbroke Sand | 2008 | 13-Oct | Tong | 89.2 | 138.1 | 113.7 | 10 | 0.17 |
| | U | Shoal Creek | 2008 | 14-Oct | Tong | 90.1 | 149.0 | 122.0 | 90 | 1.67 |
| | U | States Bank | 2005 | 2-Nov | Tong | 118.0 | 256.1 | 219.8 | 10 | 0.01 |
| | U | States Bank | 2008 | 3-Nov | Tong | 77.1 | 69.5 | 55.6 | 46.67 | 0.15 |
| Harris Creek | L | Downriver | N/A | 16-Nov | Tong | 68.3 | 87.6 | 66.9 | 3.33 | 0 |
| | L | Turkey Neck | N/A | 15-Nov | Tong | 63.7 | 72.2 | 61.8 | 0 | 0 |
| | M | Midriver | N/A | 15-Nov | Tong | 74.7 | 105.2 | 88.7 | 43.33 | 0.77 |
| | M | Mill Point | N/A | 14-Nov | Tong | 45.6 | 20.8 | 16.2 | 0 | 0 |
| | U | Upriver | N/A | 14-Nov | Tong | 76.9 | 74.3 | 61.9 | 31.03 | 0.18 |
| Little Choptank River | L | Downriver | N/A | 2-Dec | Tong | 82.4 | 119.5 | 99.0 | 90 | 1.3 |
| | L | Susquehanna | N/A | 2-Dec | Tong | 64.9 | 55.7 | 45.4 | 93.33 | 1.28 |
| | M | Midriver | N/A | 30-Nov | Tong | 72.2 | 88.6 | 75.1 | 100 | 1.38 |
| | M | Cason | N/A | 30-Nov | Tong | 75.4 | 94.0 | 78.1 | 80 | 0.88 |
| | U | Upriver | N/A | 30-Nov | Tong | 75.5 | 75.6 | 61.8 | 70 | 1.33 |
| Magothy River | M | Ulmstead Point | 2008 | 2-Nov | Tong | 107.2 | 129.9 | 97.4 | 3.7 | 0.04 |
| Severn River | L | Chinks Point | 2008 | 2-Nov | Tong | 98.3 | 94.7 | 71.8 | 20 | 0.11 |
| | M | Wade (Concrete) | 2010 | 3-Nov | Dive | 38.4 | 6.4 | 4.5 | 3.57 | 0 |
| | M | Wade (Slag) | 2010 | 3-Nov | Dive | 34.9 | 4.0 | NA | 0 | 0 |
| | M | Wade (Stone) | 2010 | 3-Nov | Dive | 35.0 | NA | NA | 3.33 | 0 |
| | M | Weems Upper | 2010 | 3-Nov | Dive | 50.3 | NA | NA | 3.33 | 0 |
| | U | Sharp Point | N/A | 11-Nov | Dive | 15.1 | 178.8 | 143.0 | 68.97 | 0.94 |
| Upper Bay | U | Six Foot Knoll | 2008 | 6-Oct | Tong | 97.3 | 88.3 | 66.7 | 33.33 | 0.1 |

- Water quality was measured at each site using a YSI.
    - Variables collected include surface and bottom temperature, salinity, and dissolved oxygen.
    - Figure 1.3 indicates sites where salinity was measured in 2011.
    - Table 1.3 shows bottom and surface salinity at sites, arranged by river/region and data collected while Table 4 gives the average bottom salinity for each region.
    - With salinity values ranging from 1.91**‰** to 13.5 **‰** and an average bottom salinity of 7.9 **‰** with a standard deviation of 2.7, overall 2011 salinity values were unusually low due to freshwater input from several large storms (including Hurricane Irene that traveled up the Bay in August).
    - Table 1.4 shows salinity values relative to areas sampled for Dermo.

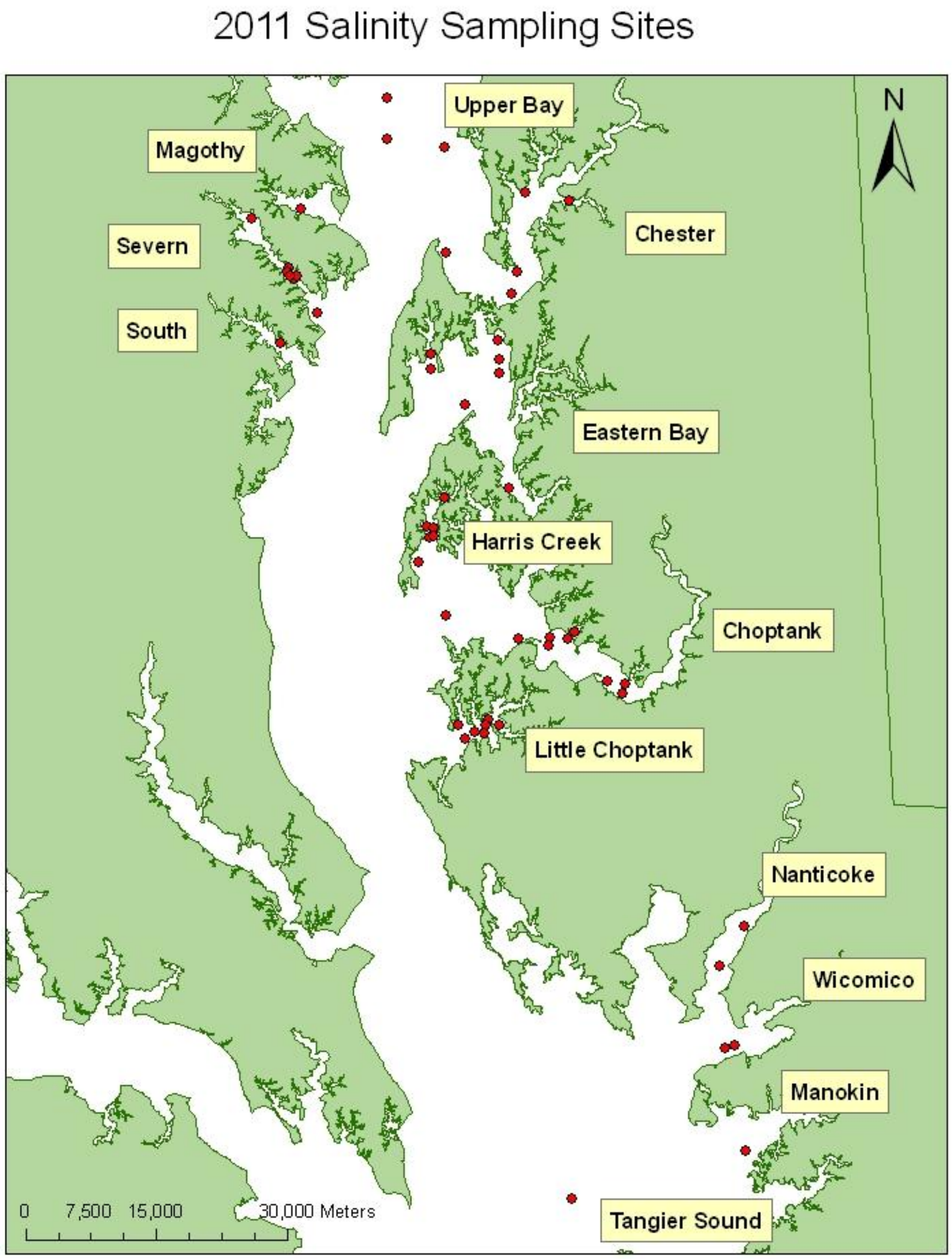



Figure 1.3 Sites sampled for salinity in 2011. Sites are indicated by red dots with rivers labeled in yellow boxes. Individual sites are listed by river in Table 1.3 below.

Table 1.3. Salinity (‰) at each site in 2011. Data are further designated by section of river/region, with the following abbreviations: L= lower, M= middle, U= upper.

| River/Region | Section | Site | Date Sampled (2011) | Surface Salinity (‰) | Bottom Salinity (‰) |
|---|---|---|---|---|---|
| Chester River | L | Blunt | 16-May | 3.43 | 3.84 |
| | L | Blunt | 8-Nov | 5.72 | 5.82 |
| | L | Strong Bay | 16-May | 2 | 2.1 |
| | L | Strong Bay | 4-Aug | 8.62 | 8.62 |
| | L | Strong Bay | 21-Sep | 5.33 | 5.72 |
| | L | Strong Bay | 30-Sep | 5.27 | 5.42 |
| | L | Strong Bay | 17-Oct | 5.79 | 6.7 |
| | M | Devil's Playground | 23-Oct | 5.2 | 5.6 |
| | M | Willow Bottom | 1-Sep | 8.6 | 9 |
| | U | Emory Wharf | 17-Feb | 8.76 | 10.54 |
| Choptank River | M | Beacons | 15-Mar | 12.38 | 12.8 |
| | M | Castle Haven | 26-Apr | 9.1 | 9.3 |
| | M | Castle Haven | 22-Jul | 8.04 | 8.58 |
| | M | Chlora Point | 22-Jul | 7.53 | 8.67 |
| | M | Cook Point | 13-Jul | 8.04 | 9.07 |
| | M | LeCompte | 26-Apr | 9.1 | 9.3 |
| | U | Bolingbroke Sand | 11-May | 7.4 | 7.4 |
| | U | Bolingbroke Sand | 17-Aug | 8.21 | 8.5 |
| | U | Bolingbroke Sand | 13-Oct | 7.17 | 7.17 |
| | U | Green Marsh | 11-Oct | 6.81 | 7.36 |
| | U | LaTrappe Creek | 16-Jun | 6.48 | NA |
| | U | LaTrappe Creek | 22-Jul | 7.13 | 7.06 |
| | U | LaTrappe Creek | 17-Aug | 9.2 | 9.3 |
| | U | Shoal Creek | 14-Oct | 7.31 | 7.38 |
| Eastern Bay | M | Cabin Creek | 8-Mar | 11.8 | 13.02 |
| | M | Cabin Creek | 29-Apr | 6.1 | 6.2 |
| | M | Cabin Creek | 4-Aug | 9.05 | 9.05 |
| | M | Mill Hill: 3"shellonstone | 19-Sep | 9.2 | 9.9 |
| | M | Mill Hill: Concrete | 19-Sep | 9.3 | 10 |
| | M | Mill Hill: Reference | 19-Sep | 9.28 | 10.03 |
| | M | Mill Hill: Shell on concrete | 19-Sep | 9.27 | 9.96 |
| | M | Mill Hill: Slag 6" | 19-Sep | 9.25 | 9.39 |
| | M | Mill Hill: slag w/3" shell | 19-Sep | 9.2 | 9.5 |
| | M | Mill Hill: slag w/6" shell | 19-Sep | 9.24 | 9.75 |
| | M | Mill Hill: Stone | 19-Sep | 9.2 | 9.9 |
| | M | Pea Hill | 13-May | 5.7 | 10.1 |
| | M | Ringold Middleground | 13-May | 5.2 | 5.5 |
| | M | Saw Mill Creek | 8-Mar | 11.8 | 13.02 |
| | M | Tilghmans Point | 13-May | 4.9 | 5.6 |
| Harris Creek | L | Downriver | 16-Nov | 8.33 | 8.66 |
| | L | Downriver | 17-Nov | 8.28 | 7.86 |
| | L | Downriver | 17-Nov | 8.45 | 8.45 |

| River/Region | Section | Site | Date Sampled (2011) | Surface Salinity (‰) | Bottom Salinity (‰) |
|---|---|---|---|---|---|
| Harris Creek (Cont) | L | Eagle Point | 20-Jul | 7.62 | 7.72 |
| | L | Planted | 15-Nov | 8.33 | 8.34 |
| | L | Turkey Neck | 26-Apr | 9.4 | 10 |
| | L | Turkey Neck | 16-Jun | 5.96 | 5.94 |
| | M | Midriver | 15-Nov | 8.31 | 8.34 |
| | M | Midriver | 15-Nov | 8.33 | 8.34 |
| | M | Midriver | 16-Nov | 8.22 | 8.31 |
| | M | Midriver | 16-Nov | 8.34 | 8.43 |
| | M | Midriver | 21-Nov | 8.25 | 8.32 |
| | M | Mill Point | 15-Jul | 7.43 | 7.62 |
| | M | Mill Point | 20-Jul | 7.62 | 7.72 |
| | M | Mill Point | 23-Oct | 8 | 8 |
| | M | Planted | 14-Nov | 8.31 | 8.31 |
| | U | Upriver | 14-Nov | 8.1 | 8.1 |
| | U | Upriver | 14-Nov | 8.16 | 8.16 |
| | U | Upriver | 14-Nov | 8.32 | 8.31 |
| | U | Upriver | 17-Nov | 8.11 | 8.13 |
| | U | Upriver | 21-Nov | 8.02 | 8.07 |
| Little Choptank River | L | Downriver | 2-Dec | 8.92 | 8.92 |
| | L | Downriver | 2-Dec | 9.06 | 9.07 |
| | L | Susquehanna | 13-Jul | 8.12 | 8.54 |
| | L | Susquehanna | 2-Dec | 8.97 | 9.17 |
| | M | Cason | 13-Jul | 8.12 | 8.54 |
| | M | Cason | 10-Oct | 7.9 | 8.24 |
| | M | Cason | 1-Dec | 8.68 | 8.68 |
| | M | McKeils Point | 13-Jul | 7.63 | 7.66 |
| | M | Midriver | 30-Nov | 8.62 | 8.64 |
| | M | Midriver | 30-Nov | 8.75 | 8.75 |
| | M | Midriver | 5-Dec | 9.15 | 9.25 |
| | U | Upriver | 30-Nov | 8.57 | 8.57 |
| | U | Upriver | 30-Nov | 8.61 | 8.58 |
| | U | Upriver | 1-Dec | 8.56 | 8.6 |
| | U | Upriver | 1-Dec | 8.59 | 8.55 |
| | U | Upriver | 5-Dec | 8.4 | 8.41 |
| | U | Upriver | 5-Dec | 8.73 | 8.75 |
| Magothy River | M | Ulmstead Point | 2-Nov | 3.91 | 4.07 |
| Manokin River | L | Drum Point | 26-Jul | 12.16 | 12.19 |
| Miles River | U | Old Orchard | 21-Nov | 8.02 | 8.02 |
| Nanticoke River | M | Wilson Shoals | 27-Jul | 10.19 | 10.39 |
| | U | Wetipquin | 27-Jul | 7.8 | 7.84 |
| Severn River | L | Chinks Point | 10-May | 1.26 | 2.19 |
| | L | Chinks Point | 2-Nov | 4.57 | 4.85 |
| | M | Navy bridge | 3-Nov | 5.07 | 5.13 |
| | M | Peach Orchard | 10-May | 1.87 | 2.41 |
| | M | Traces Hollow | 3-Nov | 4.98 | 4.97 |

| River/Region | Section | Site | Date Sampled (2011) | Surface Salinity (‰) | Bottom Salinity (‰) |
|---|---|---|---|---|---|
| Severn River (Cont) | M | Wade | 3-Nov | 5.05 | 5.12 |
| | M | Wade/Weems Upper | 4-Aug | 7.83 | 7.85 |
| | M | Weems Upper | 3-Nov | 5.121 | 5.17 |
| | U | Rock Point | 3-Nov | 5.13 | 5.17 |
| South River | M | Fox Point | 26-Apr | 4.8 | 5.7 |
| Tangier Sound | NA | Kedges Straits Add 1 | 26-Jul | 12.18 | 12.73 |
| Upper Bay | U | Swan Point | 8-Nov | 4.16 | 5.65 |
| | U | 6' knoll | 7-Oct | 0.68 | 1.91 |
| | U | 6' knoll | 8-Nov | 1.97 | 4 |
| | U | Man o' War Shoals | 4-Aug | 7.21 | 7.23 |
| Wicomico River | L | Evans | 10-Oct | 9.65 | 9.66 |
| | L | White Shoal | 10-Oct | 9.67 | 9.67 |

Table 1.4. Mean bottom salinity and *Perkinsus marinus* prevalence and intensity in each river/region surveyed. Data are further designated by section of river/region, with the following abbreviations: L= lower, M= middle, U= upper.

| River/Region | Section | Mean Prevalence (%) | SEM | Range | Mean Weighted Intensity | SEM | Range | Mean Bottom Salinity (‰) |
|---|---|---|---|---|---|---|---|---|
| Chester River | L | 52.7 | 6.8 | 0-60 | 0.27 | 0.09 | 0-0.51 | 5.2 |
| | M | - | - | - | - | - | - | 6.9 |
| | U | 36.7 | 13.3 | 0-50 | 0.21 | 0.17 | 0-0.38 | 8.8 |
| | **ALL** | **47.4** | **6.5** | **0-50** | **0.25** | **0.08** | **0-0.51** | **5.9** |
| Choptank River | L | - | - | - | - | - | - | - |
| | M | 56.7 | NA | 0-57 | 0.22 | 0.22 | 0-0.22 | 9.0 |
| | U | 39.2 | 19 | 0-90 | 0.5 | 0.25 | 0-1.67 | 7.5 |
| | **ALL** | **42.7** | **15.1** | 0-90 | **0.44** | **0.2** | **0-1.67** | **8.1** |
| Harris Creek | L | 1.7 | 1.7 | 0-3 | 0 | 0 | 0 | 8.1 |
| | M | 21.7 | 21.7 | 0-43 | 0.39 | 0.27 | 0-0.77 | 8.1 |
| | U | 31 | NA | 0-31 | 0.18 | 0.18 | 0-0.18 | 8.1 |
| | **ALL** | **15.5** | **9.1** | 0-43 | **0.19** | **0.08** | **0-0.77** | **8.1** |
| Little Choptank River | L | 91.7 | 1.7 | 0-93 | 1.29 | 0.91 | 0-1.3 | 8.8 |
| | M | 90 | 10 | 0-100 | 1.13 | 0.8 | 0-1.38 | 8.4 |
| | U | 70 | NA | 0-70 | 1.33 | 1.33 | 0-1.33 | 8.6 |
| | **ALL** | **86.7** | **5.3** | 0-100 | **1.23** | **0.55** | **0-1.38** | **8.6** |
| Magothy River | L | - | - | - | - | - | - | - |
| | M | 3.7 | NA | 0-4 | 0.04 | 0.04 | 0-0.04 | 3.9 |
| | U | - | - | - | - | - | - | - |
| | **ALL** | **3.7** | **NA** | 0-4 | **0.04** | **0.04** | **0-0.04** | **3.9** |
| Severn River | L | 20 | NA | 0-20 | 0.11 | 0.11 | 0-0.11 | 2.9 |
| | M | 2.6 | 0.9 | 0-4 | 0 | 0 | 0 | 5.0 |
| | U | 69 | NA | 0-69 | 0.94 | 0.94 | 0-0.94 | 5.1 |
| | **ALL** | **16.5** | **10.9** | 0-69 | **0.18** | **0.07** | **0-0.94** | **4.5** |
| Upper Bay | L | - | - | - | - | - | - | - |
| | M | - | - | - | - | - | - | - |
| | U | 33.3 | NA | 0-33 | 0.1 | 0.1 | 0-0.1 | 2.3 |
| | **ALL** | **33.3** | **NA** | 0-33 | **0.1** | **0.1** | **0-0.1** | **2.3** |

## Publications and Presentations

- Kulp, R.E., V. Politano, H.A. Lane, S.A. Lombardi, and K.T. Paynter. 2011. Predation of juvenile *Crassostrea virginica* by two species of mud crabs found in the Chesapeake Bay. J. Shellfish Res. 30(2): 1-6.
- National Shellfisheries Association 2011

    - Kennedy Paynter, Steve Allen, Hillary Lane, and Donald Meritt. Oyster Restoration Success and Failure in the Maryland portion of the Chesapeake Bay. (Talk)
    - Hillary Lane, Adriane Michaelis, Vince Politano, Stephanie T. Alexander, Emily Vlahovich, Heather Koopman, Don Meritt, Thomas Miller, and Kennedy Paynter. Having an egg-ceptional time: modeling overall fecundity in *Crassostrea virginica* females from the Chesapeake Bay using egg quantity, lipid content, and fatty acid composition. (Talk)
    - Adriane Michaelis, Hillary Lane, Vince Politano, Steve Allen, Don Meritt, and Kennedy Paynter. *Crassostrea virginica* spat survival in the northern Chesapeake Bay. (Talk)
    - Sara Lombardi and Kennedy Paynter. Effect of hypoxia and acidosis on adductor muscle function in the Eastern oyster, *Crassostrea virginica* and the Asian oyster, *Crassostrea ariakensis*. (Talk)
    - Karen Kesler, Vincent Politano, Kennedy Paynter. Assessing the impact of the physical and biotic components of the eastern oyster, *Crassostrea virginica*, on the benthic reef community. (Talk)
    - Grace Chon, Sara Lombardi, James Lee, Hillary Lane, Brian Lawn, and Kennedy Paynter. Cracking under pressure: Comparing shell strength of Eastern oysters (*Crassostrea virginica*) and Asian oysters (*Crassostrea ariakensis*). (Talk)
- International Conference on Shellfish Restoration 2011
    - Kennedy Paynter, Adriane Michaelis, Hillary Lane, Steven Allen, Stephan Abel, and Don Meritt. Large Scale Hatchery-based Oyster Restoration in the Maryland portion of the Chesapeake II: Results and Progress. (Talk)

**<u>Conclusions/Lessons Learned</u>**

- Final conclusions regarding each activity (ground-truthing, post-planting monitoring, and patent tong surveys) can be found in Section VIII.
- Also included are recommendations for future work/experiments.
    - Predator exclusion will be conducted.
    - Bottom type patent tong survey will be revised based on 2011 survey data and then repeated.
    - Lab experiment on density dependent predation on spat by mud crabs will be conducted.

## Section II: Bar Rehabilitation Ground Truthing 2011

In the Spring of 2011, 31 individual oyster bars were selected by the Oyster Recovery Partnership (ORP) for bar rehabilitation ground-truthing (GT) surveys by the Paynter Lab. Figure 2.1 shows the sites sampled in the 2011 season. Sites are indicated by red dots and rivers are labeled in yellow squares. Bar rehab involved the transfer of dredged shell to provide suitable oyster habitat on bars intended for planting. GT surveys were conducted on these bars pre- and post-rehabilitation.

GT transect paths within a bar were chosen based on side-scan data from The Maryland Geological Survey (MGS) and NOAA Chesapeake Bay Office (NCBO) when available. In general, darker return on a side-scan image means harder bottom. Given the goal of each new planting and the available side scan data, the Paynter Lab determined an area of approximately 10 acres to GT at each site. Transect lines of 100 or 200 m were deployed through the target area and the amount of exposed shell, substrate type, penetration and oyster density were recorded by divers every 2 meters along the transect lines. The table below outlines the score for each category, with increasing metric values indicating bottom type improvement.

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

* Increasing metric values show bottom type improvement

The mode value of each category was used to determine if the transect line was over good, OK or bad bottom. The bottom type category was determined as the category within which two of the three data types (exposed shell, substrate type and penetration) fell. The table below outlines the requirements for each bottom type categorization. The acceptable penetration range for each bottom type were made more restrictive in 2011 as compared to 2010. This was due to an increasing awarness that very hard bottom is essential for the success of oyster spat.

| Category | Exposed Shell Range | Substrate Type Range | Penetration Range |
|---|---|---|---|
| Good Bottom | 3-4 | 4-7 | 5 |
| OK Bottom | 2 | 3-4 | 3-4 |
| Bad Bottom | 1-0 | 0-2 | 0-2 |

This report contains a detailed map of each site that was surveyed, the associated mode data as well as a summary of the conclusions gleaned from the collected data.

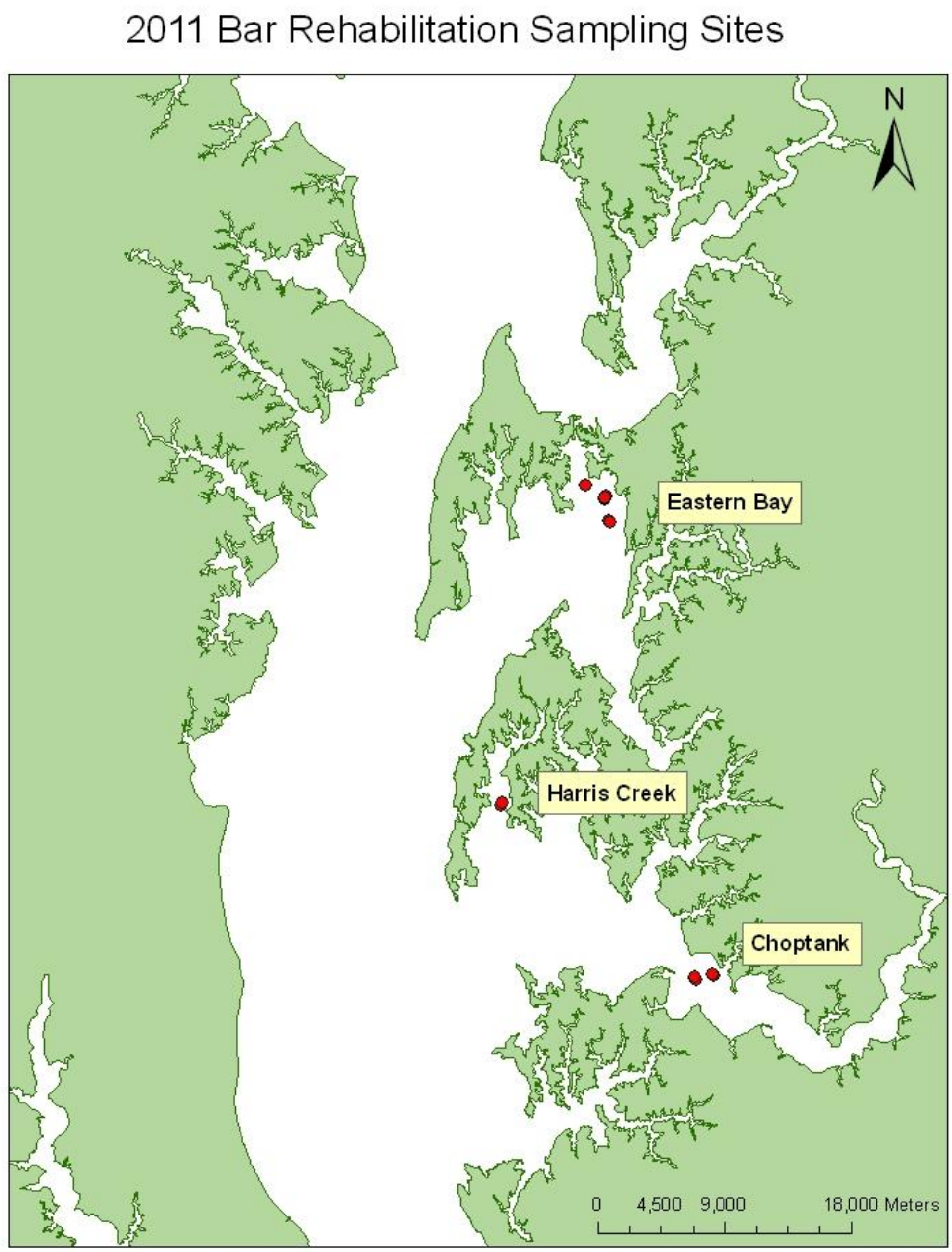
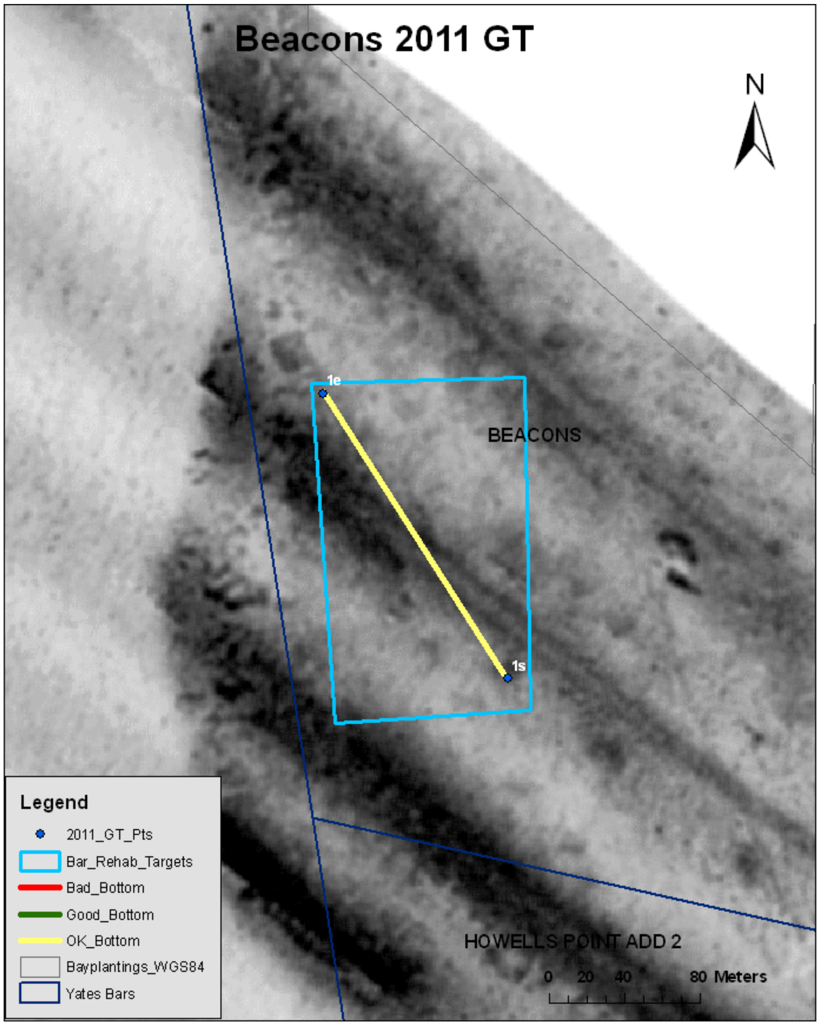
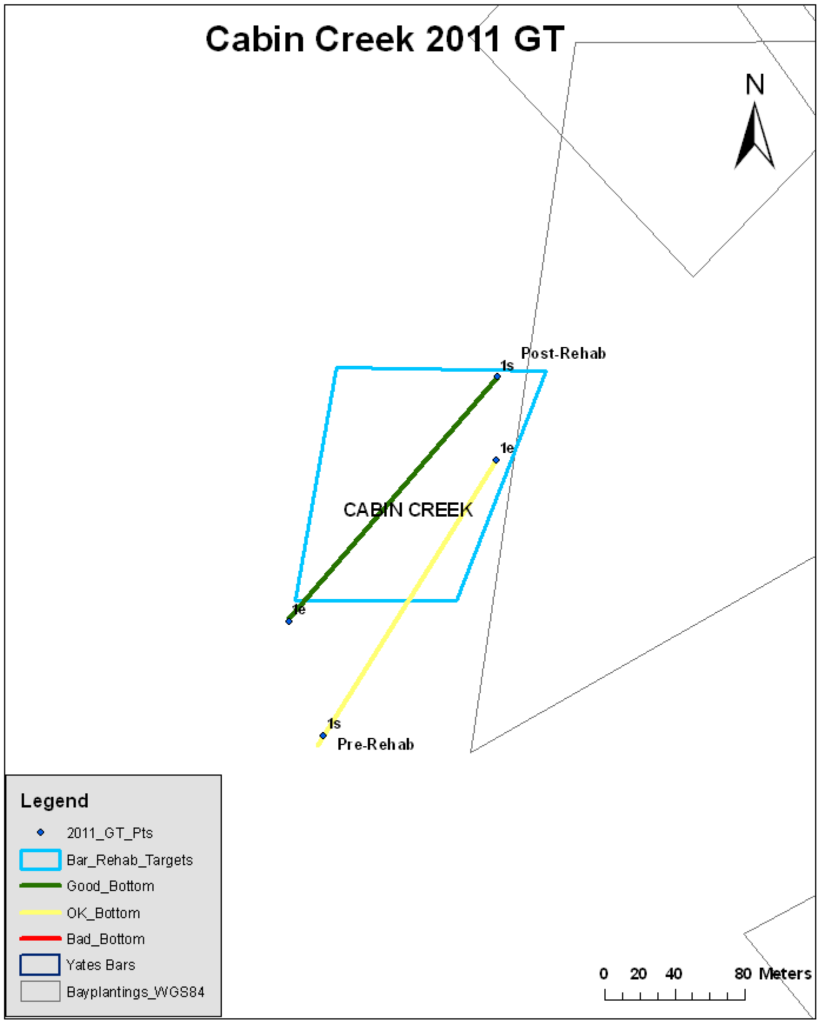



Figure 2.1. Bar rehabilitation monitoring sites in 2011. Sites are indicated with a red dot and rivers are labeled in yellow squares.



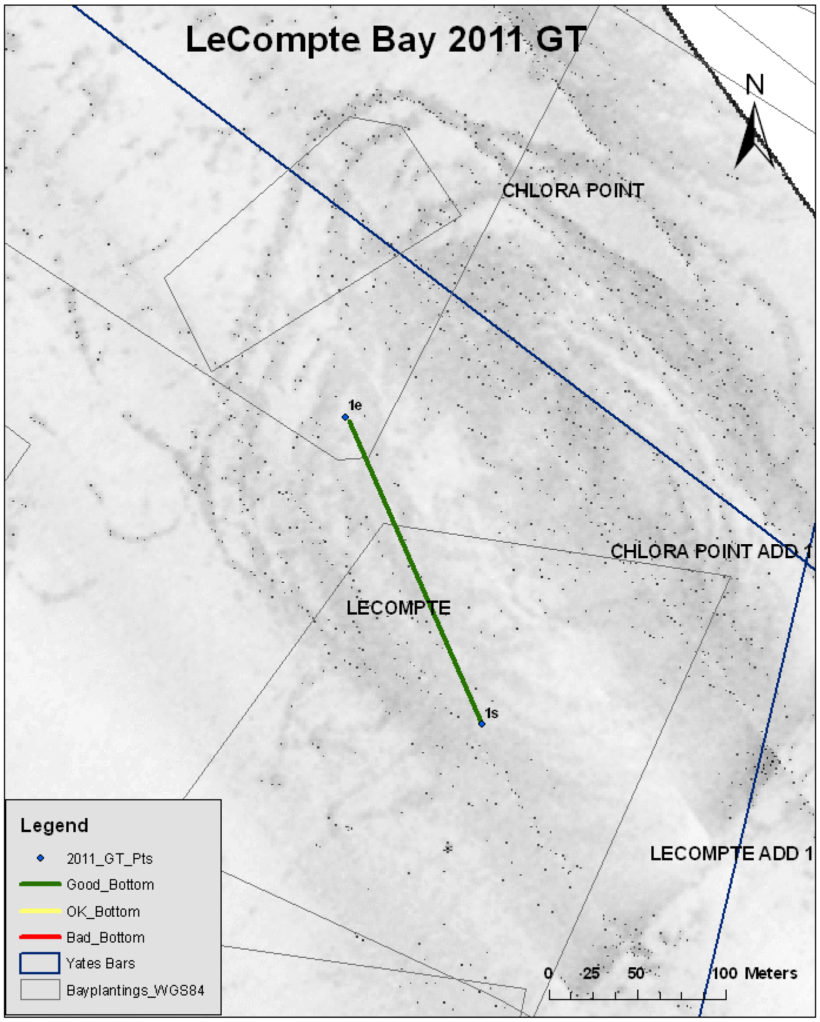

Beacons, a managed reserve bar in the Choptank River, was a planned bar rehab site. The target was selected over what appeared to be fairly consistent hard bottom, based on side-scan data and was not near any previous ORP plantings. The pre-rehab transect shown on the above map revealed hard sandy bottom, which corresponded to the dark, hard return from the side scan. This bottom was classified as "ok" based on the metric values outlined above. Because the area of the target was less than 5 acres, only a single 200-m transect was surveyed. This site was not rehabbed, and thus no post-rehab survey was performed.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Managed Reserve | Rehab | 15-Mar-11 | 1 | 100 | Zero | 0cm | Sand |




Cabin Creek, a sanctuary bar in Eastern Bay, was selected as a 2011 bar rehab site. No side-scan was available, so a target was selected based on, and adjacent to, an historic bay planting. The pre-rehab transect across the 3.5 acre site, showed ok bottom, typified by hard sandy bottom, with no shell. After rehab, the transect survey revealed good bottom of exposed loose shell and hard bottom.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | Rehab | 08-Mar-11 | 1 | 100 | Zero | 0cm | Sand |
| Sanctuary | Rehab | 29-Apr-11 | 1 | 100 | Exposed | 0cm | Loose Shell |

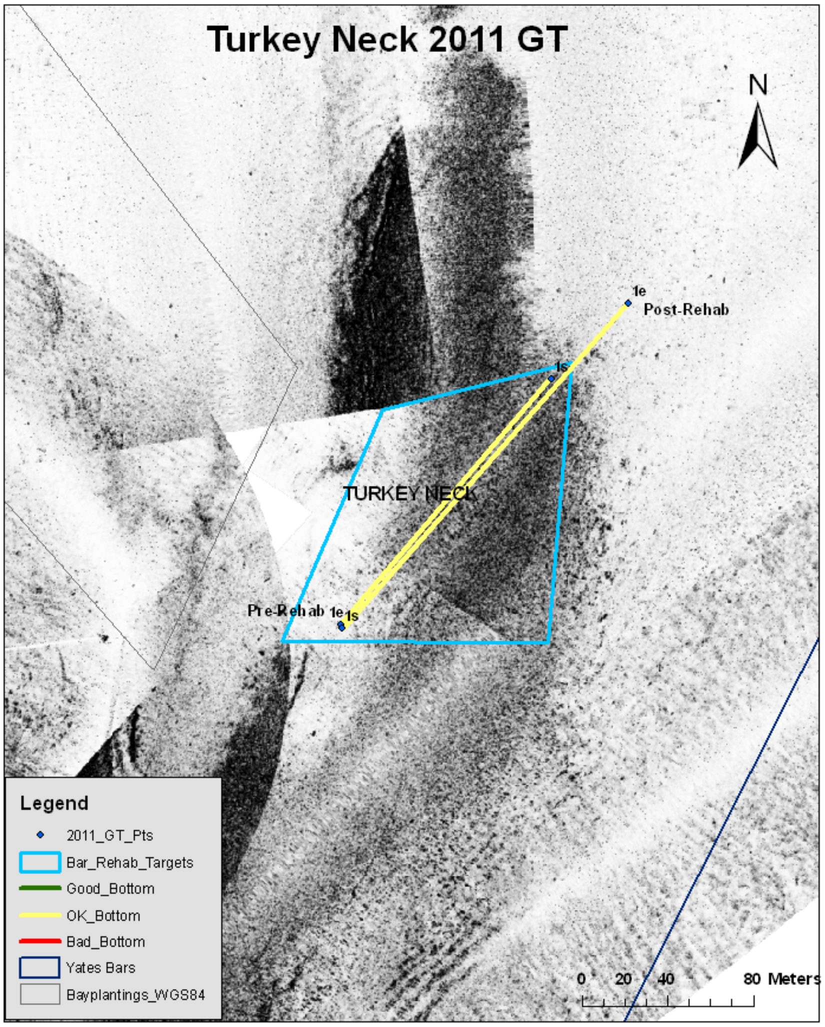



While LeCompte, a sanctuary bar in the Choptank River, was not a planned bar rehab site and was not surveyed pre-rehab, dredged shell was transferred to LeCompte. A 200-m transect was surveyed across the rehab area, based on coordinates provided from bar rehab activity, and side-scan data. The post-rehab surveyed revealed good bottom at LeCompte, with exposed shell on hard bottom.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | Rehab | 26-Apr-11 | 1 | 100 | Exposed | 0cm | Loose Shell |


Saw Mill Creek, a sanctuary bar in Eastern Bay, was a planned bar rehab site. No side-scan data was available and the target was placed over historic bay plantings. The pre-rehab 200-m transect shown on the above map revealed knuckle-deep sand with no shell, and was classfied as “ok”. This site was not rehabbed, and thus no post-rehab survey was performed.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | Rehab | 08-Mar-11 | 1 | 100 | Zero | 5cm | Sand |




Turkey Neck, a sanctuary bar in Harris Creek, was selected as a bar rehab site. The target site was placed over an area of hard-return in side-scan imagery, and a 200-m pre-rehab transect was survyed across the target, covering both dark and light areas. The pre-rehab surveyed showed ok bottom, with knuckle-deep sand and exposed shell. The 200-m post-rehab transect, which ran alongside the pre-rehab line, also showed ok bottom, with knuckle-deep sand.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | Rehab | 04-Mar-11 | 1 | 100 | Exposed | 5cm | Sand |
| Sanctuary | Rehab | 26-Apr-11 | 1 | 100 | Some | 5cm | Sand |

## Section III: Ground Truthing 2011

In the Spring of 2011, 25 individual oyster bars were selected by the Oyster Recovery Partnership (ORP) for ground-truthing (GT) surveys by the Paynter Lab. These bars were located in the Chester, Choptank, Little Choptank, Manokin, Severn, South, and Nanticoke Rivers, Cox and Harris Creeks as well as in Eastern Bay and Tangier Sound. Figure 3.1 shows the sites sampled in the 2011 season. Sites are indicated by red dots and rivers are labeled in yellow squares. Pre-planting GT surveys were performed to determine the suitability of the bottom on a target area to receive a spat-on-shell planting. The goal of these plantings are either over-plantings of hatchery plantings from previous years or new year-class plantings, as determined by the ORP.

GT transect paths within a bar were chosen based on side-scan data from The Maryland Geological Survey (MGS) and NOAA Chesapeake Bay Office (NCBO) when available. In general, darker return on a side-scan image means harder bottom. Given the goal of each new planting and the available side scan data, the Paynter Lab determined an area of approximately 10 acres to GT at each site. Transect lines of 100 or 200 m were deployed through the target area and the amount of exposed shell, substrate type, penetration and oyster density were recorded by divers every 2 meters along the transect lines. The table below outlines the score for each category, with increasing metric values indicating bottom type improvement.

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

* Increasing metric values show bottom type improvement

The mode value of each category was used to determine if the transect line was over good, OK or bad bottom. The bottom type category was determined as the category within which two of the three data types (exposed shell, substrate type and penetration) fell. The table below outlines the requirements for each bottom type categorization. The acceptable penetration range for each bottom type were made more restrictive in 2011 as compared to 2010. This was due to an increasing awareness that very hard bottom is essential for the success of oyster spat.

| Category | Exposed Shell Range | Substrate Type Range | Penetration Range |
|---|---|---|---|
| Good Bottom | 3-4 | 4-7 | 5 |
| OK Bottom | 2 | 3-4 | 3-4 |
| Bad Bottom | 1-0 | 0-2 | 0-2 |

This report contains a detailed map of each site that was surveyed, the associated mode data as well as a summary of the conclusions gleaned from the collected data.

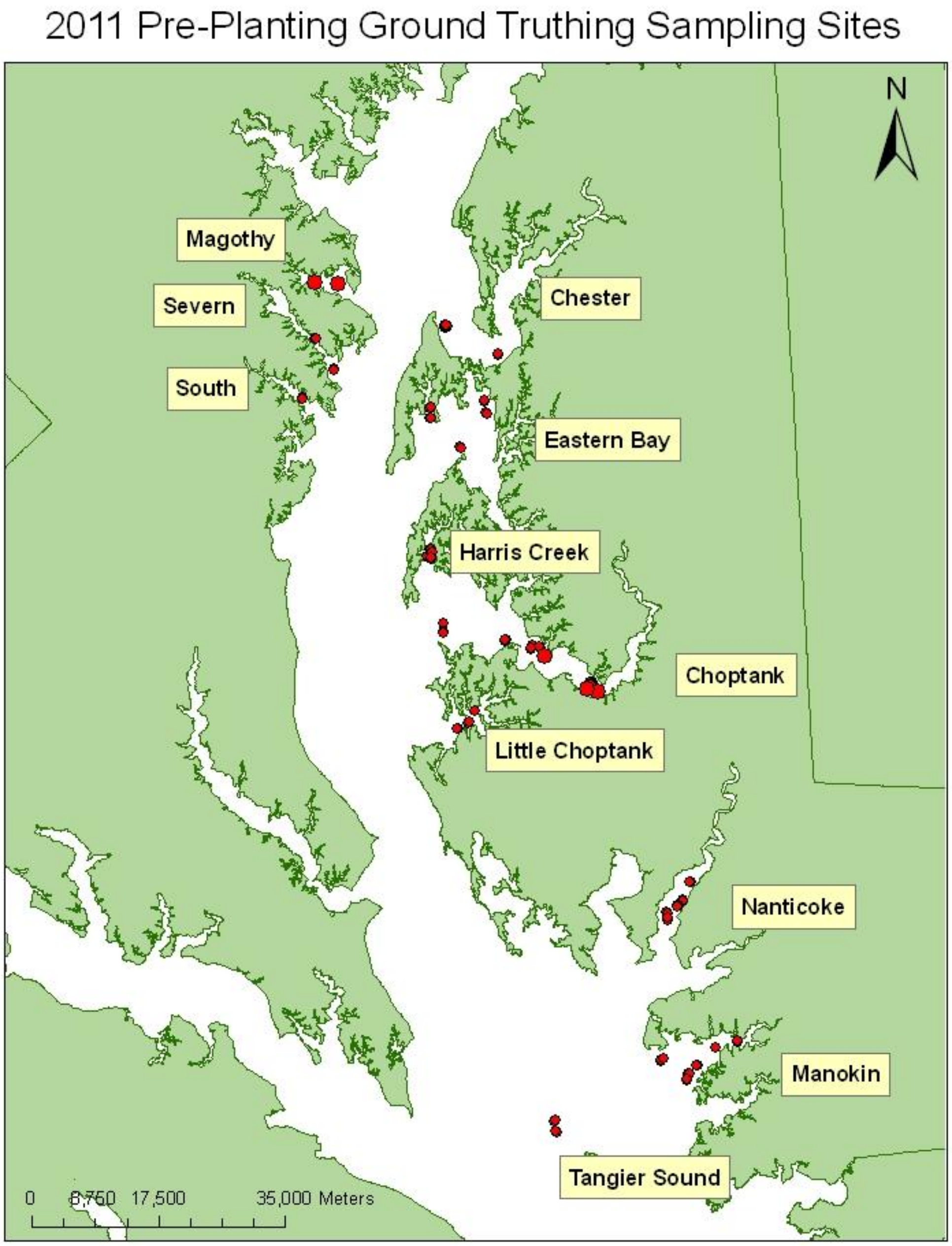
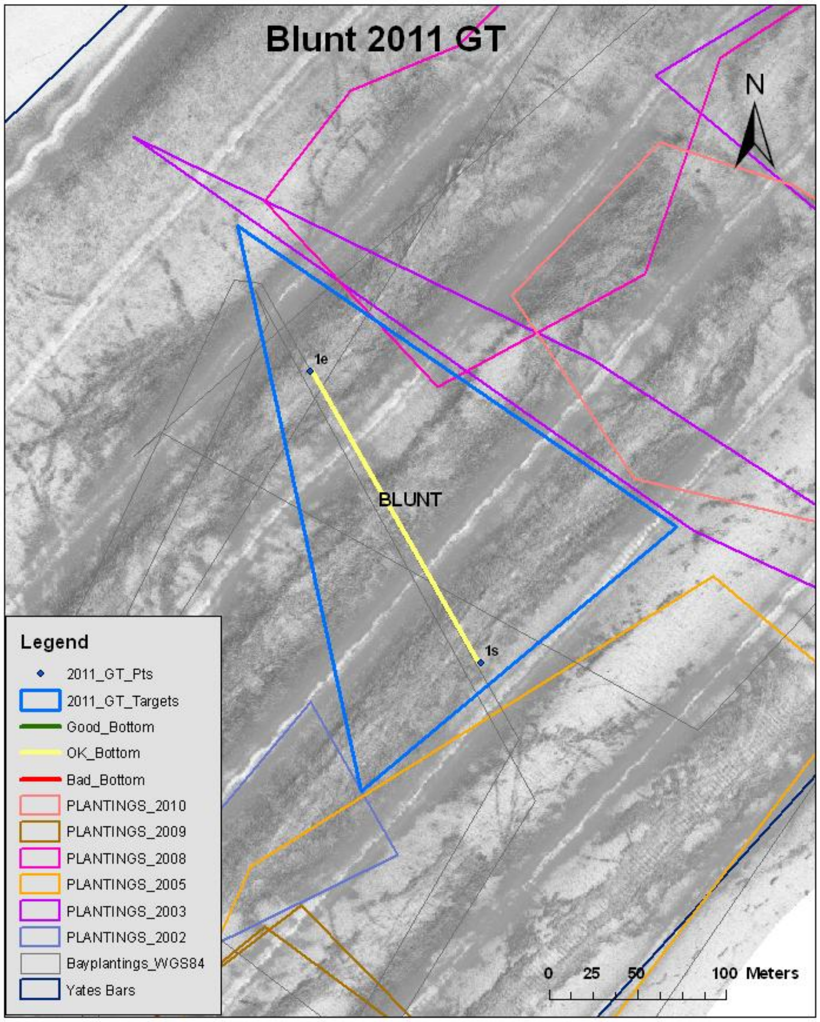
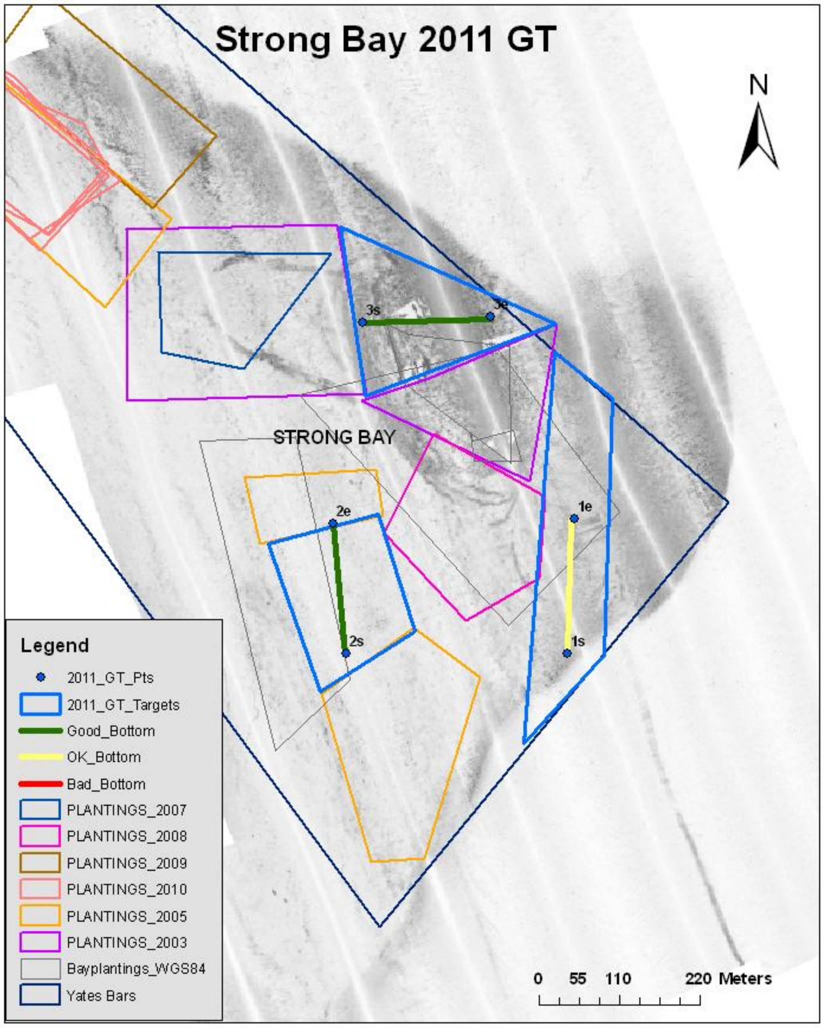



Figure 3.1. 2011 pre-planting ground-truthing sites. Sites are indicated in red and river names are in yellow boxes. Site summaries are presented below, with specfic maps of each site along with the survey data summary.



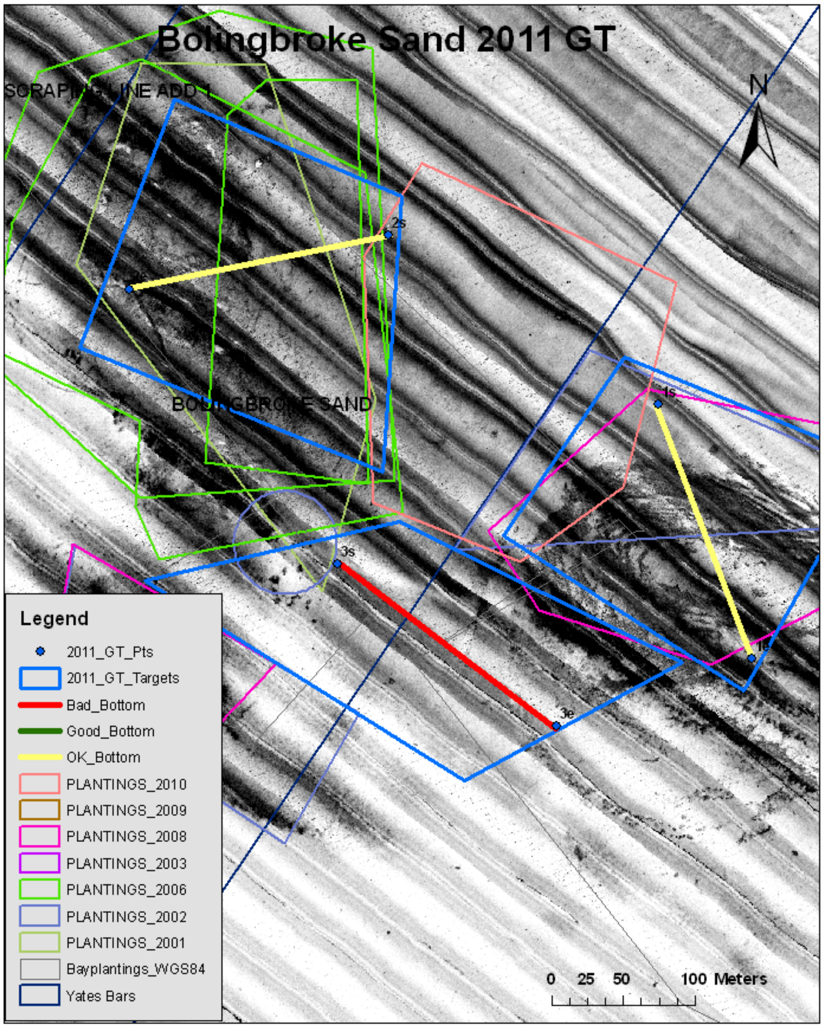

Blunt, a managed reserve bar in the Chester River, was the site of a planned new year class planting. The target was selected to expand upon previous plantings, and was adjacent to plantings from six separate years. In addition, side-scan data show what appear to be older tracklines from a previous planting outside of the marked plantings and under the target site. Because of the shape of this 8-acre target, and the side-scan image, a single 200-m transect was surveyed through the center of the plot. The survey revealed ok bottom across the target area, along the intermediate color of side-scan return.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Managed Reserve | New YC | 16-May-11 | 1 | 100 | Some | 5 cm | Sand |



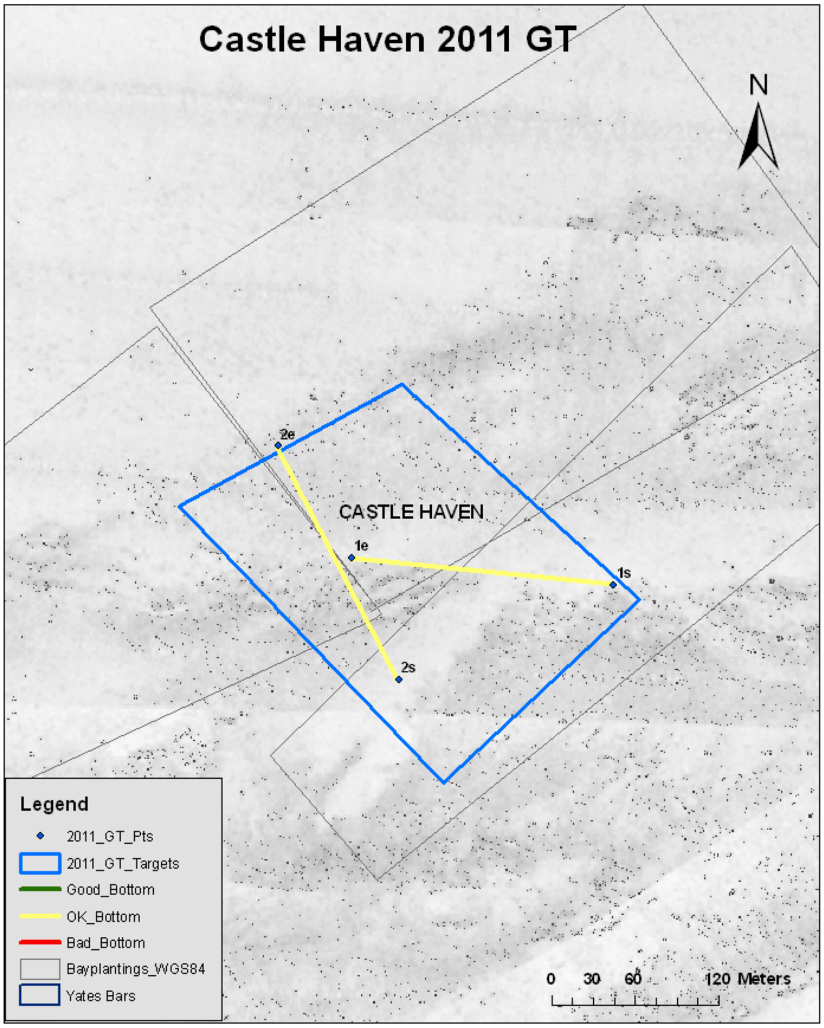

Strong Bay, a sanctuary bar in the Chester River, was a site intended for a new year class planting. As seen on the map above, Strong Bay was also the site of multiple plantings from 2003 through 2010. Side-scan sonar showed particularly hard return between the 2003 plantings at the northern end of the Yates Bar, and moderately hard return at the southern end. Three targets were created, one at the eastern corner of the Yates Bar, adjacent to 2003 and 2008 plantings, one further south between 2005 plantings, and a third between the 2003 plantings. A single 200-m transect at the first target showed ok bottom of hard sand and patchy exposed shell. Transects surveyed in the second and third targets (each a single 200-m transect) revealed hard bottom with exposed shell, and were classified as good for planting.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | Add year class | 16-May-11 | 1 | 100 | Very Little/Patchy | 0cm | Sand |
| Sanctuary | Add year class | 16-May-11 | 1 | 100 | Exposed | 0cm | Loose Shell |
| Sanctuary | Add year class | 16-May-11 | 1 | 100 | Exposed | 0cm | Loose Shell |



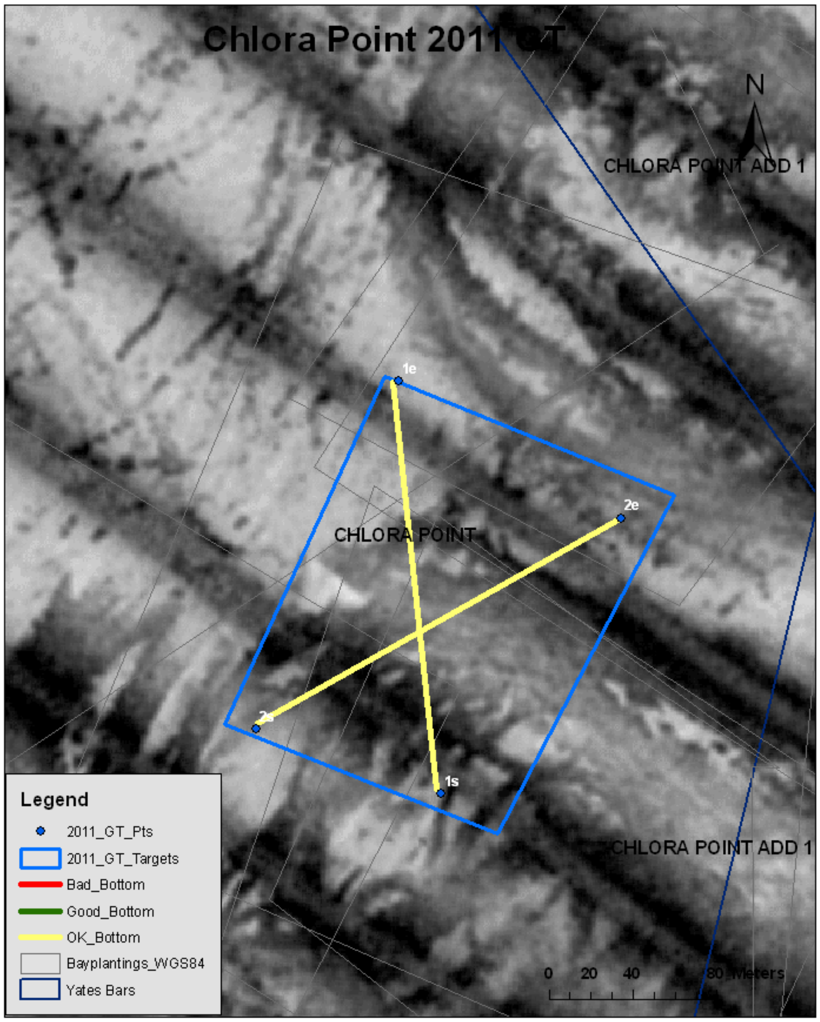

Bolingbroke Sand, a sanctuary bar in the Choptank River, was a site of planned repopulation through spat-on-shell planting. Three targets were selected, each between 8 and 10 acres. Side scan data showed fairly dark or hard return at two of the three targets, as well as evidence of a prior planting (2008) at one target. A single transect was surveyed in each target. Both targets showing harder return possessed transects over mainly sandy bottom, and were classified as ok bottom. The third target was across elbow-deep mud, and was graded as bad bottom.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | Repopulate | 11-May-11 | 1 | 100 | Zero | 5-10cm | Sand |
| Sanctuary | Repopulate | 11-May-11 | 2 | 100 | Exposed | 10cm | Sand |
| Sanctuary | Repopulate | 11-May-11 | 3 | 100 | Zero | 40cm | Mud |



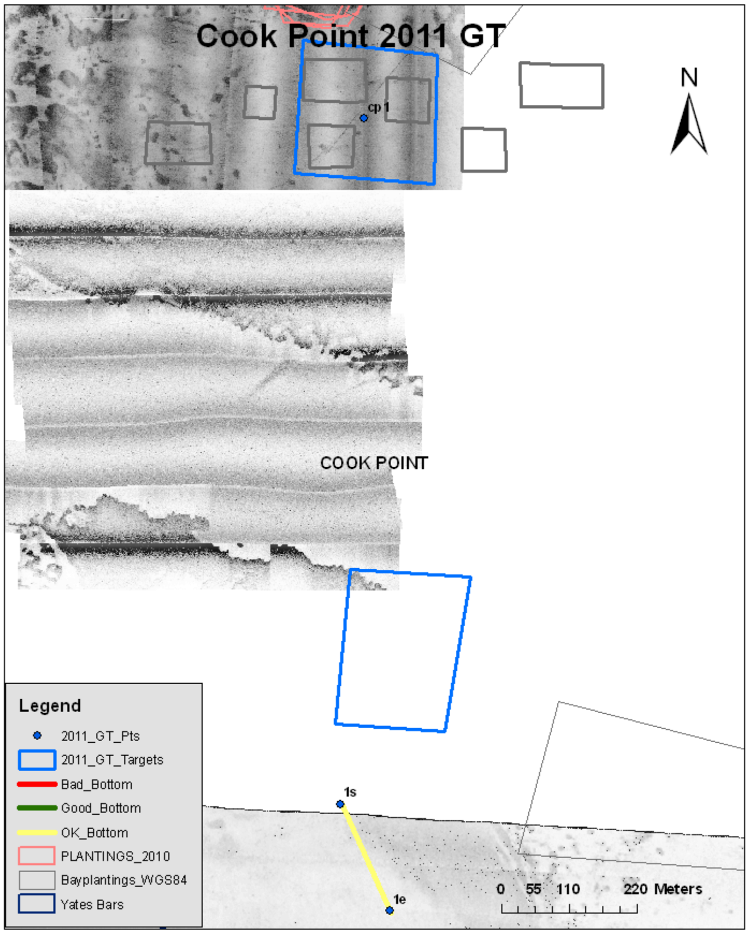

Castle Haven, a sanctuary bar in the Choptank River, was a planting target intended to establish a new sanctuary reef. Side-scan data showed light to moderate return, and a target was selected atop of historic bay plantings and across the areas of hardest return. Two transect lines were surveyed, each 200-m long, and each yielding ok bottom. The light to moderate side-scan data corresponded with the actual knuckle-deep sandy bottom.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 22-Jul-11 | 1 | 100 | Very Little/Patchy | 5cm | Sand |
| Sanctuary | New reef | 22-Jul-11 | 2 | 100 | Very Little/Patchy | 5cm | Sand |



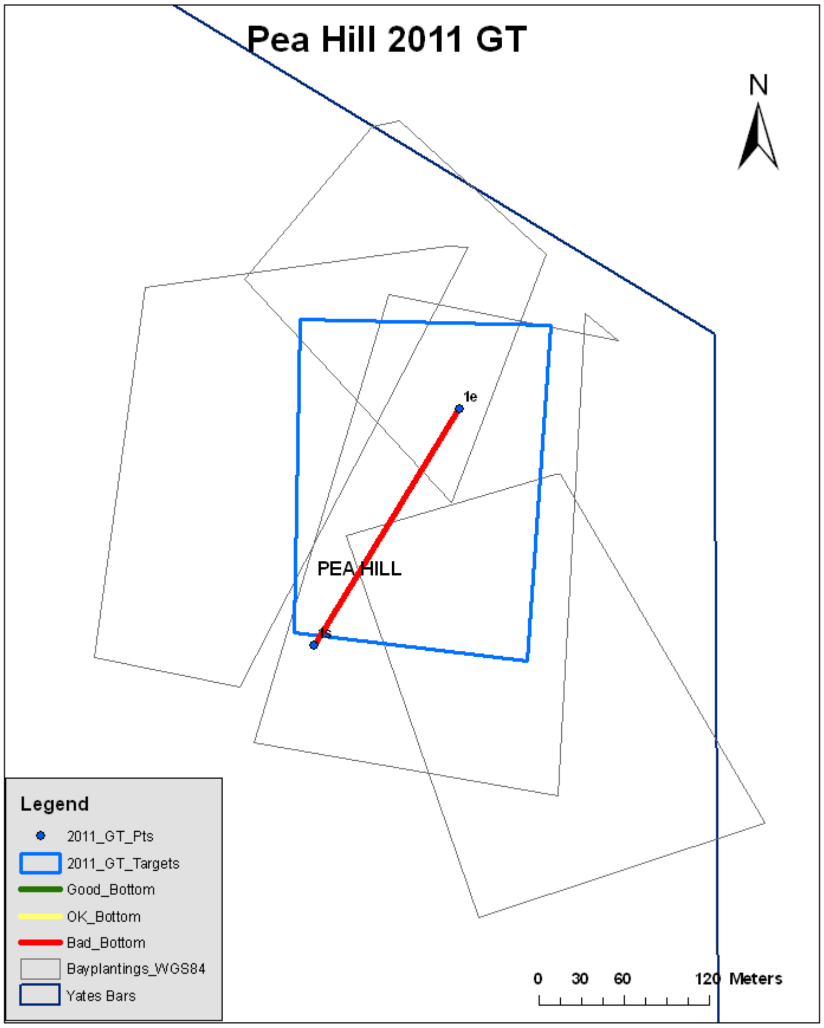

Chlora Point, a sanctuary bar in the Choptank River, was a planting target selected to create a new reef. Side-scan data showed areas of hard return within the Yates Bar and atop historic bay plantings, but not over any recent plantings. The target was placed over such an area and the GT survey revealed ok bottom. Mode data from the two transects (each 200-m) surveyed showed knuckle-deep sand with some exposed shell.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 22-Jul-11 | 1 | 100 | Some | 5cm | Sand |
| Sanctuary | New reef | 22-Jul-11 | 2 | 100 | Some | 5cm | Sand |



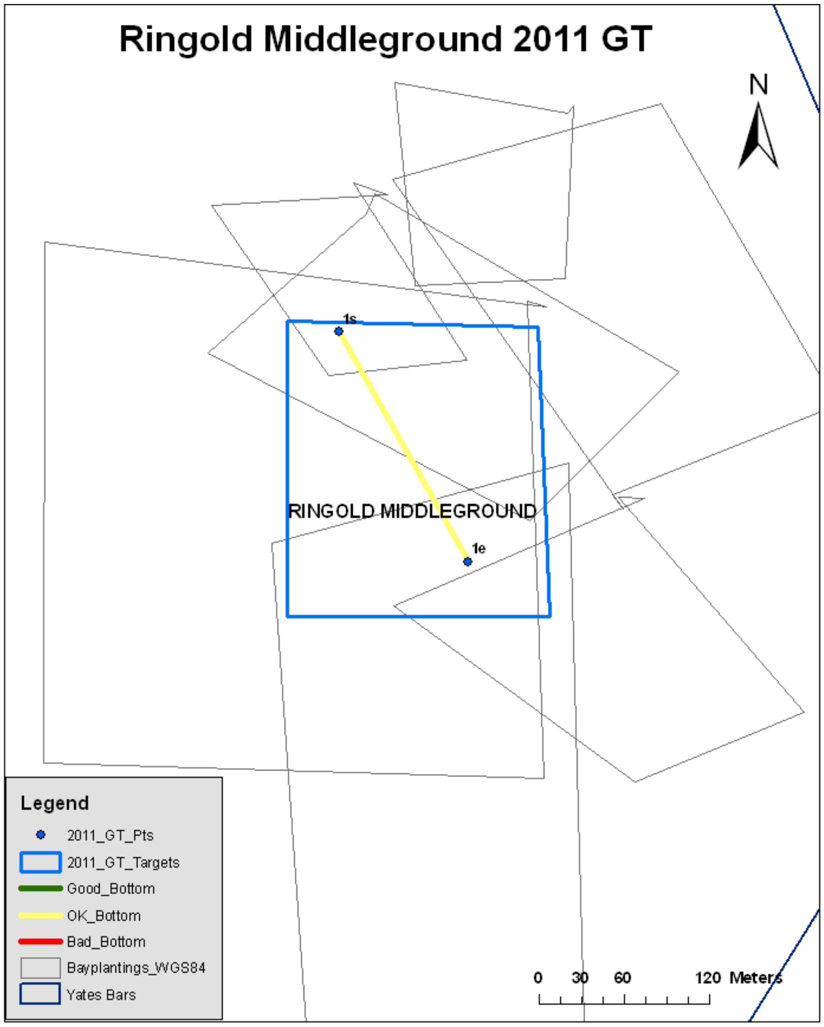

Cook Point, a sanctuary bar in the Choptank River, was the intended site for a new reef. Two targets were planned: the first, located at the northern portion of the above map was adjacent to a 2010 planting, and overtop of alternate substrate. Side-scan data precedes the deployment of alternate substrate at Cook Point, but coordinates were provided and substrate mounds are shown as gray polygons above. Because of the nature of the alternate substrate, a transect was not placed through this target. Instead, a diver dropped in the center of the mounds and swam, noting much relief and hard bottom suitable for planting. The second target was placed south of the mounds, over an area where side-scan data were not available. Upon arriving to the site, the fish-finder was used to evaluate the bottom. The location of the original target appeared soft and muddy, as inferred by the return on the fish-finder. Instead, a transect was surveyed south of the target, on what appeared to be harder bottom based on the return of the fish-finder and available side-scan data. This 200-m transect showed hard, sandy bottom with some shell and the planting target was shifted south to include this transect.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 13-Jul-11 | 1 | 100 | Some | 0cm | Sand |



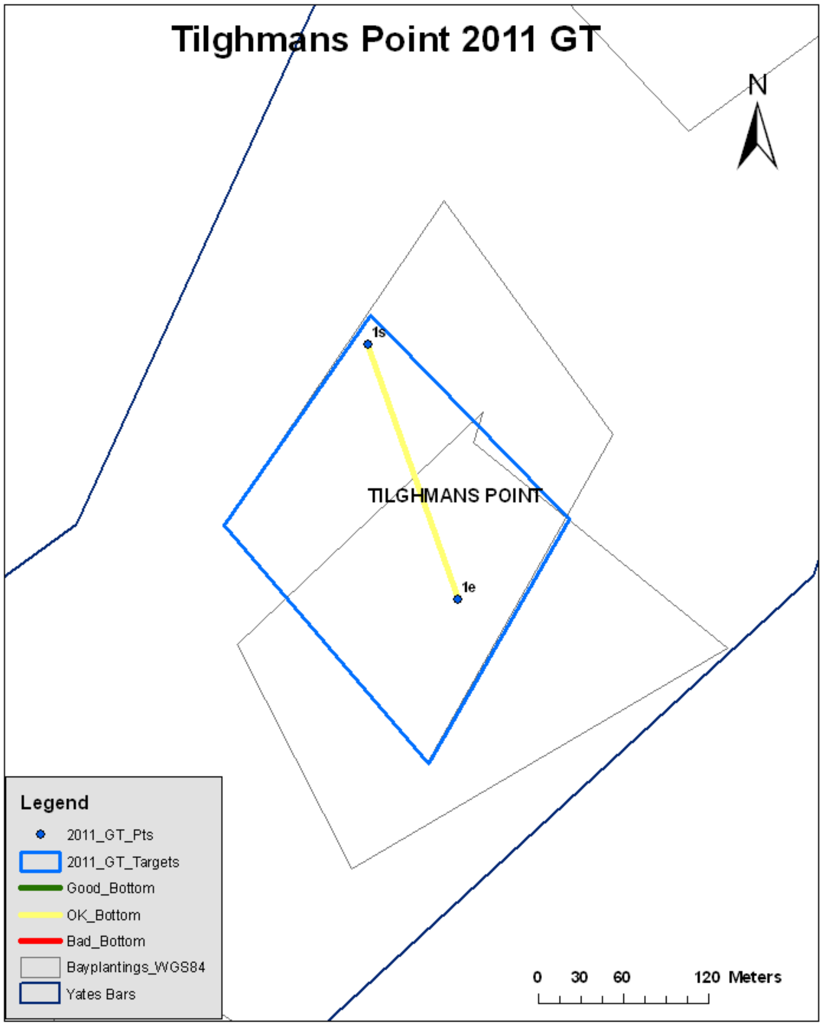

Pea Hill, a sanctuary bar in Eastern Bay was the potential site of a new reef planting. Side-scan data were not available for this site, and the target was placed over historic bay plantings within the Yates Bar. A single 200-m transect through the target showed finger-deep mud with no exposed shell. This was classified as bad bottom, not suitable for planting.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 13-May-11 | 1 | 100 | Zero | 10cm | Mud |



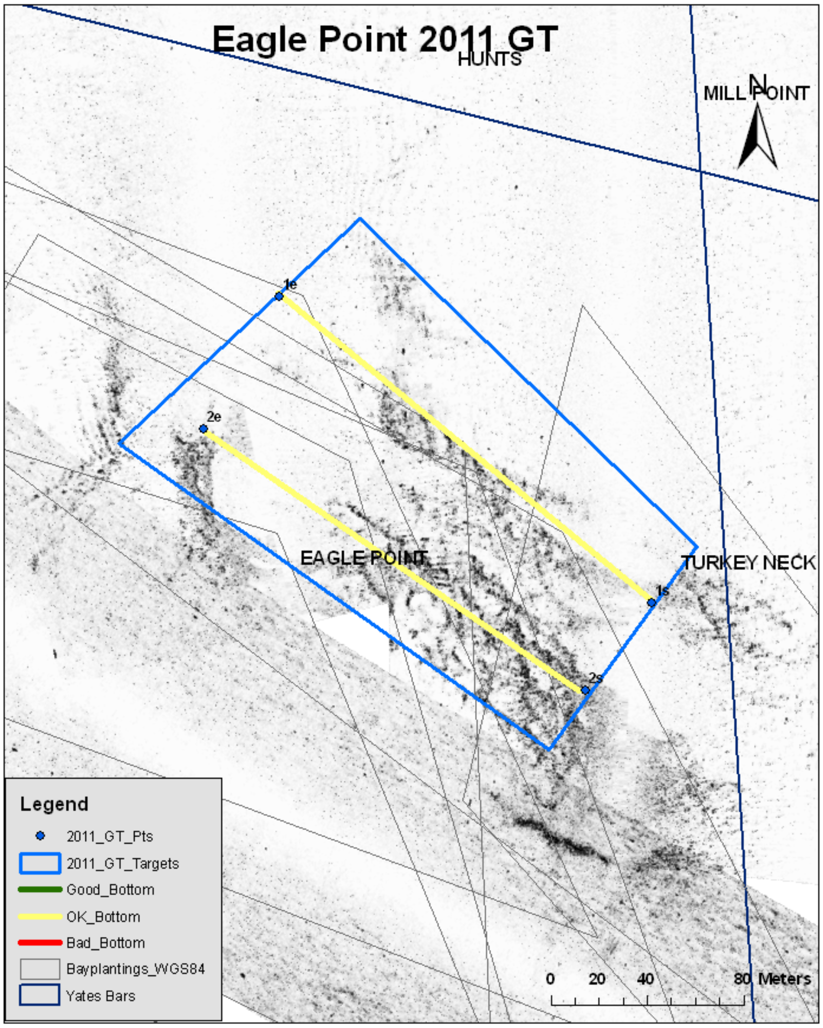

Ringold Middleground, a sanctuary bar in Eastern Bay, was the potential site of a new reef planting in 2011. Side-scan data were not available for this bar, and the target polygon was placed over historic bay plantings. A single 200-m transect survey showed mode data of knuckle-deep sand with some exposed shell. This was classified as ok bottom for planting.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 13-May-11 | 1 | 100 | Some | 5cm | Sand |



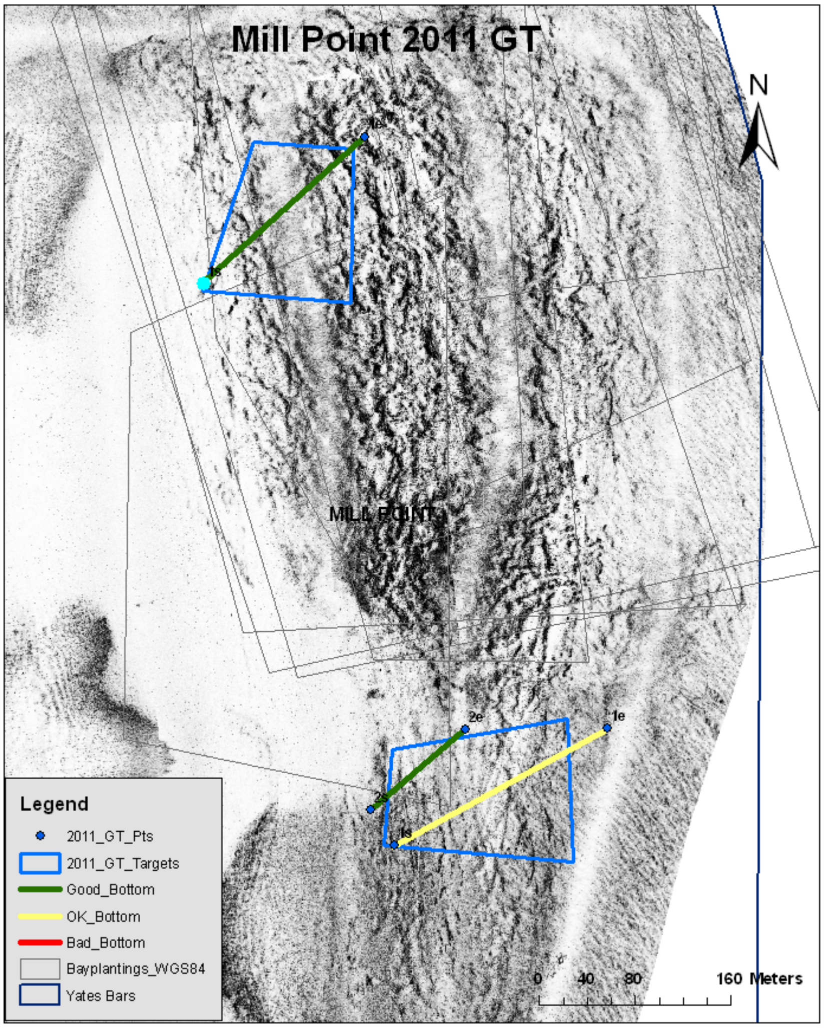

Tilghmans Point, a sanctuary bar in Eastern Bay, was an intended planting site for a new reef in 2011. No side-scan data were available for this location, and the target was placed within the Yates Bar over historic plantings. A single 200-m transect surveyed across the center of the target revealed bottom classified as ok for planting, with knuckle-deep sand and some exposed shell.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 13-May-11 | 1 | 100 | Some | 5cm | Sand |



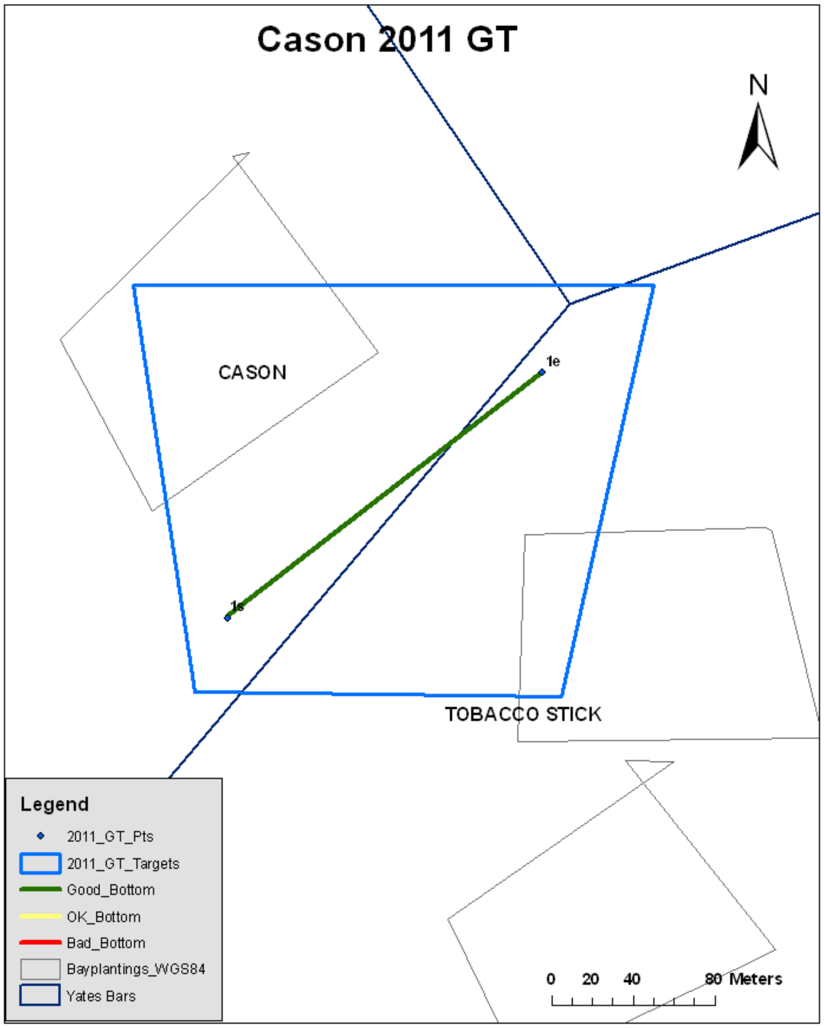

Eagle Point, a sanctuary bar in Harris Creek, was an intended new reef planting. Available side-scan data revealed some areas of dark or hard return, among lighter patches. A target was placed over two areas of darkest return and two 200-m transects were surveyed across the plot. Both transects showed finger-deep mud with exposed shell, and the area was classified as ok bottom.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 20-Jul-11 | 1 | 100 | Exposed | 10cm | Mud |
| Sanctuary | New reef | 20-Jul-11 | 2 | 100 | Exposed | 10cm | Mud |




Mill Point, a sanctuary bar in Harris Creek, was the intended site of a new reef planting. Side-scan data showed several areas of dark or hard return, as seen on the center and east side of the above map. Two targets were created, at the north and south ends of this area of hard return. A single 200-m transect survey of the north target showed good bottom with knuckle-deep loose shell. Two transects were completed in the south target. The first 200-m transect showed ok bottom with knuckle-deep mud and some exposed shell. The second 100-m transect was classified as good, based on mode data of hard bottom with loose shell.

| Bar Name | Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|---|
| Mill Point North | Sanctuary | New reef | 15-Jul-11 | 1 | 100 | Exposed | 5cm | Loose Shell |
| Mill Point South | Sanctuary | New reef | 20-Jul-11 | 1 | 100 | Some | 5cm | Mud |
| Mill Point South | Sanctuary | New reef | 20-Jul-11 | 2 | 50 | Exposed | 0cm | Loose Shell |

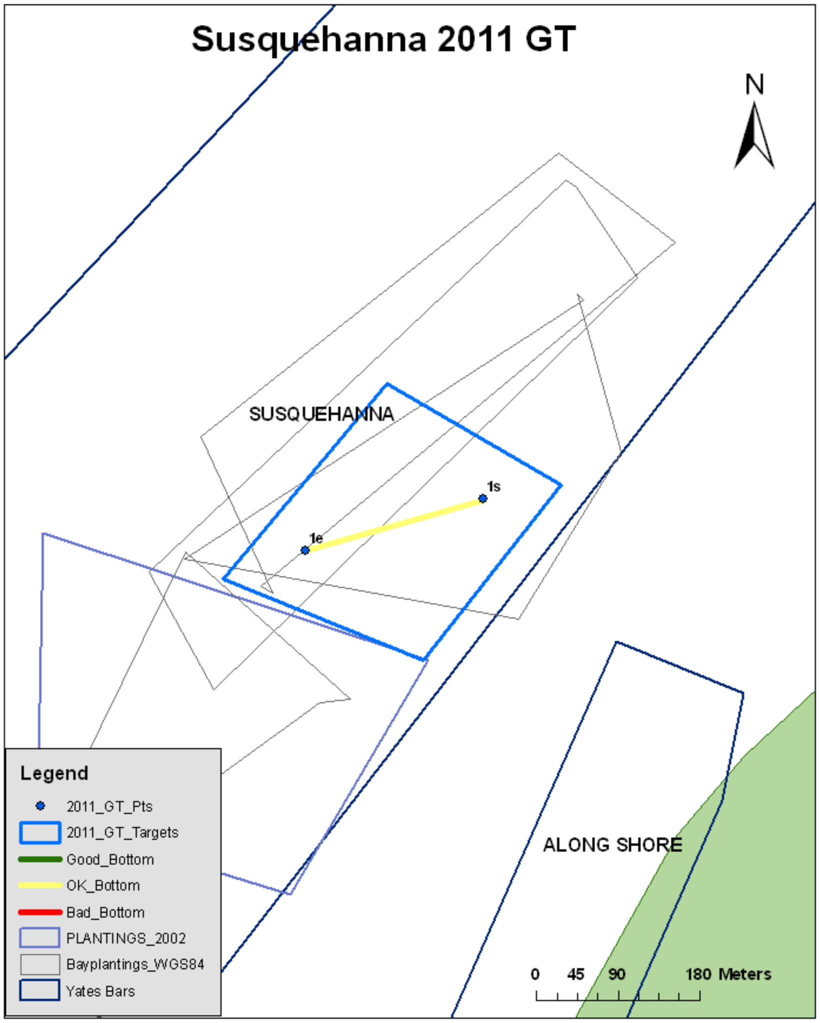



Cason, a sanctuary bar in the Little Choptank River, was a planting target intended to establish a new reef. Since no side-scan data were available, the target was selected based on depth and historic bay plantings. One transect was completed across the target, and the bottom was classifed as good based on mode data of hard bottom with loose shell.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 13-Jul-11 | 1 | 100 | Some | 0cm | Loose Shell |

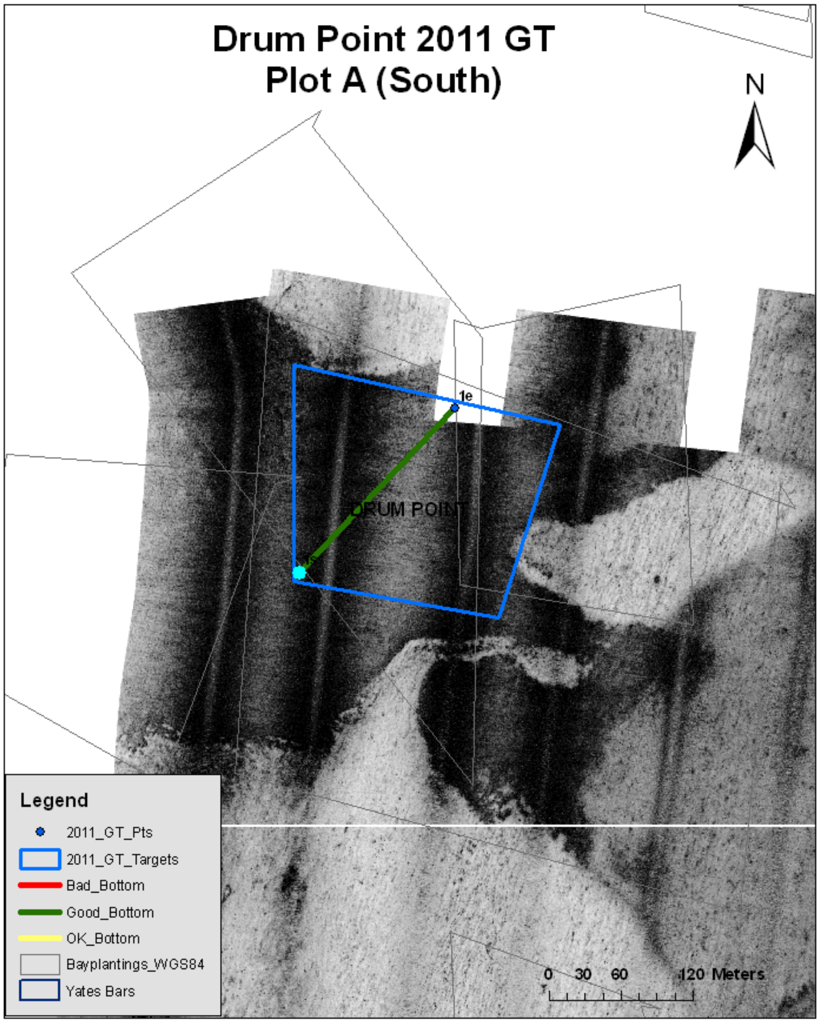

McKeils Point, a sanctuary bar in the Little Choptank, was the site of a potential new reef planting. Side-scan data were not available, and the target was placed over multiple historic bay plantings. A transect line was not deployed at McKeils Point because of several trot lines running across the bar. Instead, a diver dropped at a single point and did a survey of the bottom surrounding that point. The diver found finger-deep loose shell. Using the fish-finder, bottom appeared fairly consistent across the bar. Based on diver observation and fish-finder imaging, this bottom was classified as good for planting.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 13-Jul-11 | 1 | 1 | Exposed | 10cm | Loose Shell |



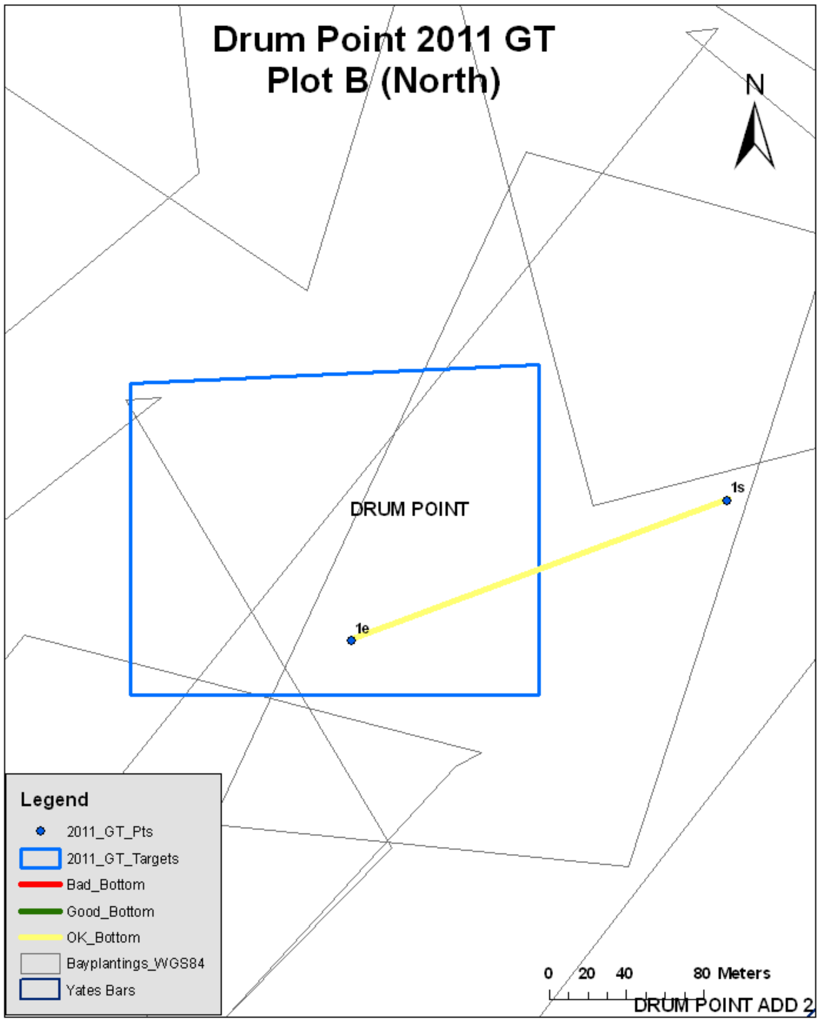

Susquehanna, a sanctuary bar in the Little Choptank River, was the intended site of a new reef planting. No side-scan data were available, and a single target was placed over historic bay plantings, and adjacent to a 2002 planting. A single 200-m transect was surveyed over the area, revealing knuckle-deep shell hash, with some exposed shell. This was classified as ok bottom for planting.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 13-Jul-11 | 1 | 100 | Some | 5cm | Shell Hash |



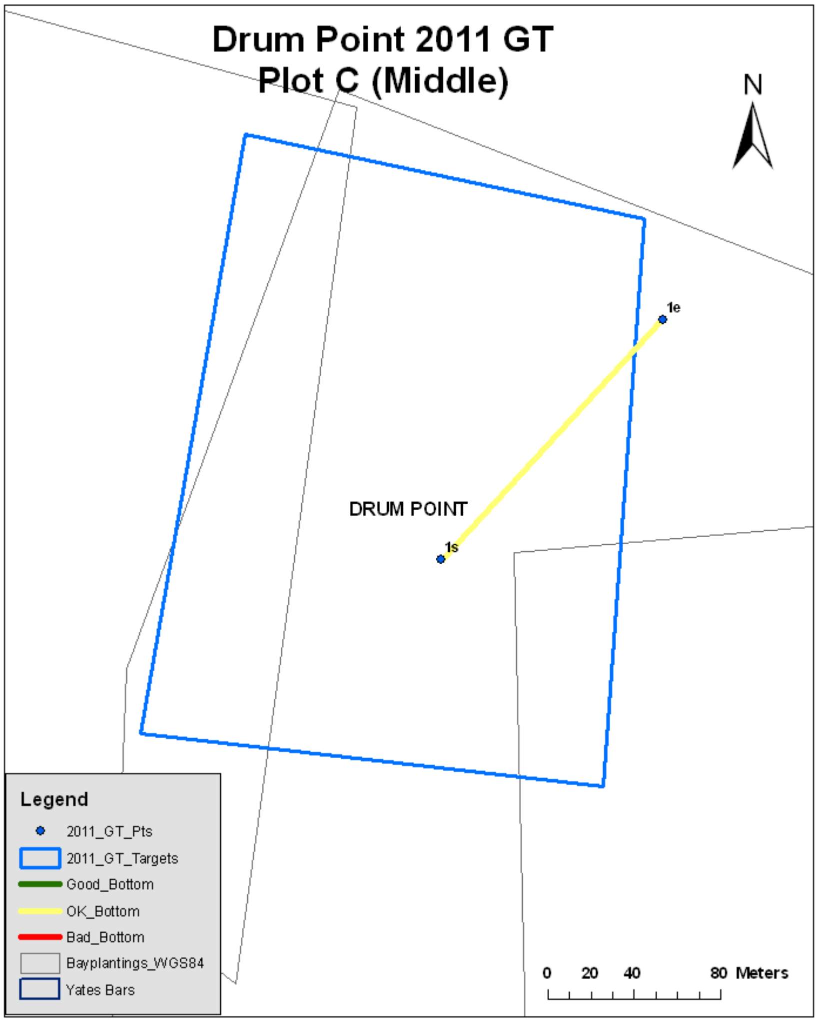

Drum Point, a sanctuary bar in the Manokin River, was the intended site of a new reef planting. Side-scan data were available for a portion of this area. Three targets were surveyed, but because of the distance between targets, all three are depicted in separate maps. The target above was placed over an area of very dark return from side-scan data. A single 200-m transect was surveyed through the center of this target, revealing exposed shell on a hard bottom of loose shell. The transect area was classified as good bottom for planting.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 26-Jul-11 | 1 | 100 | Exposed | 0cm | Loose Shell |



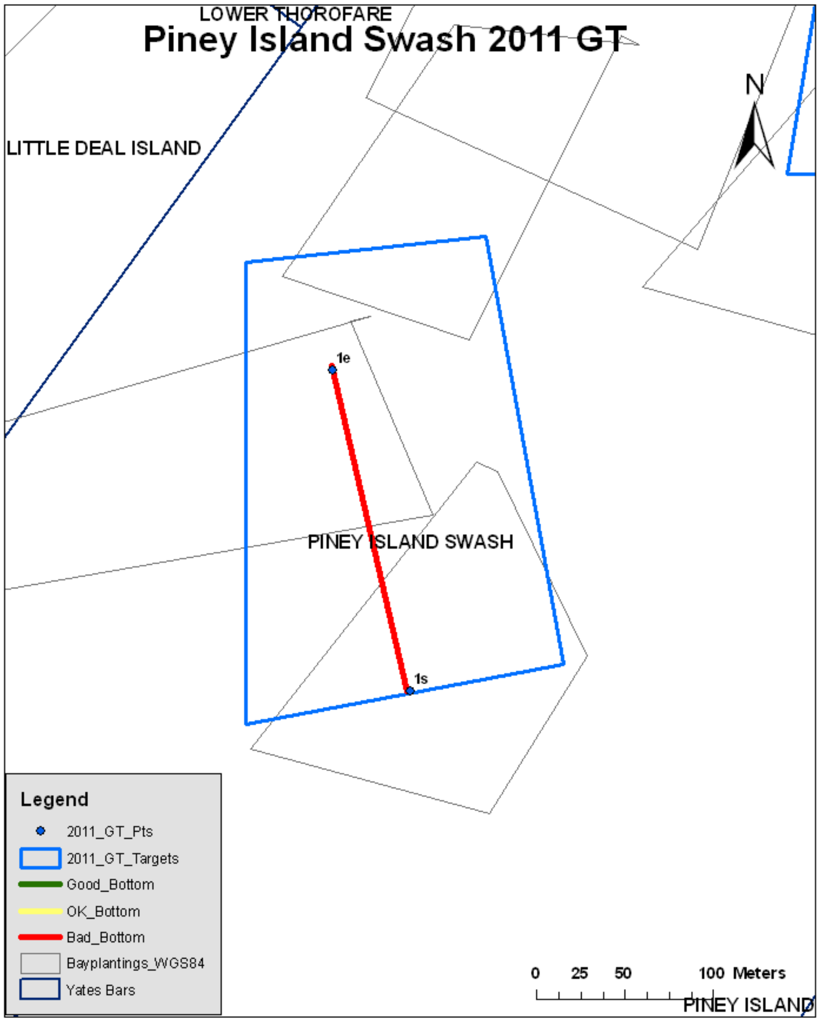

The second target at Drum Point in the Manokin River did not have available side-scan data. Instead, the target was placed over historic bay plantings. On site, the fish-finder was used to gauge the bottom before deploying the transect line, and it showed that the western half of the target was likely poor bottom (soft mud). The target was shifted east, and a single 200-m transect was surveyed. This transect revealed knuckle-deep sand with zero shell, and was classified as ok bottom.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 26-Jul-11 | 1 | 100 | Zero | 5cm | Sand |



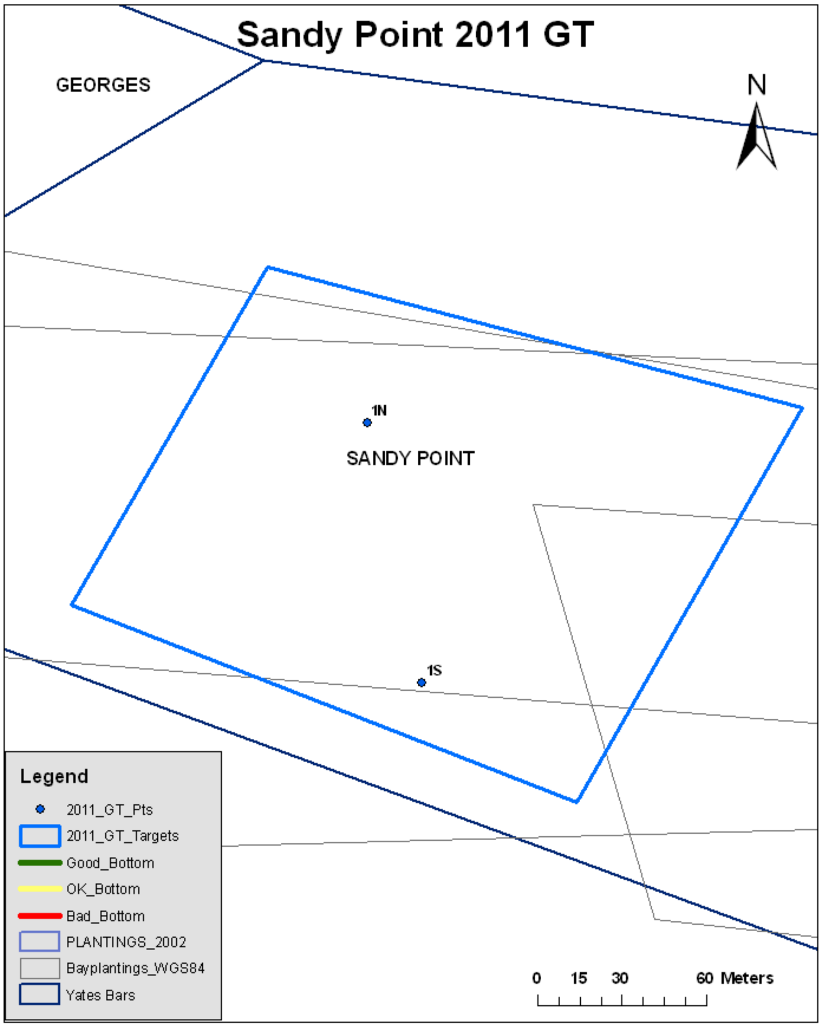

The third Drum Point target also did not have side-scan data available, and the target was placed over historic bay plantings. Again, the fish-finder showed that a portion of the planned target was not hard bottom and the target was shifted to the northeast. A single 200-m transect was surveyed and showed finger-deep sand with very little exposed shell. This bottom was graded as ok bottom for planting.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 26-Jul-11 | 1 | 100 | Very Little/Patchy | 10cm | Sand |



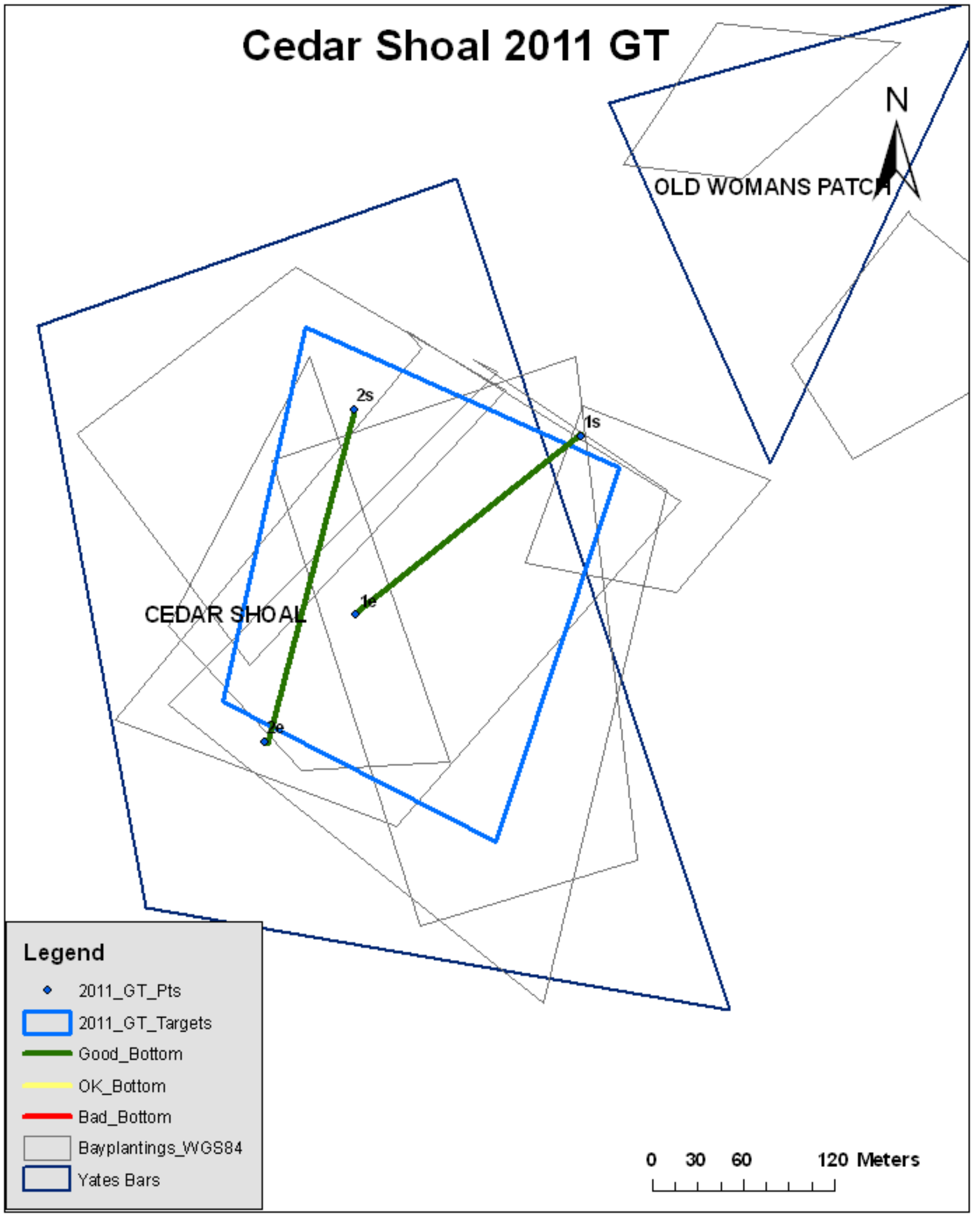

Piney Island Swash, a sanctuary bar in the Manokin River, was the potential site of a new reef planting. Side-scan data were not available for this area, and the target was placed over historic bay plantings. A single 200-m transect showed mode data of shoulder-deep mud with no exposed shell. This area was classified as bad bottom, not suitable for planting.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 26-Jul-11 | 1 | 100 | Zero | 70cm | Mud |



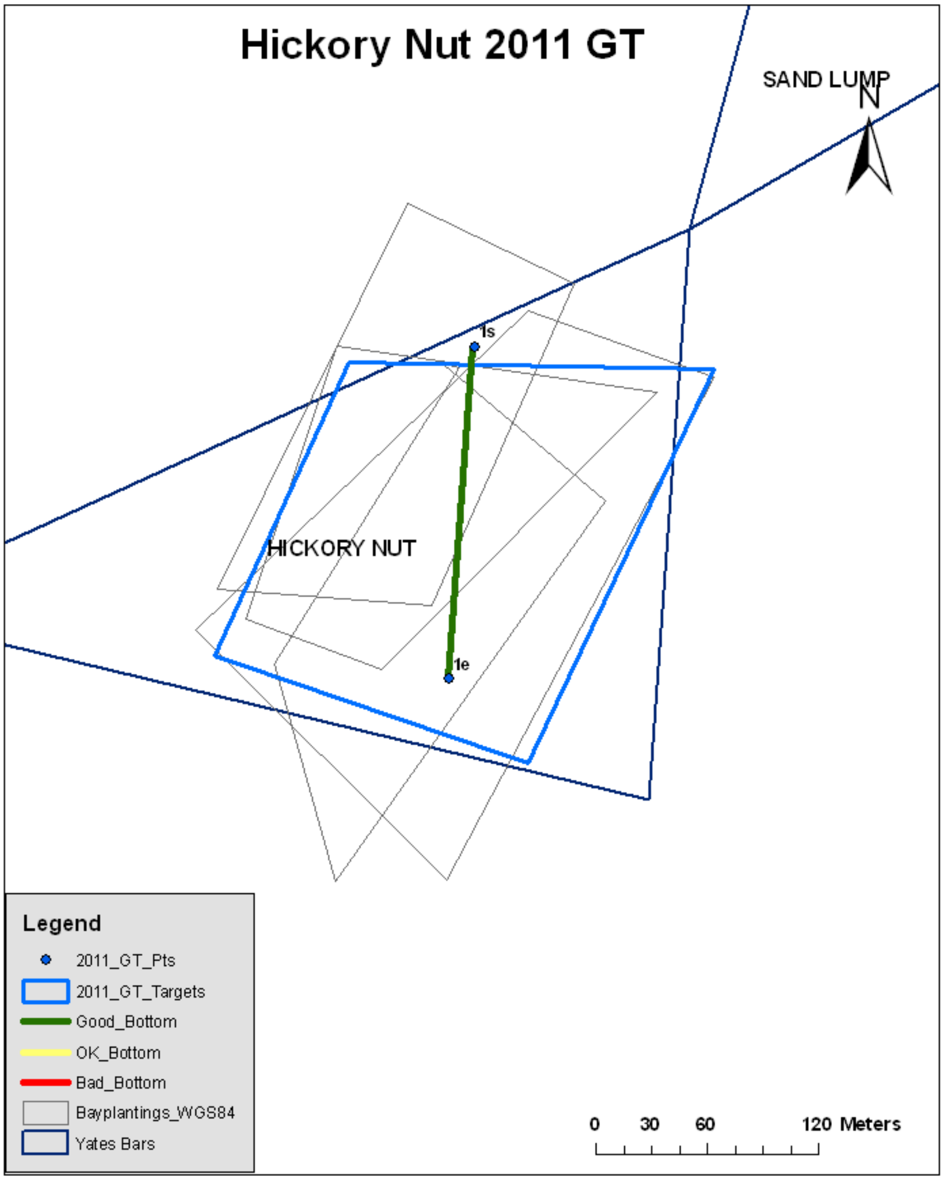

Sandy Point, a sanctuary bar in the Manokin River, was the potential site of a new reef planting. Side-scan data were not available for this site, and a target was placed over historic bay plantings within the Yates Bar. Fish-finder imaging showed two distinct bottom types across the target, with what appeared to be soft bottom at the northern end and hard bottom at the southern end. Rather than survey a full transect across the area, a diver dropped twice, once at each end of the target. The diver swam large transects without a line to confirm the fish-finder's data. The northern portion of the plot was muddy and unsuitable for planting, while the southern half was made up of a large shellbed, and was classified as good bottom.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 26-Jul-11 | NA | 1 N | Zero | 10cm | Mud |
| Sanctuary | New reef | 26-Jul-11 | NA | 1 S | Exposed | 0cm | Loose Shell |



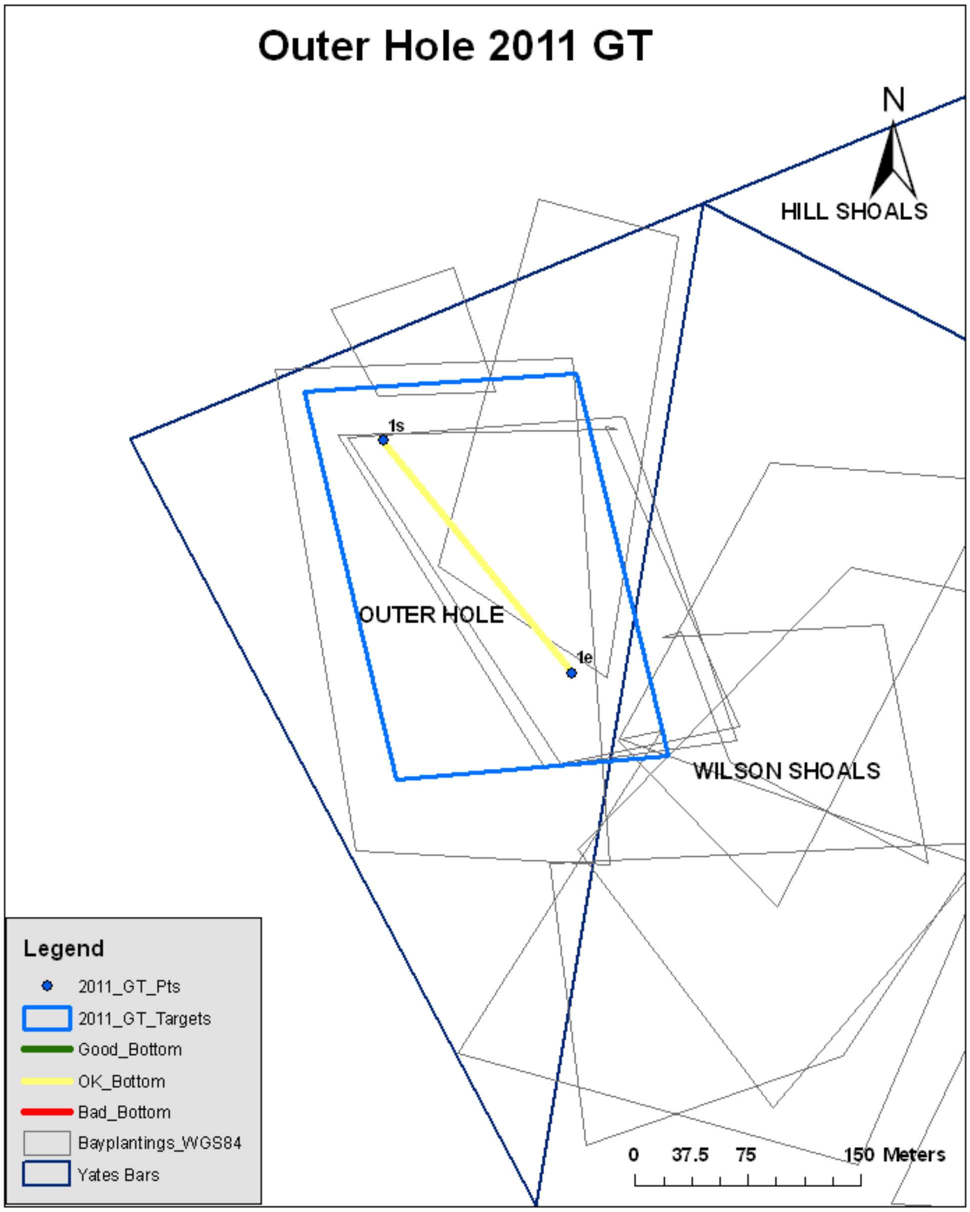

Cedar Shoal, a sanctuary bar in the Nanticoke River, was a planting target intended to establish a new sanctuary reef. Side-scan data were not available, and the planting target was placed over a series of historic bay plantings. Two transects across the target revealed good bottom, with a hard substrate of loose shell.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 27-Jul-11 | 1 | 100 | Exposed | 0cm | loose shell |
| Sanctuary | New reef | 27-Jul-11 | 2 | 100 | Exposed | 0cm | loose shell |



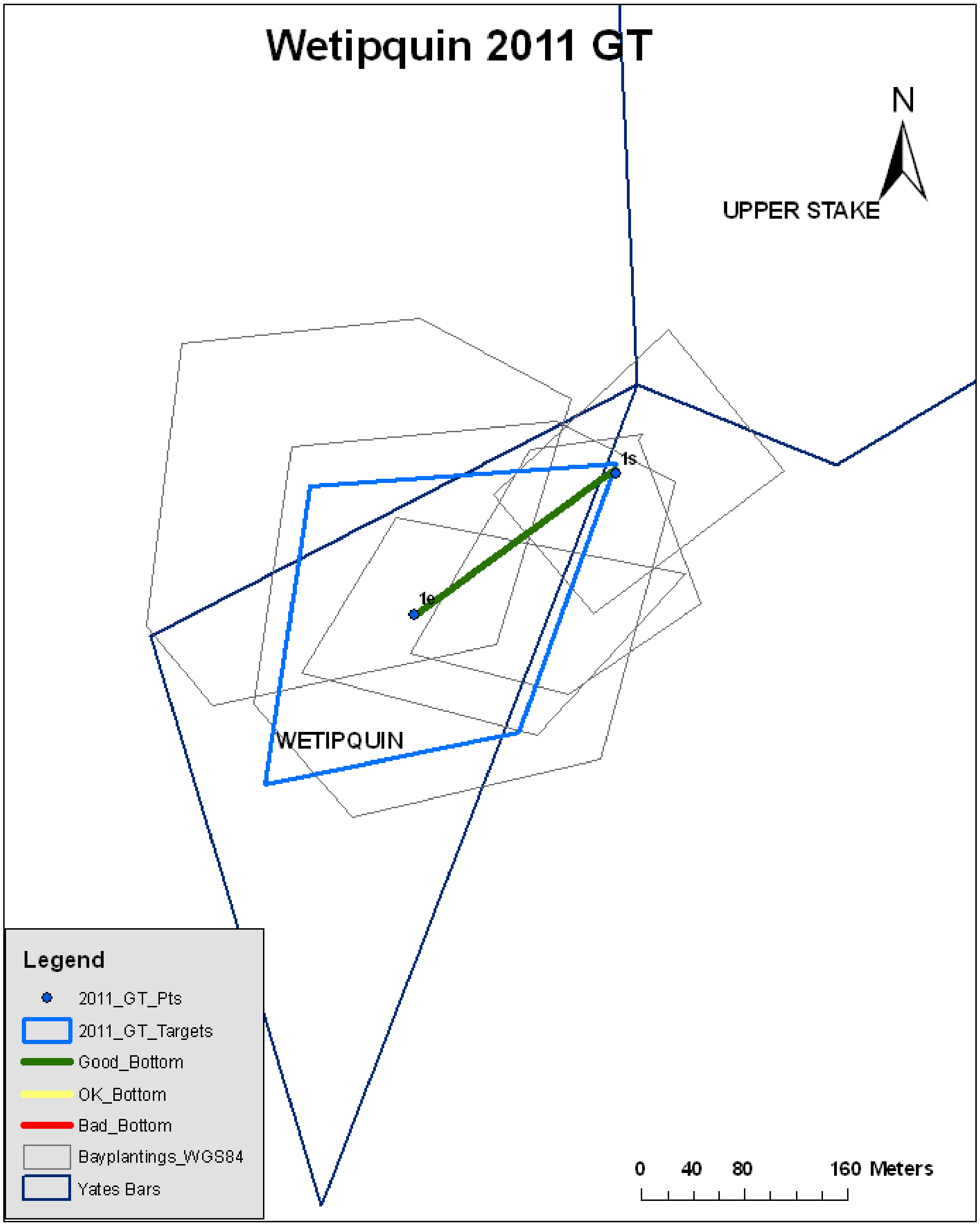

Hickory Nut, a sanctuary bar in the Nanticoke River, was the site of a planned new reef planting. Side-scan data were not available, thus a target was placed over historic bay plantings. A single 200-m transect was surveyed across the center of the target, revealing hard bottom of loose shell. This bottom was classified as good for planting.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 27-Jul-11 | 1 | 100 | Exposed | 0cm | Loose Shell |




Outer Hole, a sanctuary bar in the Nanticoke River, was the potential site of a new reef planting. Side-scan data were not available for this site, and the target was placed over historic bay plantings within the Yates Bar. A single 200-m transect revealed finger-deep mud with exposed shell. This target was classified as ok bottom.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 27-Jul-11 | 1 | 100 | Exposed | 10cm | Mud |

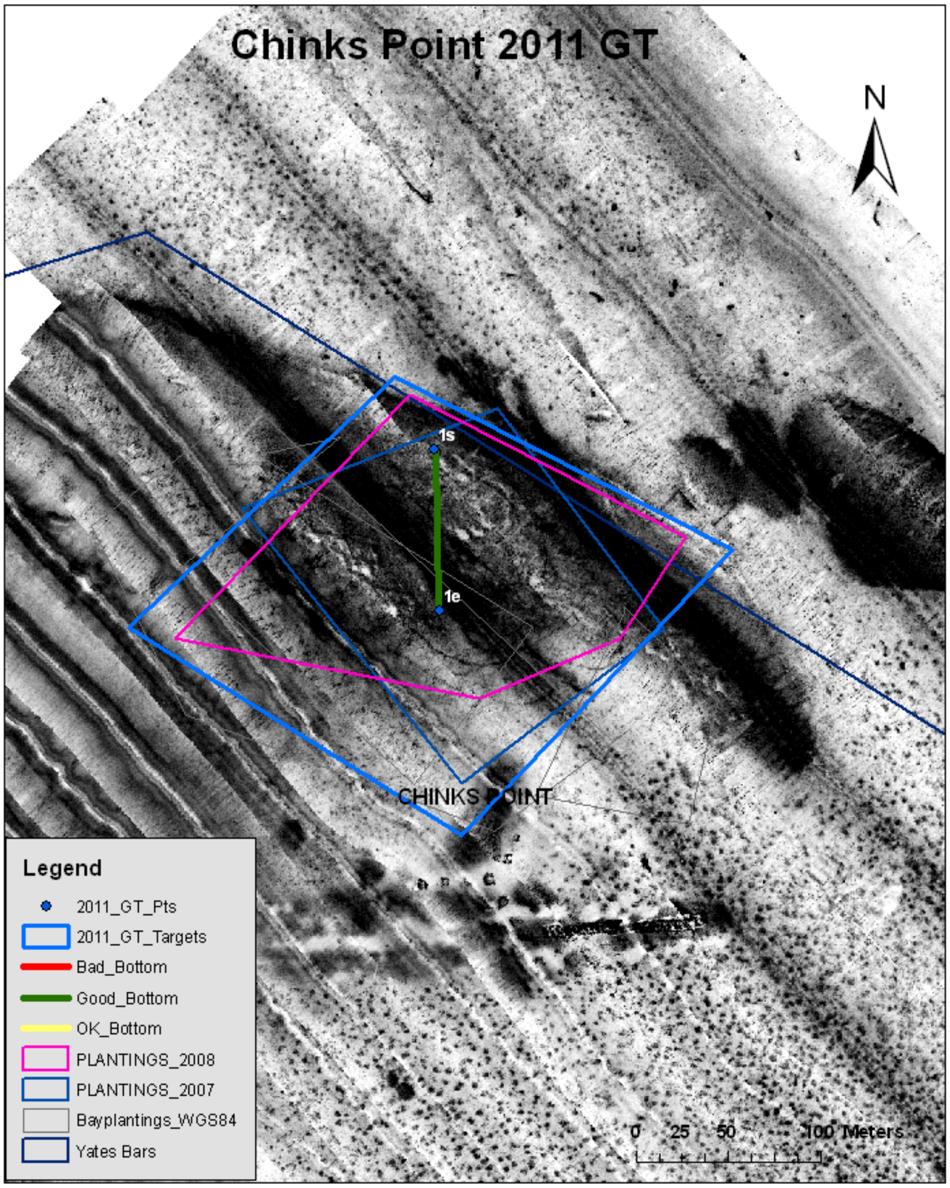



Wetipquin, a sanctuary bar in the Nanticoke River, was the intended site of a new reef planting. Side-scan data were not available for this area, and the target was placed over a series of historic plantings within the Yates Bar. A single 200-m transect through the target revealed finger-deep loose shell and was classified as good for planting.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 27-Jul-11 | 1 | 100 | Exposed | 10cm | Loose Shell |

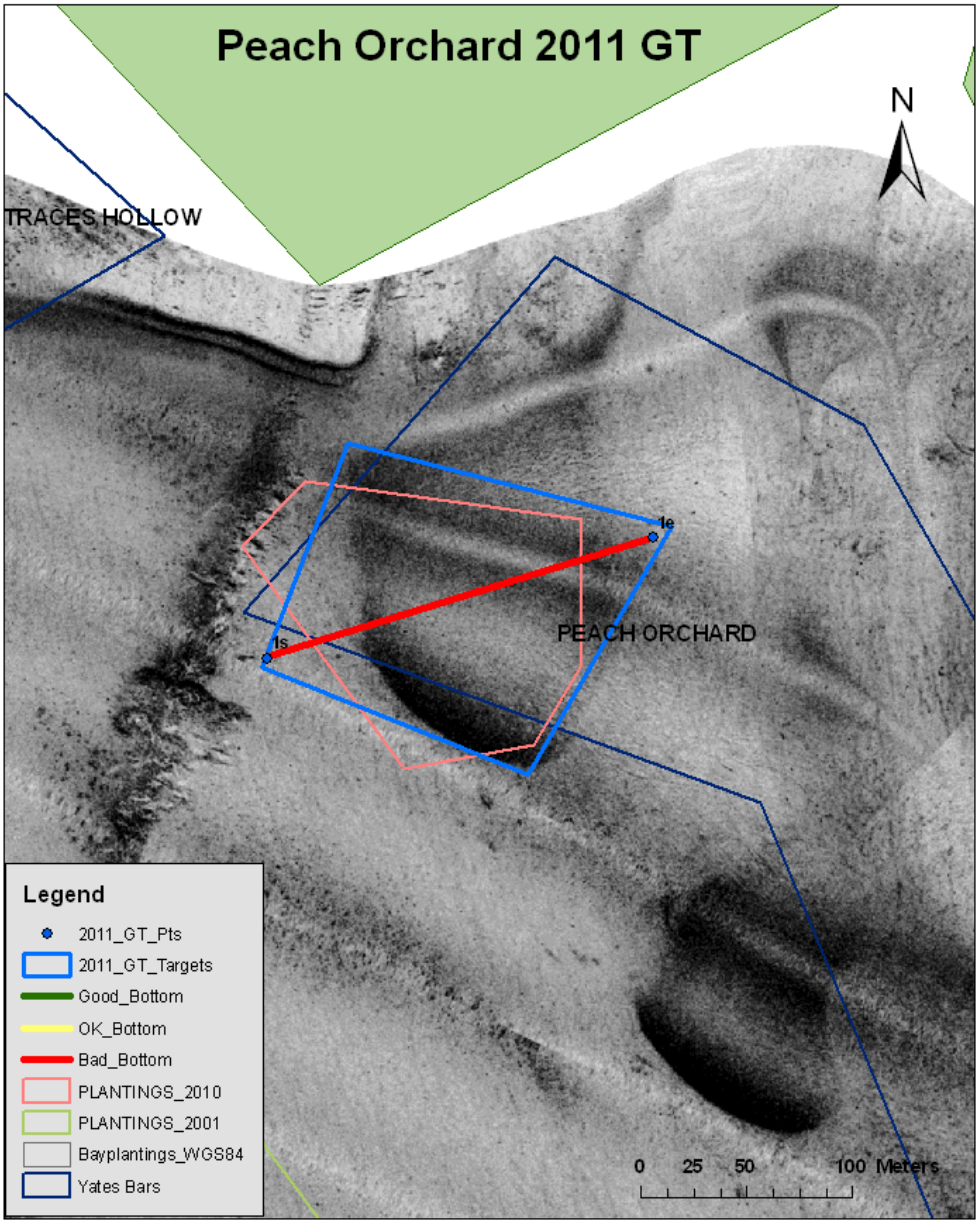

Wilson Shoals, a sanctuary bar in the Nanticoke River, was the intended site of a new reef planting in 2011. Side-scan data were not available for this area, and the target was placed over a series of historic plantings within the Yates Bar. Two 200-m transects were surveyed through the target area, and both revealed bottom good for planting. Mode data showed primarily hard bottom of loose shell.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 27-Jul-11 | 1 | 100 | Exposed | 0cm | Loose Shell |
| Sanctuary | New reef | 27-Jul-11 | 2 | 100 | Exposed | 0cm | Loose Shell |



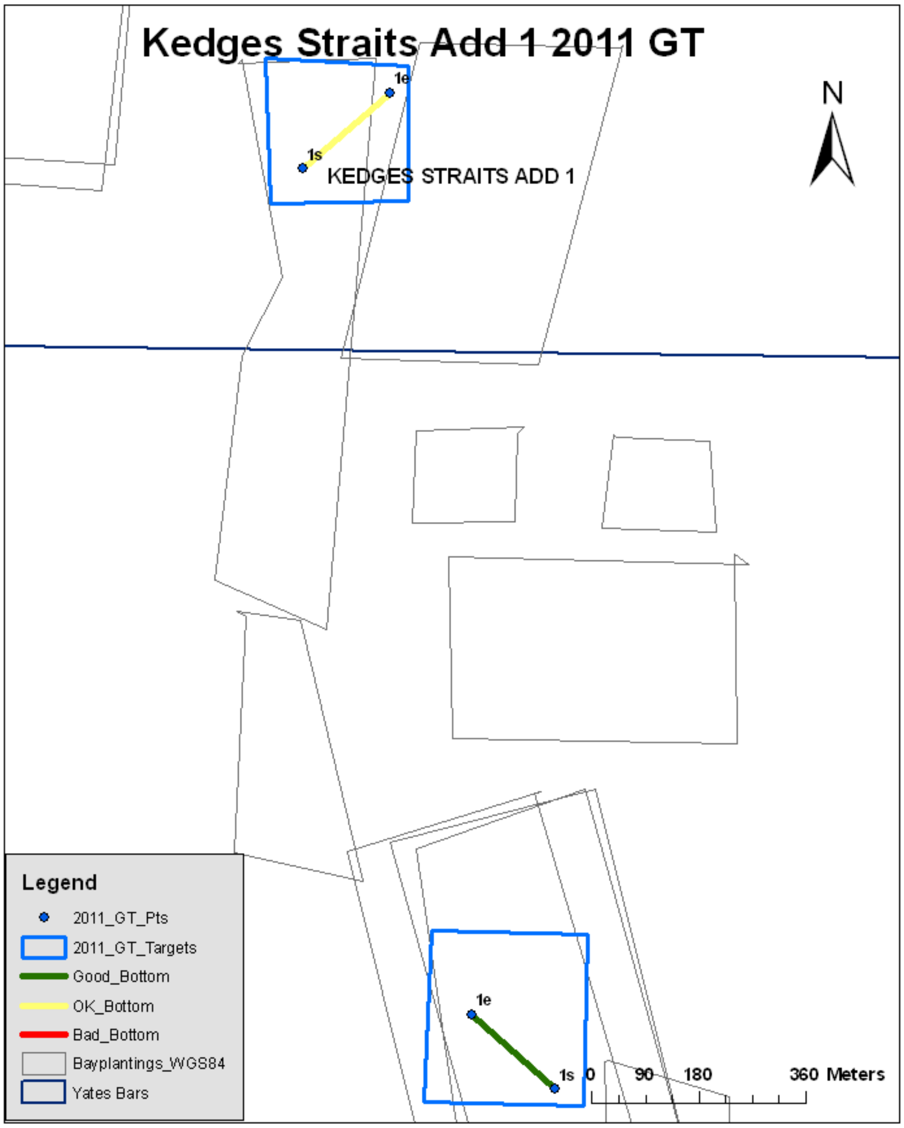

Chinks point, a sanctuary bar in the Severn River, was a planting target intended to overplant atop 2007 and 2008 plantings. Side-scan data showed hard return with evidence (planting lines) from at least one previous planting. The selected target encompassed the tracklines from the 2007 and 2008 plantings, and a single 200-m transect was surveyed through the center. The GT survey revealed good bottom, primarily hard bottom with exposed shell corresponding to the dark return of side-scan images.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | Overplant | 10-May-11 | 1 | 100 | Exposed | 0cm | loose shell |




Peach Orchard, a sanctuary bar in the Severn River, was the intended target of an additional year class planting over a 2010 planting. A target was placed over an area of dark side-scan return, as well as over a 2010 planting. A single 200-m transect surveyed revealed hard bottom with mud, and zero exposed shell. Though, there were almost an equal number of points in which the primary substrate was rock (rock: 40, mud: 46), this target was classified as bad bottom, not suitable for planting.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | Add year class | 10-May-11 | 1 | 100 | Zero | 0cm | Mud |




Kedges Straits Add 1, a sanctuary bar in Tangier Sound, was the intended site of a new reef planting. Side-scan data were not available for this site, and two targets were created over historic bay plantings. The northern target was within the Yates Bar, while the southern target was outside of the Yates Bar, but still over historic plantings. In each target, a single 200-m transect was surveyed. In the northern target, mode data of finger-deep sand with no exposed shell was classified as ok bottom. In the southern target, hard bottom with loose shell resulted in a good bottom score.

| Bar Type | Objective | Date | Transect # | # Points | Mode Exposed Shell | Mode Penetration | Mode Primary Substrate |
|---|---|---|---|---|---|---|---|
| Sanctuary | New reef | 26-Jul-11 | 1 | 100 | Zero | 10cm | Sand |
| Sanctuary | New reef | 26-Jul-11 | 1 | 100 | Exposed | 0cm | Loose Shell |

## Section IV: Post-Planting Monitoring 2011

**Data Summary:**

In 2011, 13 sites planted with spat on shell from the Horn Point Oyster Hatchery in Cambridge, Maryland were surveyed by a diver 4-8 weeks after the planting occurred. The purpose of these surveys was to determine the density and short-term survivorship of spat on shell plantings. Due to the generally low salinity across the Bay during the 2011 planting season and the expected influence low salinity would have on oyster growth, attempts were made to sample each planting site toward the end of the 8-week window. This was done as weather and scheduling would allow, in order to accommodate potential slow spat growth in 2011. The diver survey date, number of acres planted and amount of spat planted at each of the 13 locations is presented in Table 4.1**.** As suggested by the planting dates, many of the 2011 plantings involved multiple plantings over the same areas in an attempt to increase the density of spat planted at a single location. This method follows the planting method from 2010, where many sites were overplanted, in contrast to years previous to 2010, where more sites were planted with fewer spat deployed at each site.

Table 4.1 – 2011 ORP hatchery planting & sampling summary. Rivers are further divided into sections as follows, L: lower, M: middle, and U: upriver.

| Region/River | Section | Site | 2011 Planting Dates | Acres Planted | Amount of Spat Planted (millions) | Sample Date (2011) |
|---|---|---|---|---|---|---|
| Chester River | L | Blunt | 8/8, 8/10, 8/15, 8/16 | 6.3 | 31.8 | 8-Nov |
| | M | Devil's Playground | 9/6,9/26 | 7.71 | 40.3 | 24-Oct |
| Choptank River | M | Cook Point | 5/16-6/1 | 8 | 93.2 | 13-Jul |
| | M | Howells Point | 8/29 | 7.26 | 19.4 | 13-Sep |
| | M | Howells Point | 7/11-7/12 | 7.26 | 18 | 13-Sep |
| | M | LeCompte | 6/13-6/15 | 6.11 | 35.2 | 17-Aug |
| | U | Bolingbroke Sand | 6/20, 21, 27, 28 | 11.57 | 64.9 | 17-Aug |
| Eastern Bay | M | Cabin Creek | 6/6-6/7 | 4.24 | 21.3 | 4-Aug |
| Harris Creek | L | Turkey Neck | 5/9-5/10 | 3.81 | 30 | 16-Jun |
| | M | Mill Point | 7/26,8/1,8/2,10/4 | 6.45 | 51.7 | 24-Oct |
| Little Choptank River | M | Cason | 9/7,9/12,9/19 | 7.52 | 45.7 | 10-Oct |
| Nanticoke River | L | Evans | 7/18,7/19,8/22,9/27 | 11.67 | 46.8 | 10-Oct |
| | L | White Shoal | 8/30 | 5.63 | 16.6 | 10-Oct |

Figure 4.1 shows the planting locations monitored by the Paynter Lab from 2009 through 2011. Most plantings in all years were concentrated in the Chester River, Eastern Bay and the Choptank River. These areas were selected because the bottom type in these rivers has been extensively examined, both by divers from the Paynter Lab as well as through side scan sonar images collected by NOAA and MGS. The only year where plantings occurred on the western

shore was 2009, indicating a temporary shift in the geographic focus of plantings during that year.

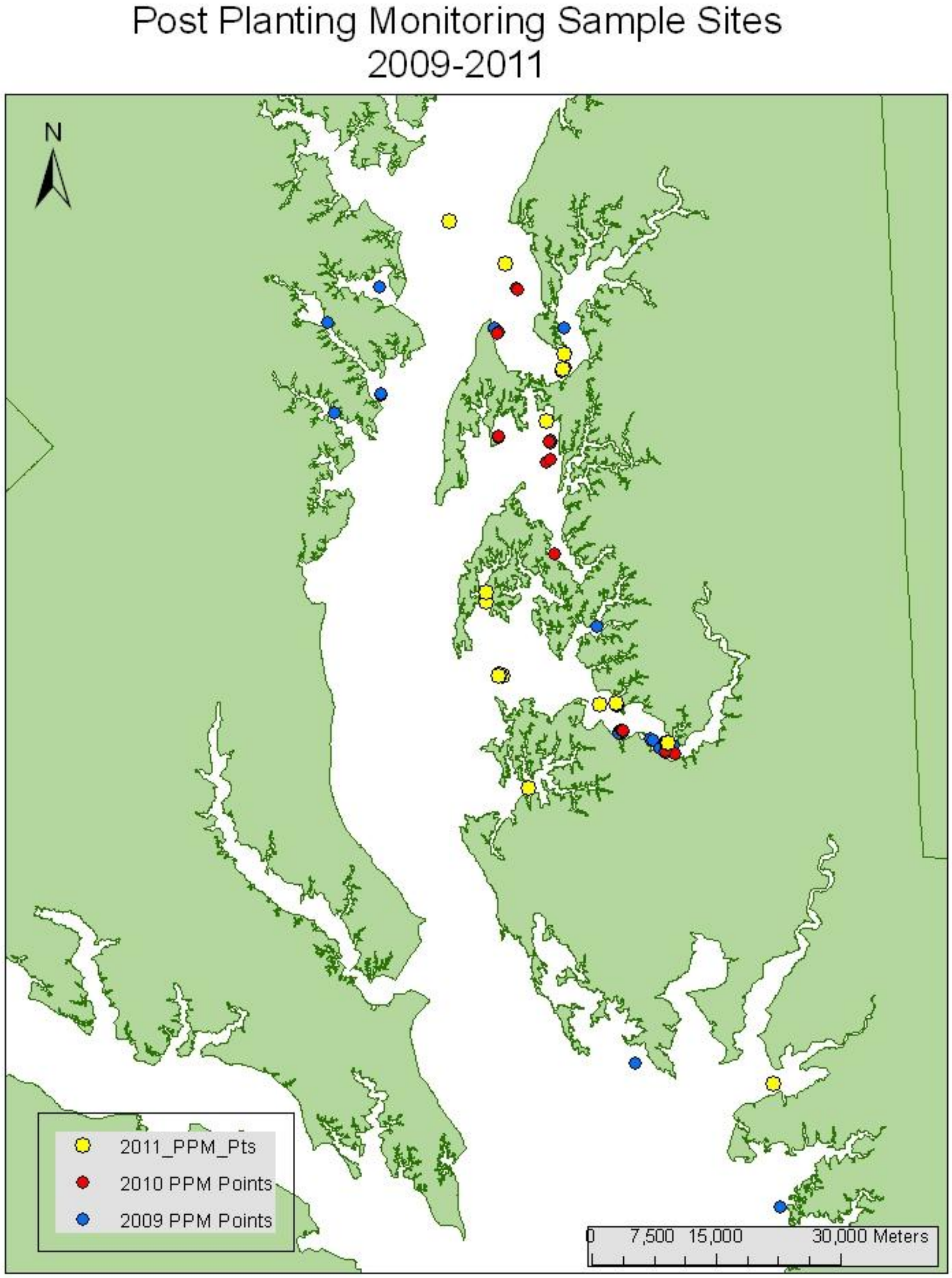



Figure 4.1. Map of planting locations from 2009 through 2011.

Using the planting boat's track lines as a target, divers collected hatchery shells from each survey location. Divers placed a 0.3m x 0.3m quadrat on the bottom and collected all shells contained within the quadrat. Attempts were made to collect at least three quadrat samples at each site. When shell densities were too low for quadrat sampling, such that the diver could not find shell in areas with few track lines, the diver would instead haphazardly collect 50 to 100 shells from throughout the bar. Each shell was examined for live spat, boxes, scars, and gapers. Additionally, the first 50 live spat observed in each sample were measured for shell height. The means of those shell metrics are summarized in Table 4.2 for all sample locations in 2011.

Table 4.2 **–** 2011 post-planting monitoring survey data. Rivers are further divided into sections as follows, L: lower, M: middle, and U: upriver.

| | | | | **Mean Count per Shell** | | | | |
|---|---|---|---|---|---|---|---|---|
| **Region/River** | **Section** | **Bar Name** | **# Shells Sampled** | **Live** | **Gapers** | **Scars** | **Boxes** | **Shell Height (mm)** |
| Chester River | L | Blunt | 55 | 7.1 | 0.1 | 0.3 | 0.4 | 28.2 |
| | M | Devil's Playground | 49 | 2.4 | 0 | 3 | 0.3 | 11.4 |
| Choptank River | M | Cook Point | 369 | 3.3 | 0.1 | 2.4 | 0.2 | 13.1 |
| | M | Howells Point | 100 | 7.2 | 0 | 1.5 | 0.1 | 26.1 |
| | M | Howells Point | 100 | 19.2 | 0.1 | 4.2 | 0 | 18.5 |
| | M | LeCompte | 173 | 0.1 | 0.1 | 2.4 | 0.1 | 19.5 |
| | U | Bolingbroke Sand | 84 | 1.1 | 0 | 1.8 | 0.1 | 24.3 |
| Eastern Bay | M | Cabin Creek | 122 | 0.8 | 0 | 3.3 | 0.2 | 19.4 |
| Harris Creek | L | Turkey Neck | 132 | 1.9 | 0.1 | 2.1 | 0.2 | 10.8 |
| | M | Mill Point | 120 | 2.4 | 0 | 1.4 | 0.1 | 29.7 |
| Little Choptank River | M | Cason | 55 | 5.5 | 0 | 1.3 | 0.1 | 10.6 |
| Nanticoke River | L | Evans | 51 | 2.6 | 0.1 | 0.9 | 0 | 30.8 |
| | L | White Shoal | 43 | 3.1 | 0 | 3.6 | 0.4 | 18.7 |

In addition to the metrics listed above, each shell was inspected for the presence of *Stylochus*. Values are not included in the table, as they were generally low across all sites. *Stylochus* were only observed at three sites: Cooks Point in the Choptank River (n = 1), Cabin Creek in Eastern Bay (n = 1) and Hail Point in the Chester River (n = 1).

The amount of spat per shell was multiplied by the total amount of shell planted on each bar to calculate the amount of spat detected on the bar by the post-planting monitoring survey. Spat survival was then calculated as the percentage of spat planted that was detected by the survey. The mean spat survival for 2011 plantings was 27.0% (±27.6). However, it is important to note the range of the data was 0.4% survival (LeCompte) to 89.4% survival (Howells Point 8/29). The percent survival of spat planted by bar is presented in Table 4.3**.**

Table 4.3 **–** 2011 spat survival by bar. Rivers are further divided into sections as follows, L: lower, M: middle, and U: upriver.

| **Region/River** | **Section** | **Bar Name** | **Mean # Live Spat/Shell** | **Amount of Shell Planted** | **Amount of Spat Planted (Millions)** | **Live Spat Calculated from Survey (Millions)** | **2011 % Survival** |
|---|---|---|---|---|---|---|---|
| Chester River | L | Blunt | 7.1 | 2,892,096 | 31.8 | 20.5 | 64.6 |
| | M | Devil's Playground | 2.4 | 1,809,792 | 40.3 | 4.3 | 10.8 |
| Choptank River | M | Cook Point | 3.3 | 5,443,200 | 93.2 | 18.2 | 19.5 |
| | M | Howells Point | 7.2 | 1,555,200 | 18 | 11.3 | 62.4 |
| | M | Howells Point | 19.2 | 904,896 | 19.4 | 17.3 | 89.4 |
| | M | LeCompte | 0.1 | 2,332,800 | 35.2 | 0.1 | 0.4 |
| | U | Bolingbroke Sand | 1.1 | 3,110,400 | 64.9 | 3.4 | 5.2 |
| Eastern Bay | M | Cabin Creek | 0.8 | 1,555,200 | 21.3 | 1.3 | 6 |
| Harris Creek | L | Turkey Neck | 1.9 | 1,555,200 | 30 | 2.9 | 9.7 |
| | M | Mill Point | 2.4 | 3,237,696 | 51.7 | 7.8 | 15 |
| Little Choptank River | M | Cason | 5.5 | 2,714,688 | 45.7 | 14.9 | 32.7 |
| Nanticoke River | L | Evans | 2.6 | 3,364,992 | 46.8 | 8.7 | 18.7 |
| | L | White Shoal | 3.1 | 904,896 | 16.6 | 2.8 | 16.9 |
| | | | | **MEAN** | | | **27.0±7.7** |

Identical metrics were collected in 2008 – 2010 from sites comparable to those sampled in 2011 (see Table 4.4). In 2011 and 2010, the total acreage planted was less than both 2008 and 2009, due to the fact that an over-planting approach was used where plantings were often repeated over previous plantings. Survival was highest in 2011 of all four years, despite record low salinities for the Chesapeake Bay in 2011. Table 4.5 is a summary of the average salinity during planting season (July – November) in each river by the Paynter Lab during planting season from 2009 through 2011. In the rivers that have multiple years of data, 2011 has the lowest average salinity of any year. In order to compensate for low salinities in the northern portion of the Bay in 2011, plantings were concentrated in the southern portion of the Maryland portion of the Bay. Many of these plantings were at locations that have not been restored by the ORP previously and therefore the higher survival observed in 2011 may be a result of the new locations and not the viability of the spat themselves.

Table 4.4 **–** Comparison of 2008 – 2011 post planting monitoring survey summary metrics.

| | | | | | Means per Year | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sample Year** | **Sample Locations** | **Sites Planted** | **Total Acreage Planted** | **Total Spat Planted (Millions)** | **Initial Spat per Shell** | **Survey Spat per Shell** | **Shell Height (mm)** | **% Survival** | **Spat Detected on PPM Survey (Millions)** |
| 2008 | 20 | 27 | 215.64 | 369.95 | 30.23 | 3.94 | 14.94 | 17.0 | 62.89 |
| 2009 | 19 | 56 | 408.82 | 761.96 | 17.9 | 3.4 | 11.45 | 12.0 | 91.44 |
| 2010 | 13 | 16 | 99.56 | 373.76 | 14.86 | 2.03 | 20.13 | 12.8 | 47.84 |
| 2011 | 12 | 13 | 93.53 | 514.95 | 16.51 | 4.36 | 20.07 | 27.0 | 139.04 |

Table 4.5 **–** Average salinity during post-planting monitoring season (July – November) by river collected by the Paynter Lab from 2009 through 2011. In rivers with multiple years of data, 2011 consistently has the lowest average salinity.

| | Annual Salinity (ppt) | | |
|---|---|---|---|
| **River** | **2009** | **2010** | **2011** |
| Chester | 10.8 | 10.5 | 6.6 |
| Choptank | 15.6 | 11.9 | 8.8 |
| Eastern Bay | 12.9 | 13.7 | 9.7 |
| Harris Creek | - | - | 7 |
| Little Choptank | 12.7 | - | 8.2 |
| Severn | 11.5 | 8.7 | 5.6 |

In order to examine the source of the variability seen in post-planting spat per shell and percent survival, 2008 -- 2011 spat per shell and percent survival data were examined for relationships with amount of spat and shell planted, density of spat and shell planted, spat growth rate, as well as location of planting. In 2009, a significant negative relationship was observed between initial spat per shell and survival. However, this relationship was not observed in any other year, indicating that the trend observed in 2009 was an anomaly.

The data collected from the 2008 – 2011 post planting monitoring surveys do not conclusively show any relationship between spat survival and amount of spat and shell planted, density of spat and shell planted, spat growth rate or location of planting. The 2011 spat survival relative to initial spat per shell is shown below (Figure 4.2) and is also shown alongside data from 2008 – 2010 (Figure 4.3). No trend was observed in survival relative to spat growth rate (Figure 4.4), indicating that the environmental variation known to impact spat growth (oxygen concentration, food availability) does not seem to be correlated with survival of spat in the northern Chesapeake Bay. Additionally, 2011 data was evaluated for trends related to site salinity, timing of planting, and whether or not the site was overplanted. These comparisons also yielded no obvious relationships.

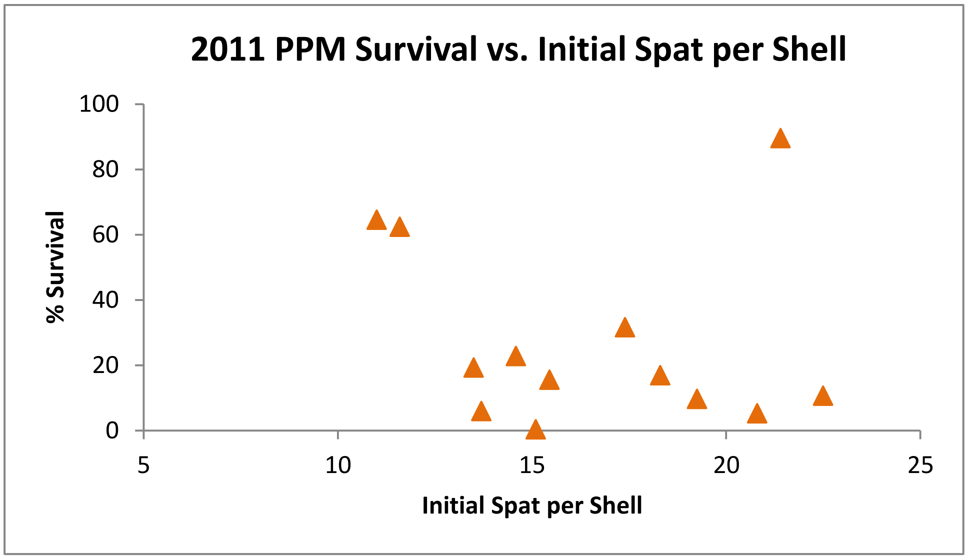



Figure 4.2 **–** Survival by initial spat per shell for the 2011 post-planting monitoring survey. The data show no trend in survival with initial spat per shell.

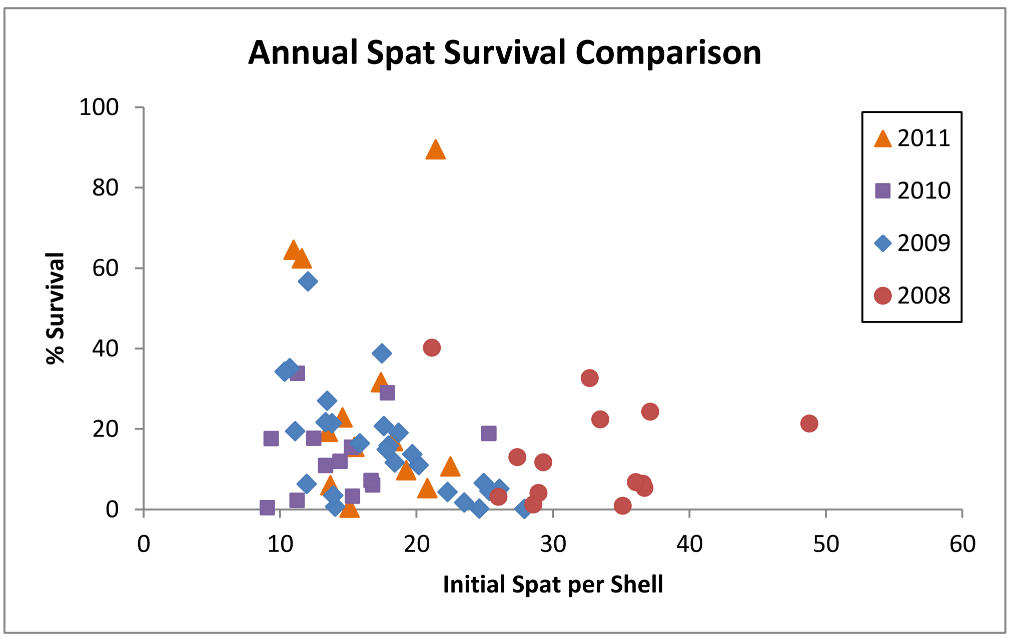



Figure 4.3 **–** Annual comparison of survival by initial spat per shell. Overall, no trend in survival with initial spat per shell was observed despite the 2009 data alone showing a significant negative trend in survival with initial spat per shell. However, the lack of a significant trend present in the other three years of data indicates that the trend in 2009 was likely an anomaly. Therefore, these data do not provide evidence for a relationship between initial spat per shell and spat survival 4 – 8 weeks post planting.

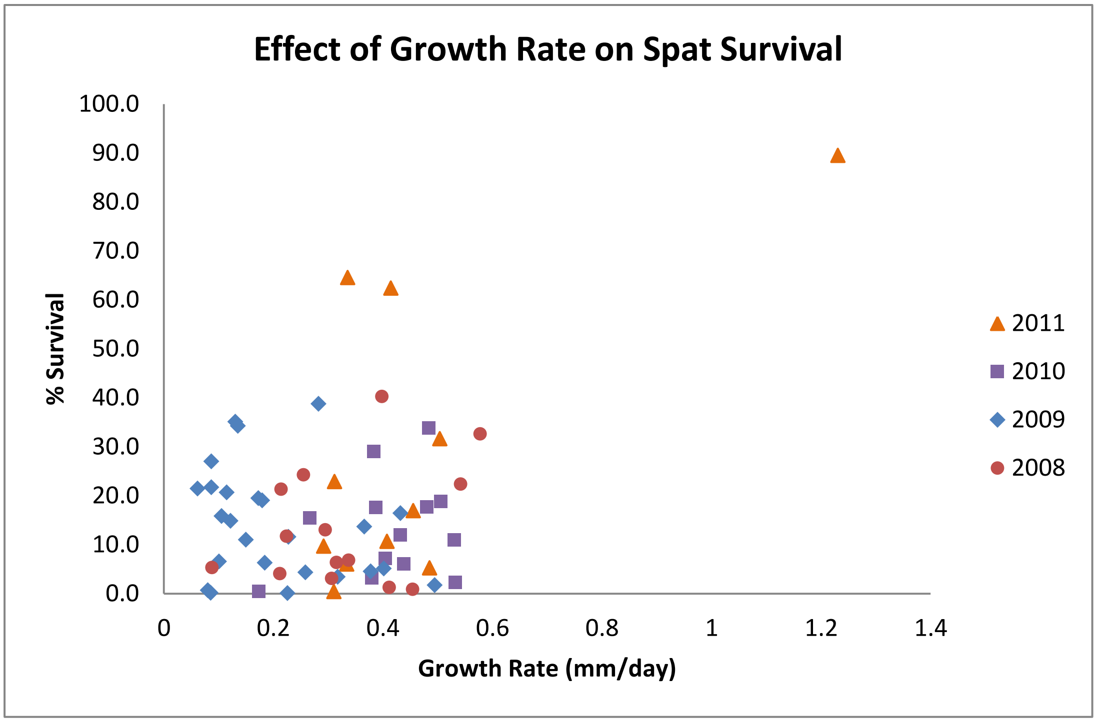



Figure 4.4 **–** Spat growth rate (mm/day) by percent survival for the post planting monitoring surveys conducted in 2008 – 2011. No trend was observed in survival with growth rate in any year. One very fast growing site, Howell Point (planted on 8/29/2011) was observed to have very high survival, but this site was an outlier and is not reflective of a trend in the 2011 data or the post planting monitoring data from all years combined.

Quadrat-based sampling was employed for the first time during the 2010 survey and yielded valuable data on the density of spat at plantings and how density was related to the survival of spat. The quadrat-based collected method was employed again in 2011, where appropriate. At certain sites the presence of alternate substrate or very low shell densities prevented quadrats from being used effectively to collect hatchery shells. By using a quadrat to collect shells within a standard area, density comparisons could be made. At each bar, divers attempted to collect at least three quads. Below, Table 4.6 shows the bars sampled using quadrats, as well the metrics per quad. (Data presented above in Table 2 for 2011 includes sums and averages of these quadrat data for comparison across all bars.)

Table 4.6 **–** Summary of metrics collected per quad for post planting monitoring sites sampled using the quadrat method in 2011. Rivers are further divided into sections as follows, L: lower, M: middle, and U: upriver.

| | | | | | | Average per Shell | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Region/River** | **Section** | **Bar Name** | **Planting Dates** | **Sample Date** | **# of Shells Sampled** | **Live** | **Gapers** | **Scars** | **Boxes** | **Spat Shell Height (mm)** |
| Chester River | L | Blunt | 8/8, 8/10, 8/15, 8/16 | 8-Nov | 30 | 6 | 0 | 0 | 1 | 28.7 |
| | | | | | 11 | 6.3 | 0 | 0 | 0 | 27.2 |
| | | | | | 14 | 9.1 | 0 | 1 | 1 | 28.7 |
| | M | Devil's Playground | 9/6,9/26 | 24-Oct | 4 | 0.3 | 0 | 4 | 0 | 3 |
| | | | | | 2 | 1 | 0 | 2 | 0 | 16 |
| | | | | | 13 | 2 | 0 | 2 | 1 | 13.6 |
| | | | | | 4 | 8.3 | 0 | 5 | 1 | 13 |
| Choptank River | M | Lecompte | 6/13/15 | 17-Aug | 28 | 0.2 | 0 | 4 | 1 | 25.3 |
| | | | | | 22 | 0.3 | 0 | 1 | 0 | 7.3 |
| | | | | | 38 | 0.1 | 0 | 2 | 0 | 26 |
| | | | | | 19 | 0 | 0 | 2 | 0 | - |
| | | | | | 22 | 0 | 0 | 0 | 0 | - |
| | | | | | 19 | 0 | 0 | 1 | 0 | - |
| | | | | | 12 | 0 | 0 | 3 | 0 | - |
| | | | | | 11 | 0 | 0 | 5 | 0 | - |
| | | | | | 2 | 0 | 1 | 4 | 0 | - |
| | U | Bolingbroke Sand | 6/20, 21, 27, 28 | 17-Aug | 18 | 1.4 | 0 | 2 | 0 | 23.7 |
| | | | | | 10 | 0.9 | 0 | 1 | 0 | 26.2 |
| | | | | | 19 | 2.2 | 0 | 0 | 0 | 25.8 |
| | | | | | 17 | 0.5 | 0 | 2 | 0 | 20.6 |
| | | | | | 5 | 0 | 0 | 4 | 0 | - |
| | | | | | 15 | 1.5 | 0 | 2 | 0 | 25 |
| Eastern Bay | M | Cabin Creek | 6/6-6/7 | 4-Aug | 22 | 0.2 | 0 | 2 | 0 | 11.5 |
| | | | | | 25 | 0.3 | 0 | 4 | 0 | 5.4 |
| | | | | | 15 | 0.2 | 0 | 3 | 0 | 18.3 |
| | | | | | 5 | 2 | 0 | 2 | 0 | 21.6 |
| | | | | | 6 | 1.3 | 0 | 3 | 0 | 26.7 |
| | | | | | 4 | 0.3 | 0 | 3 | 0 | 23 |
| | | | | | 6 | 1.2 | 0 | 4 | 1 | 25.6 |
| Harris Creek | L | Turkey Neck | 5/9-5/10 | 16-Jun | 26 | 3.5 | 0 | 8 | 0 | 8.8 |
| | | | | | 36 | 1.6 | 0 | 1 | 0 | 11.3 |
| | | | | | 33 | 2 | 0 | 2 | 0 | 10 |
| | | | | | 13 | 0.9 | 0 | 1 | 0 | 12.2 |
| | | | | | 9 | 2.6 | 0 | 1 | 0 | 19.6 |
| | | | | | 15 | 1.5 | 0 | 1 | 0 | 7.4 |
| | M | Mill Point | 7/26,8/1,8/2,10/4 | 24-Oct | 12 | 3.2 | 0 | 1 | 0 | 28.6 |
| | | | | | 18 | 1.9 | 0 | 1 | 0 | 31.7 |
| | | | | | 23 | 2.5 | 0 | 1 | 0 | 28.1 |
| | | | | | 25 | 1.8 | 0 | 2 | 0 | 28.6 |
| | | | | | 30 | 1.9 | 0 | 2 | 0 | 31.5 |
| | | | | | 12 | 3.3 | 0 | 2 | 0 | 29.4 |
| Little Choptank River | M | Cason | 9/7,9/12,9/19 | 10-Oct | 12 | 3.8 | 0 | 1 | 0 | 9.8 |
| | | | | | 8 | 5.1 | 0 | 1 | 0 | 7.8 |
| | | | | | 10 | 7.4 | 0 | 3 | 0 | 14 |
| | | | | | 25 | 5.6 | 0 | 1 | 0 | 10.7 |
| Nanticoke River | L | Evans | 7/18,7/19,8/22,9/27 | 10-Oct | 6 | 0.2 | 0 | 0 | 0 | 38 |
| | | | | | 6 | 5.5 | 0 | 2 | 0 | 29 |
| | | | | | 11 | 2.5 | 0 | 1 | 0 | 29.8 |
| | | | | | 3 | 1.7 | 0 | 1 | 0 | 26.6 |

The amount of live spat per shell in each quad was multiplied by the total amount of shell found in each quad to calculate the amount of spat per quad detected by the post-planting monitoring survey. Spat survival was then calculated as the percentage of spat planted (per quad as the initial spat per shell multiplied by the total shells per quad) that was detected by the survey. The mean per quad spat survival for 2011 plantings was 13.8%. However, it is important to note the range of the data was 0.00% survival (Lecompte) to 82.5 % survival (Blunt). It is interesting to note that although the plantings were not directly on top of each other, the lowest quad survival in 2010 was recorded at Blunt (0%), which is the bar with the highest quad survival in 2011. This is just one example of the variation found in spat survival between years. The quad-sampled percent survival of spat planted by bar in 2011 is presented in Table 4.7**.** A comparison of the quad-sampled percent survival to the bar survival at each site is presented in Table 4.8; at each bar, survival values are relatively similar.

Table 4.7 – 2011 spat survival by bar, per quad. Rivers are further divided into sections as follows, L: lower, M: middle, and U: upriver.

| Region/River | Section | Bar Name | Shells in Quad | Initial Spat per Quad | Mean Live per Shell | Total Live Spat per Quad | Quad % Survival | Site % Survival | SEM |
|---|---|---|---|---|---|---|---|---|---|
| Chester River | L | Blunt | 30 | 330 | 6 | 179 | 54.2 | 64.6 | 5.9 |
| | | | 11 | 121 | 6.3 | 69 | 57 | | |
| | | | 14 | 154 | 9.1 | 127 | 82.5 | | |
| | M | Devil's Playground | 4 | 90 | 0.3 | 1 | 1.1 | 12.8 | 8.1 |
| | | | 2 | 45 | 1 | 2 | 4.4 | | |
| | | | 13 | 292.5 | 2 | 26 | 8.9 | | |
| | | | 4 | 90 | 8.3 | 33 | 36.7 | | |
| Choptank River | M | Lecompte | 28 | 422.8 | 0.2 | 6 | 1.4 | 0.4 | 0.2 |
| | | | 22 | 332.2 | 0.3 | 6 | 1.8 | | |
| | | | 38 | 573.8 | 0.1 | 3 | 0.5 | | |
| | | | 19 | 286.9 | 0 | 0 | 0 | | |
| | | | 22 | 332.2 | 0 | 0 | 0 | | |
| | | | 19 | 286.9 | 0 | 0 | 0 | | |
| | | | 12 | 181.2 | 0 | 0 | 0 | | |
| | | | 11 | 166.1 | 0 | 0 | 0 | | |
| | | | 2 | 30.2 | 0 | 0 | 0 | | |
| | U | Bolingbroke Sand | 18 | 374.4 | 1.4 | 26 | 6.9 | 5.3 | 1.5 |
| | | | 10 | 208 | 0.9 | 9 | 4.3 | | |
| | | | 19 | 395.2 | 2.2 | 41 | 10.4 | | |
| | | | 17 | 353.6 | 0.5 | 9 | 2.5 | | |
| | | | 5 | 104 | 0 | 0 | 0 | | |
| | | | 15 | 312 | 1.5 | 23 | 7.4 | | |
| Eastern Bay | M | Cabin Creek | 22 | 301.4 | 0.2 | 4 | 1.3 | 5.7 | 2 |
| | | | 25 | 342.5 | 0.3 | 8 | 2.3 | | |
| | | | 15 | 205.5 | 0.2 | 3 | 1.5 | | |
| | | | 5 | 68.5 | 2 | 10 | 14.6 | | |
| | | | 6 | 82.2 | 1.3 | 8 | 9.7 | | |
| | | | 4 | 54.8 | 0.3 | 1 | 1.8 | | |
| | | | 6 | 82.2 | 1.2 | 7 | 8.5 | | |
| Harris Creek | L | Turkey Neck | 26 | 501.8 | 3.5 | 91 | 18.1 | 10.5 | 1.9 |
| | | | 36 | 694.8 | 1.6 | 59 | 8.5 | | |
| | | | 33 | 636.9 | 2 | 66 | 10.4 | | |
| | | | 13 | 250.9 | 0.9 | 12 | 4.8 | | |
| | | | 9 | 173.7 | 2.6 | 23 | 13.2 | | |
| | | | 15 | 289.5 | 1.5 | 23 | 7.9 | | |
| | M | Mill Point | 12 | 186 | 3.2 | 38 | 20.4 | 15.6 | 1.8 |
| | | | 18 | 279 | 1.9 | 35 | 12.5 | | |
| | | | 23 | 356.5 | 2.5 | 57 | 16 | | |
| | | | 25 | 387.5 | 1.8 | 44 | 11.4 | | |
| | | | 30 | 465 | 1.9 | 57 | 12.3 | | |
| | | | 12 | 186 | 3.3 | 39 | 21 | | |
| Little Choptank River | M | Cason | 12 | 208.8 | 3.8 | 45 | 21.6 | 31.4 | 4.4 |
| | | | 8 | 139.2 | 5.1 | 41 | 29.5 | | |
| | | | 10 | 174 | 7.4 | 74 | 42.5 | | |
| | | | 25 | 435 | 5.6 | 140 | 32.2 | | |
| Nanticoke River | L | Evans | 6 | 81 | 0.2 | 1 | 1.2 | 18.3 | 8.3 |
| | | | 6 | 81 | 5.5 | 33 | 40.7 | | |
| | | | 11 | 148.5 | 2.5 | 28 | 18.9 | | |
| | | | 3 | 40.5 | 1.7 | 5 | 12.3 | | |
| | | | **MEAN:** | **251.7** | **2.1** | **30.9** | **13.8** | **18.3** | **3.8** |

Table 4.8-- Comparison of bar calculated survival to quad calculated survival. Rivers are further divided into sections as follows, L: lower, M: middle, and U: upriver. Values are similar within each bar.

| **Region/River** | **Section** | **Bar Name** | **2011 Bar % Survival** | **2011 Quad % Survival** |
|---|---|---|---|---|
| Chester River | L | Blunt | 64.6 | 64.6 |
| Choptank River | M | LeCompte | 0.4 | 0.4 |
| | U | Bolingbroke Sand | 5.2 | 5.3 |
| Eastern Bay | M | Cabin Creek | 6 | 5.7 |
| Harris Creek | L | Turkey Neck | 9.7 | 10.5 |
| | M | Mill Point | 15 | 15.6 |
| Nanticoke River | U | Evans | 18.7 | 18.3 |

In order to examine the source of the variability seen in post-planting spat per shell and percent survival at the quadrat level, 2011 quadrat data were examined for a relationship between spat survival and initial spat density. These data were also compared to quadrat data collected during the 2010 post-planting monitoring survey. As in the comparisons without quadrat-sampling, and also similar to 2010, no clear trend was observed. Figure 4.5 shows that there was no direct relationship between the initial spat per quad and spat survival in 2011 or 2010.

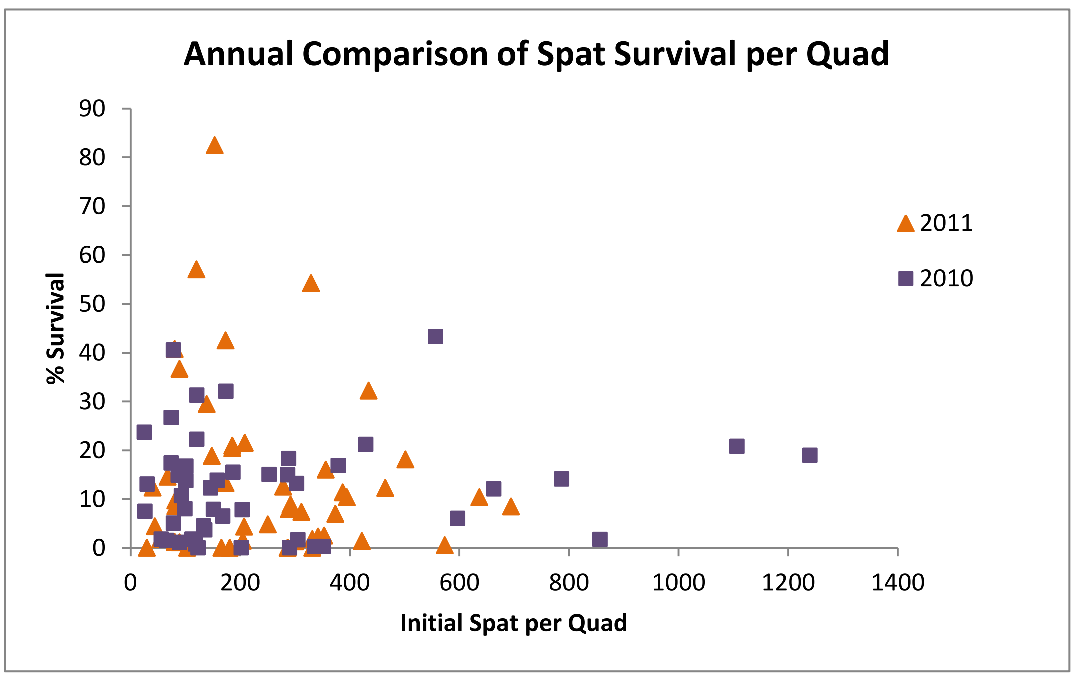



Figure 4.5– 2011 and 2010 data showing the spat survival relative to initial hatchery spat per quad. No clear trend exists between initial spat density and survival in either year.
The intent behind quadrat-based sampling was to collect data across a range of shell densities, in order to identify any patterns related to spat-planting density. However, achieving a wide

range of initial spat on shell densities proved difficult in 2010, as most of the quad collected had less than 500 spat initially in the area sampled by the quad (see Figure 4.5). An attempt was made to address this issue in 2011, and some high density quads were collected, but still a majority of the quads contained less than 500 spat initially in the area sampled by the quad (see Figure 4.5). Therefore, although it is difficult to make conclusive statements about the effect of initial spat density on spat survival, these data do not suggest that initial spat density (at least in densities less than 600 spat/quad) impacts spat survival 4 – 8 weeks post planting.

**Conclusions:**

The overall spat survival observed during the 2011 post-planting monitoring survey was the highest of the four years that this intensive survey has taken place. 2011 was an anomalous year in many respects; the mean salinity in the Chesapeake Bay during the first 2/3 of the planting season was at record lows due to the path of hurricane Irene centered over the Chesapeake followed by the remains of Tropical Storm Lee shortly thereafter, during the heart of planting season. Not only did these storms decrease the salinity in the Bay significantly, but these systems may have also affected the presence of predators in the Bay that could have also had an impact on spat survival. In order to compensate for this low salinity, the ORP shifted its focus to planting sites in the southern half of the Maryland portion of the Chesapeake Bay, rather than some of the planned more northern sites. The flexibility of the ORP to adapt to the environmental variation experienced during the planting season paid off, as average spat survival was 27% in 2011. Survival was not directly tied to the location of the planting, as high survival was observed at the northern-most and southern-most sites planted. Although no direct effect of salinity on spat survival was observed in 2011, the avoidance of very low salinity sites during the beginning of the planting season was prudent and a target salinity range for planting sites should continue to be used in the future. In addition, site selection was improved based on available side-scan sonar data and targets planted in 2011 may have constituted more favorable bottom conditions.

The quadrat method of sample collection is a valuable tool for starting to understand the effect of density on spat survival. Unfortunately, the range of densities at which we are currently able to collect spat is not large enough to observe a trend. However, due to the valuable nature of data collected at the same scale (quadrat) and the ease of which the diver can collect using quads, we recommend continued use of the quadrat sampling method whenever possible.

The data collected during the post-planting monitoring survey from 2008 – 2011 speaks to the variation present in the survival of hatchery spat on shell 4 – 8 weeks post planting. For example, the bar with the lowest quadrat-based survival in 2010 (0%) was the bar with the highest quadrat-based survival in 2011 (83%). Spat survival at the bar level consistently ranges from 0% to over 60% in each year sampled and does not seem to be related to any of the variables that we have measured in our survey (total amount of spat and shell, density of spat and shell, growth rate, location, environment). Considering the complex process involved in executing a successful hatchery spat on shell planting, from the spawning of spat at the hatchery, to their transport to the site, to the conditions they grow in and the sampling method used to estimate survival, it is not surprising that pinpointing factors that consistently influence survival is extremely difficult.

The large scale of the planting survey further exacerbates the difficulties mentioned above and therefore during the 2011 planting season, the Paynter lab partnered with the Horn Point Lab hatchery to design and execute a small-scale experiment to examine the effect of spat size and bottom type on spat survival. These variables are difficult to control in large plantings and we felt that only through a small experiment could accurate data be collected and analyzed. Detailed analyses of the data collected in this experiment will be presented to the ORP in a separate report, but the data generally showed no effect of spat size on survival and a significant substrate effect. Spat planted on muddy bottom survived significantly worse than spat planted on sandy or shelly bottom. Additionally, three bars were selected to investigate any effects of sidedness on spat survival. The intent of this project was to study the orientation of the shell on the bottom (cup-side up or down) and evaluate the spat survival relative to this orientation. This was also done in collaboration with the Horn Point Laboratory hatchery and data will be analyzed and also presented to the ORP in a separate report. These experiments are just a start at understanding the individual factors that could influence short term spat survival and we hope to not only continue to conduct small-scale experiments but also to apply our experimental findings to large-scale plantings in the future. Our experimental plans for the 2012 planting season include another deployment of the bottom type/spat size experiment mentioned above as well as an experiment aimed at understanding how the size of spat predators affects survival.

## Section V: Patent Tong Survey 2011

Patent tong surveys were conducted throughout 2011 on oyster bars in the Chester, Choptank, Magothy, Miles and Severn Rivers as well as the Upper Bay. Below is the list of all sites sampled. Rivers are further divided into sections as follows, L: lower, M: middle, and U: upriver.

Table 5.1. Oyster bars tonged during the 2011 field season by river and site. Rivers are further divided into sections as follows, L: lower, M: middle, and U: upriver.

| Region/River | Section | Bar Name | Planting Year | Date Surveyed (2011) |
|---|---|---|---|---|
| Chester River | L | Blunt | 2008 | 12-Sep |
| | U | Copper's Hill | 2007, 2008 | 9-Sep |
| | U | Drum Point | 2007 | 1-Sep |
| | L | Strong Bay | 2008 | 17-Oct |
| | L | Strong Bay | 2005 | 21, 30-Sep; 5, 11, 13, 17, 18-Oct |
| | M | Willow Bottom | 2007 | 1-Sep |
| Choptank River | U | Bolingbroke Sand | 2008 | 10/13, 10/14 |
| | U | Green Marsh | 2008 | 11-Oct |
| | U | Shoal Creek II | 2005, 2008 | 14, 31-Oct |
| | U | States Bank | 2005, 2008 | 2, 3-Nov |
| Magothy River | M | Ulmstead Point | 2006 | 2-Nov |
| Miles River | U | Old Orchard | 2008 | 21-Nov |
| Severn River | L | Chinks Point | 2008 | 2-Nov |
| Upper Bay | U | Six Foot Knoll | 2008 | 7-Oct |

Sampling occurred at these bars using an extensive patent tong survey throughout the planted area. A grid of 25m x 25m cells was overlaid on the planted area and each grid cell was sampled with hydraulic patent tongs. Figure 5.1 shows an example of the grid with sampling points from Willow Bottom oyster bar 2011 patent tong survey. Figure 5.2 indicates the sampling sites for the 2011 patent tong survey. Red dots represent individual bars sampled, rivers are labeled in yellow. Number and size (mm) of live and dead (box) oysters were recorded at each grab. In addition, shell score (the amount of shell substrate collected in each tong grab) was quantified on a scale of zero to five. The density of oysters at each point was calculated using the area of the tongs and a population estimate was generated using this density data. The total biomass of oysters at each bar was calculated according to Lidell (2007). The density of oysters and shell score at each patent tong survey point was recorded using GIS. These spatial data allowed for shell score and density plots to be generated to illustrate the spatial distribution of shell and oysters at each site (Figures 5.3-15).

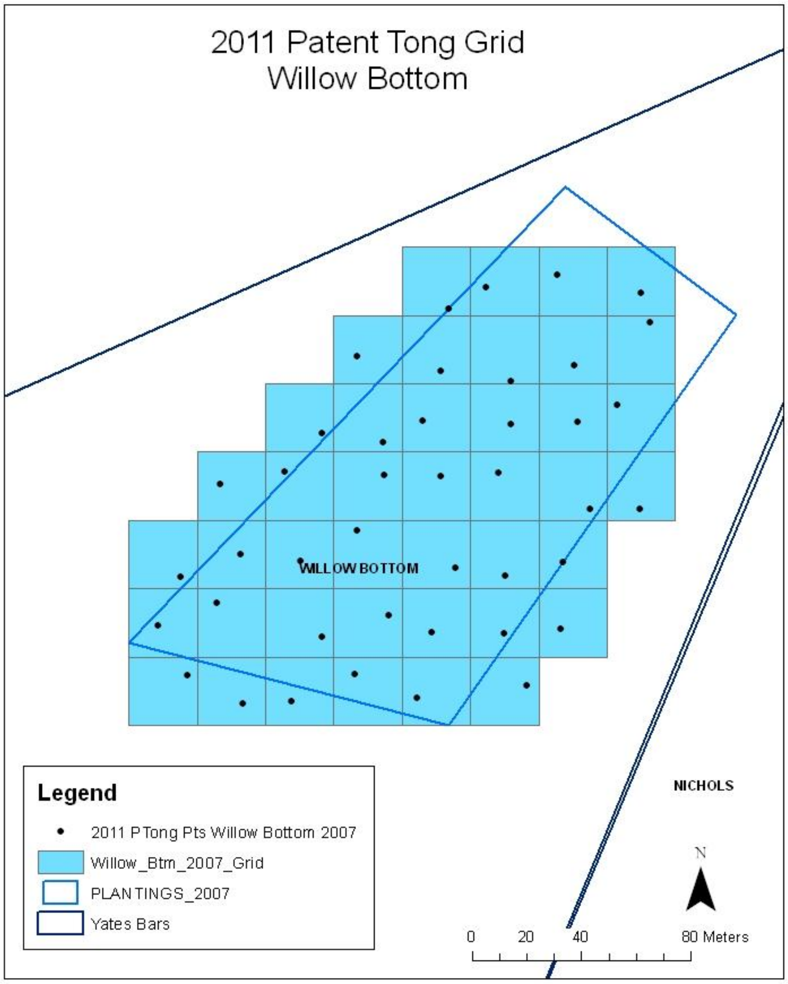



Figure 5.1. Example of a patent tong grid used in the 2011 patent tong season. Each grid cell is 25x25m in size and each black point represents one patent tong grab.

Table 5.2 summarizes the metrics collected for each site sampled in 2011 (amount of live and dead oysters, percentage of oysters found that were dead, live oyster size and density, percent of area sampled with greater than 5oy/$m^2$, percent of area sampled with shell coverage, population estimate, total biomass and *Perkinsus marinus* (Dermo) prevalence and weighted prevalence). At Strong Bay and States Bank multiple year classes were sampled and disease was determined separately for each age class. At Strong Bay older animals had higher disease prevalence and weighted prevalence than their younger counterparts, but the opposite was true at States Bank. At Old Orchard and Willow Bottom, too few animals were found to test for Dermo.

2011 Patent Tong Sampling Sites

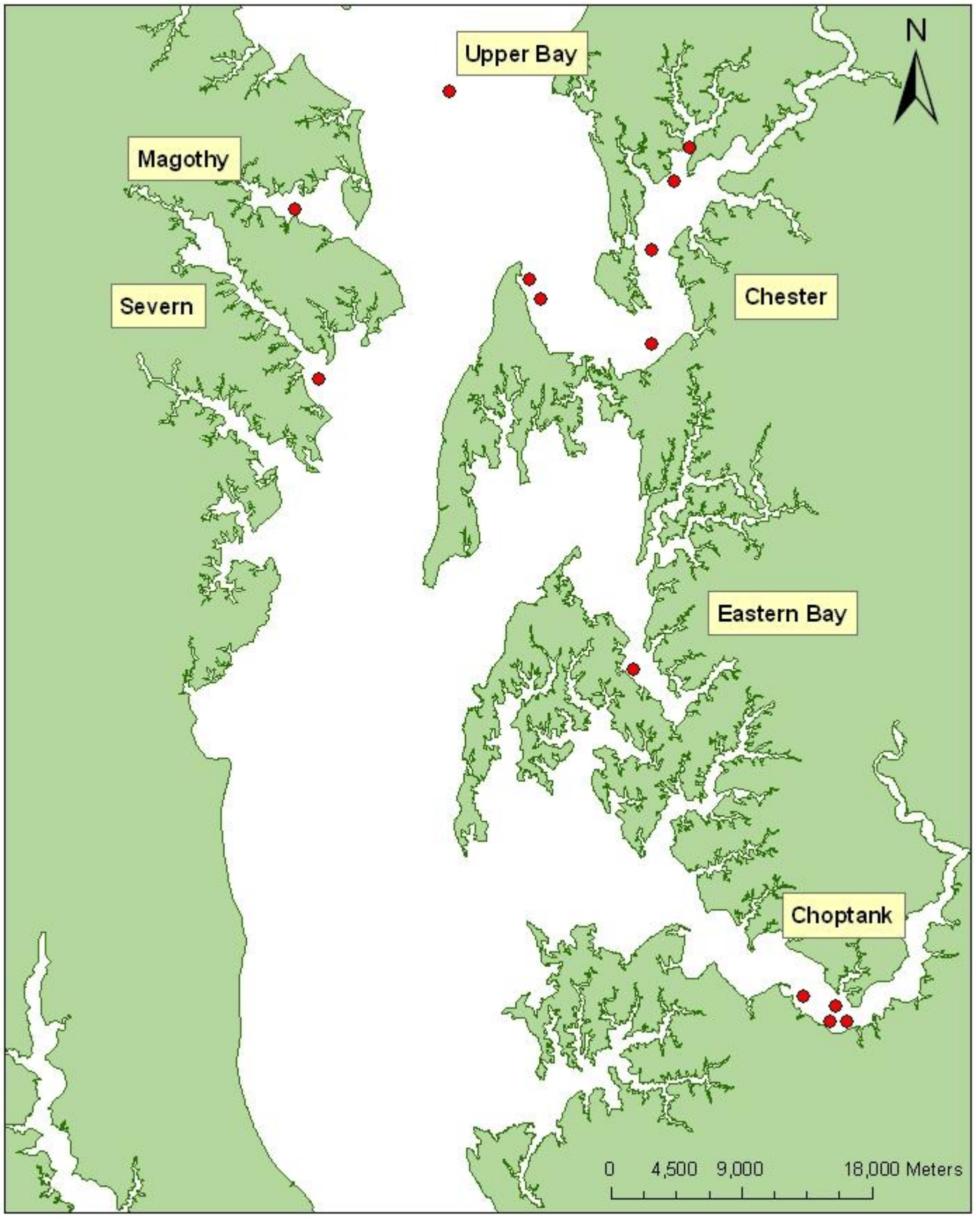



Figure 5.2. 2011 patent tong survey sampling sites. Red dots represent individual bars sampled, rivers are labeled in yellow. Bar names can be found in Table 5.1, above.

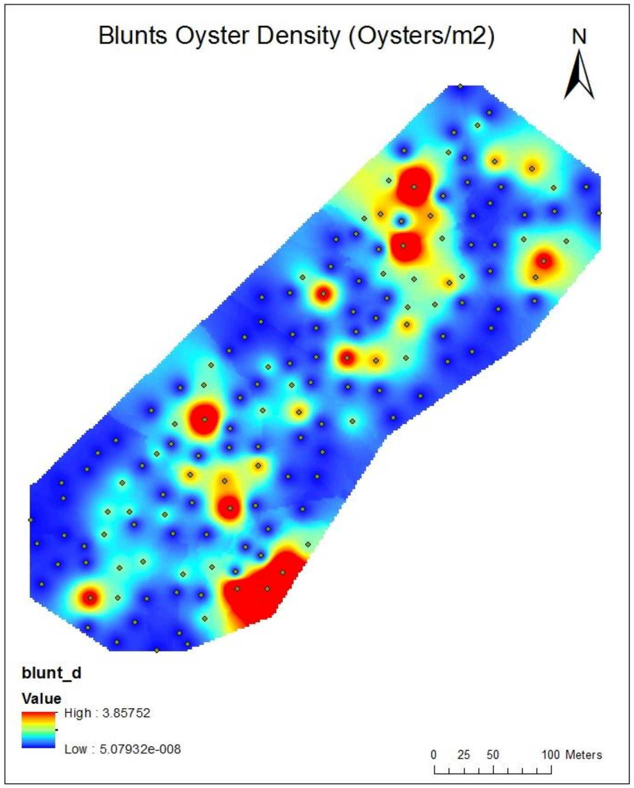
Table 5.2. Data collected on 2011 patent tong surveys.

| Region/River | Bar Name | Planting Year | # Live Oysters Collected | # Dead Oysters Collected | Dead Oysters (% of Total) | Average Live Oyster Length (mm) | SEM | Average Live Oyster Density (#/m$^2$) | SEM | % Total Area >5 oy/m$^2$ | % Total Area with Shell Coverage | Population Estimate (Oysters) | Biomass (kg) | Dermo Prevalence (%) | Dermo Weighted Prevalence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chester River | Blunt | 2008 | 112 | 7 | 6 | 104 | 1.8 | <1 | 0.1 | 0 | 98.7 | 38,674 | 63 | 32.3 | 0.05 |
| | Copper's Hill | 2007, 2008 | 55 | 4 | 7 | 95 | 2.6 | <1 | 0.1 | 0 | 51.6 | 18,992 | 27 | 50 | 0.22 |
| | Drum Point | 2007 | 45 | 2 | 4 | 104 | 1.2 | 1 | 0.1 | 0.7 | 15 | 15,539 | 29 | 23.3 | 0.04 |
| | Strong Bay | 2008 | 243 | 13 | 5 | 86 | 1.5 | 2 | 0.2 | 3.3 | 39.9 | 83,909 | 112 | 60 | 0.22 |
| | Strong Bay | 2005 (A) | 1743 | 85 | 5 | 100 | 0.4 | 2 | 0.1 | 11.6 | 56.7 | 99,772 | 839 | 60 | 0.51 |
| | Strong Bay | 2005 (E) | - | - | - | - | - | - | - | - | - | - | - | 58.6 | 0.29 |
| | Willow Bottom | 2007 | 9 | 3 | 25 | 111 | 5 | <1 | 0 | 0 | 13.1 | 3,108 | 6 | N/A | N/A |
| Choptank River | Bolingbroke Sand | 2008 | 267 | 6 | 2 | 90 | 0.8 | 1 | 0.1 | 3.3 | 49.7 | 103,649 | 126 | 10 | 0.17 |
| | Green Marsh | 2008 | 530 | 23 | 4 | 105 | 0.6 | 4 | 0.3 | 17 | 32.7 | 205,745 | 368 | 56.7 | 0.22 |
| | Shoal Creek | 2005 | 2144 | 86 | 4 | 88 | 0.3 | 11 | 0.3 | 39.2 | 58.8 | 832,298 | 837 | 90 | 1.67 |
| | Shoal Creek | 2008 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | States Bank | 2005 | 2330 | 43 | 2 | 82 | 0.2 | 13 | 0.3 | 41.8 | 54.9 | 904,503 | 787 | 10 | 0.01 |
| | States Bank | 2008 | - | - | - | - | - | - | - | | | | | 46.7 | 0.15 |
| Magothy River | Ulmstead Point | 2006 | 121 | 26 | 18 | 106 | 0.6 | 4 | 0.5 | 3.3 | 10.5 | 41,782 | 79 | 3.7 | 0.04 |
| Miles River | Old Orchard | 2008 | 8 | 1 | 11 | 77 | 7.4 | <1 | 0 | 0 | 7.2 | 2,451 | 3 | N/A | N/A |
| Severn River | Chinks Point | 2008 | 310 | 11 | 3 | 90 | 0.6 | 4 | 0.6 | 3.9 | 23.5 | 107,044 | 133 | 20 | 0.11 |
| Upper Bay | Six Foot Knoll | 2008 | 149 | 236 | 61 | 86 | 0.8 | 1 | 0.4 | 1.3 | 38.6 | 51,450 | 56 | 33.3 | 0.1 |
| | **2011 Mean** | **-** | **576** | **39** | **11** | **94** | **-** | **4** | **-** | **9** | **39.4** | **-** | **-** | **39.6** | **0.27** |
| | **2011 Total** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **2,508,915** | **3,465** | **-** | **-** |

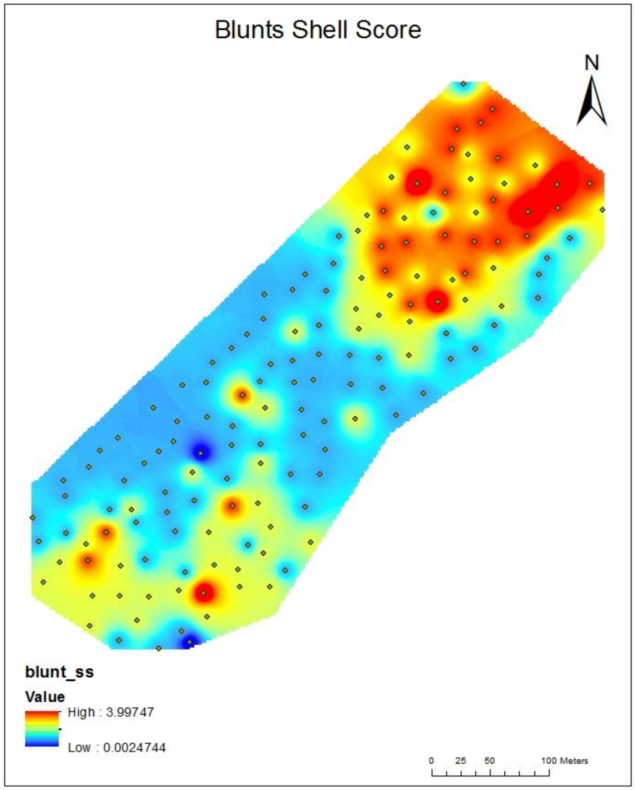
Table 5.3 below compares the population estimate at each bar surveyed in 2011 to the expected population based on the following mortality calculation: it is assumed that approximately 90% of spat are lost within one year after planting and 15% of the remaining population each subsequent year. As data below show, the estimated population of all bars falls below the expected calculated population. Additionally, the oyster density is again shown with biomass (per $m^2$). These values are metrics used to evaluate the success of a restored bar. A bar described as successful possesses both an oyster density of 15 or more oysters/$m^2$ and a biomass density of 15 or more g/$m^2$. Of the bars surveyed in 2011, none fit those criteria.

Table 5.3. A comparison of expected oyster population to estimated oyster population. Also shown are the oyster density and biomass per $m^2$ at each surveyed bar. Rivers are further divided into sections as follows, L: lower, M: middle, and U: upriver.

| Region/River | Section | Bar Name | Planting Year | Spat Planted | Expected 2011 Population (Oysters) | Population Estimate (Oysters) | % of Expected | Bar Oyster Density (#/m2) | Biomass(g) /m2 |
|---|---|---|---|---|---|---|---|---|---|
| Chester River | L | Blunt | 2008 | 21,040,000 | 1,520,140 | 38,674 | 2.5 | 0.4 | 0.7 |
| | L | Strong Bay | 2005 | 44,880,000 | 1,991,349 | 99,772 | 5 | 1.8 | 3.0 |
| | L | Strong Bay | 2008 | 15,120,000 | 1,092,420 | 83,909 | 7.7 | 2 | 2.6 |
| | M | Willow Bottom | 2007 | 7,680,000 | 471,648 | 3,108 | 0.7 | 0.1 | 0.2 |
| | U | Drum Point | 2007 | 2,310,000 | 141,863 | 15,539 | 11 | 0.6 | 1.2 |
| Choptank River | U | Bolingbroke Sand | 2008 | 10,720,000 | 774,520 | 103,649 | 13.4 | 1.5 | 1.8 |
| | U | Green Marsh | 2008 | 11,970,000 | 864,833 | 205,745 | 23.8 | 4.3 | 7.6 |
| Magothy River | M | Ulmstead Point | 2006 | 1,350,000 | 70,471 | 41,782 | 59.3 | 3.7 | 7.0 |
| Miles River | U | Old Orchard | 2008 | 9,670,000 | 698,658 | 2,451 | 0.4 | 0.1 | 0.1 |
| Severn River | L | Chinks Point | 2008 | 11,500,000 | 830,875 | 107,044 | 12.9 | 3.9 | 4.8 |
| Upper Bay | U | Six Foot Knoll | 2008 | 13,600,000 | 982,600 | 51,450 | 5.2 | 1.2 | 1.3 |

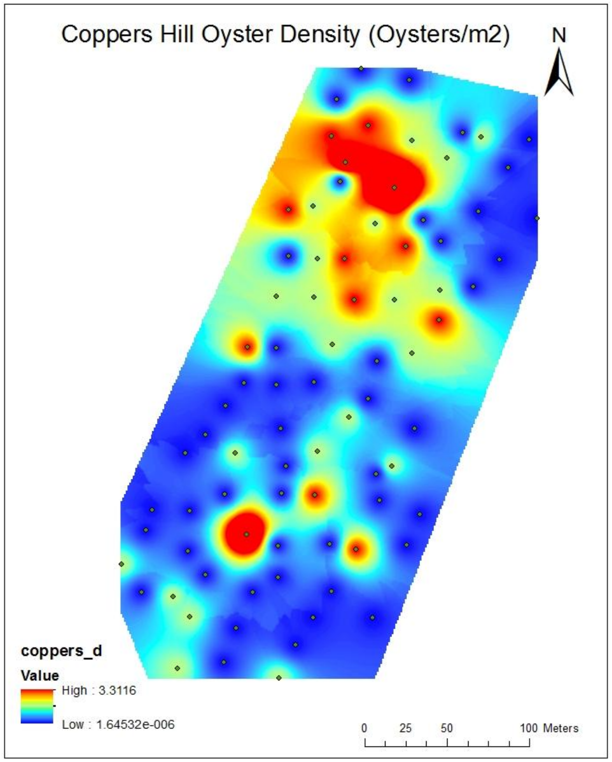



3a

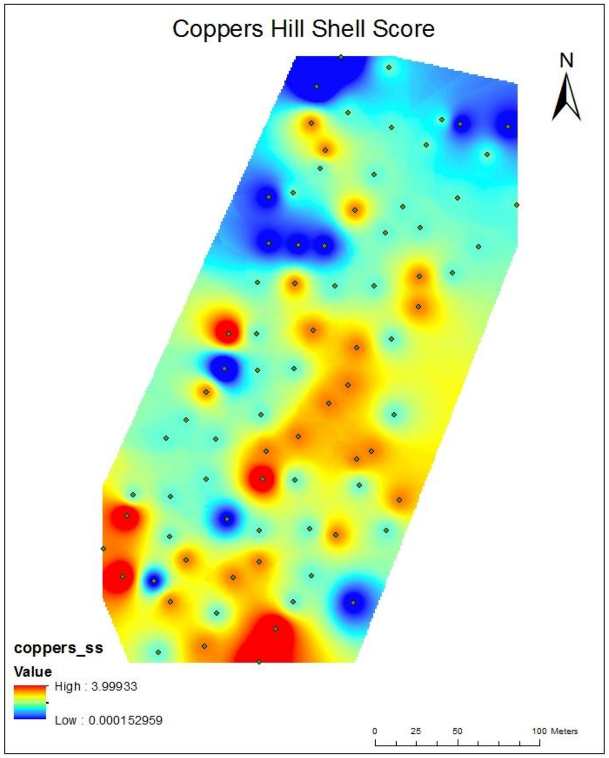



3b

Figure 5.3. Oyster density (3a) and shell score (3b) plots at Blunts, an oyster bar in the Chester River that was planted in 2008. Where oyster density was highest, shell score, overall, was also high. No oyster densities greater than 5oy/$m^2$ were observed, despite 99% shell coverage, indicating that not all areas with shell had oysters present.

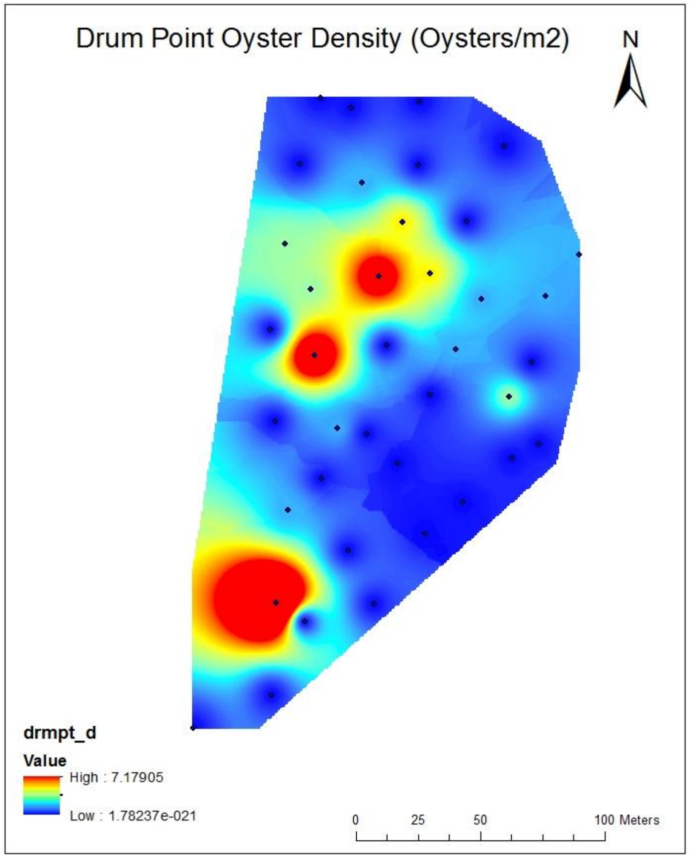



4a

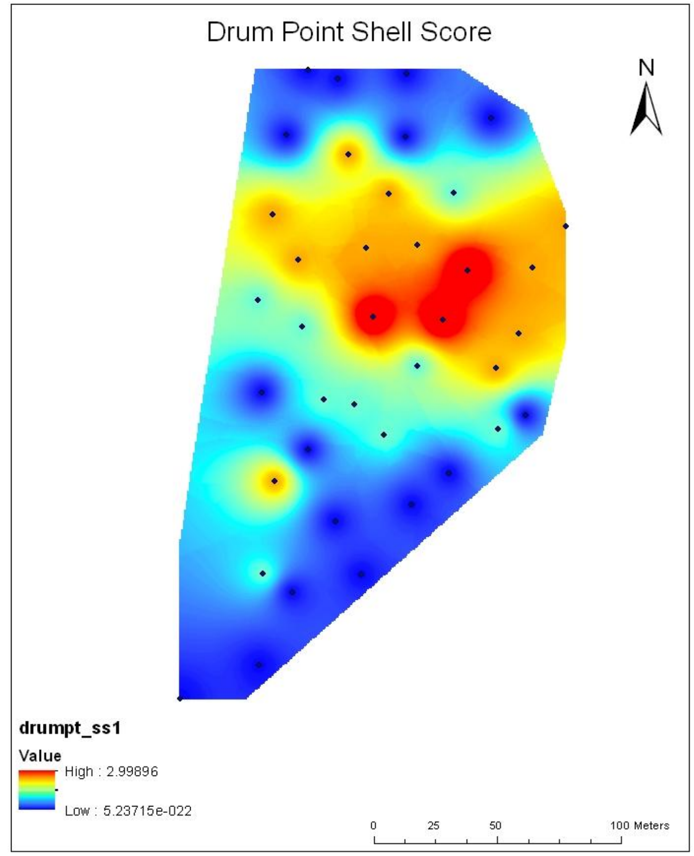



4b

Figure 5.4. Oyster density (4a) and shell score (4b) plots at Coppers Hill, an oyster bar in the Chester River that was planted in 2007 and 2008. The 2011 survey indicated no oyster densities greater than 5oy/m$^2$ and 52% shell coverage while the 2010 survey indicated 57% of the bar with oyster densities greater than 5oy/m$^2$ and 99% shell coverage. The source of this decline in oyster density and shell is likely a result of the bar being opened between the 2010 and 2011 surveys but also could be related to the increase in the prevalence of dermo at the site from 2010 (20%) to 2011 (50%), although infection intensity was very low in both years.

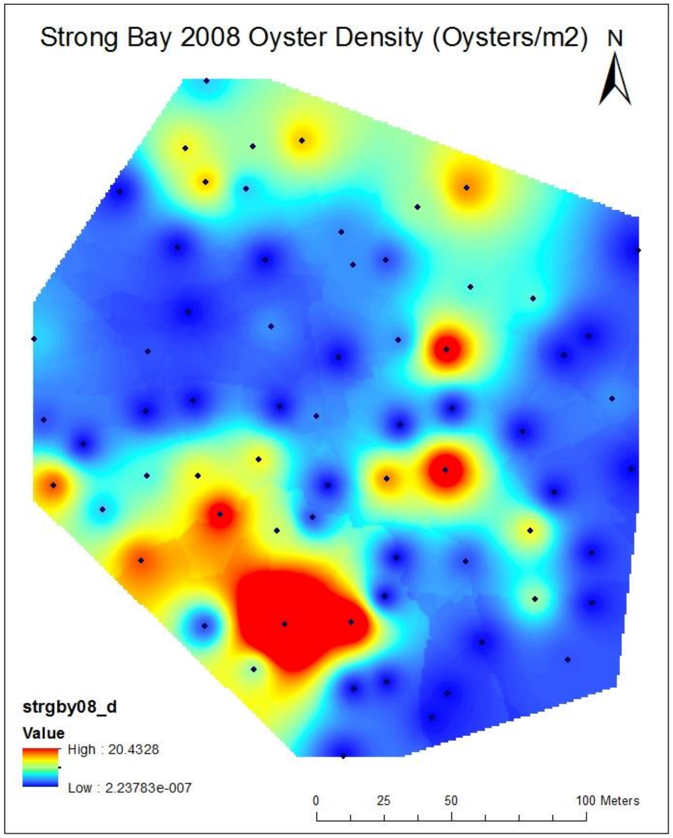



5a

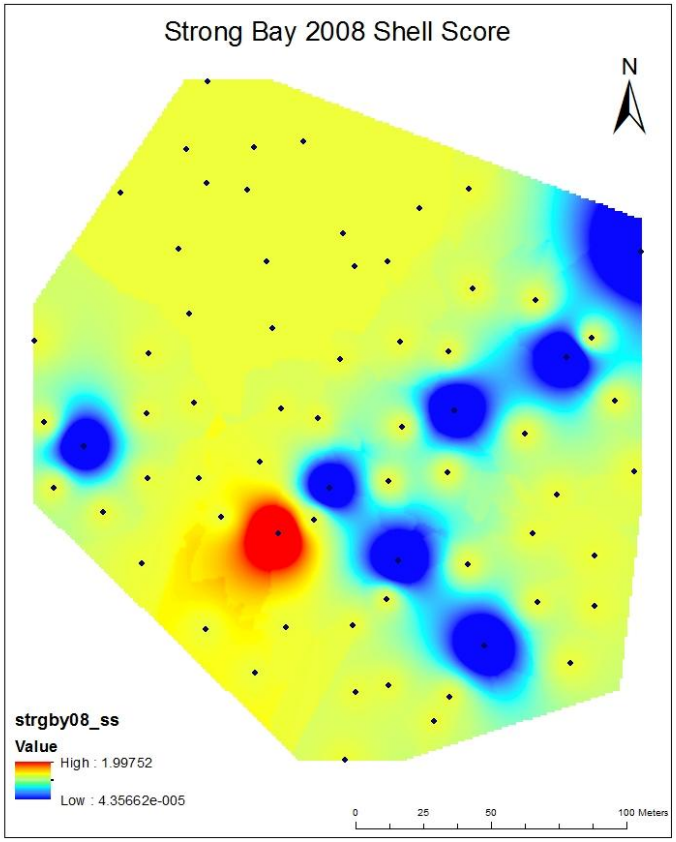



5b

Figure 5.5. Oyster density (5a) and shell score (5b) plots at Drum Point, an oyster bar in the Chester River that was planted in 2007. Both oyster density and shell score were low at this bar. Only 0.7% of the area surveyed had oysters at densities greater than $5oy/m^2$ and only 15% of the bar had any shell coverage. A decline in oyster density and shell coverage was observed at Drum Point between the 2010 and 2011 surveys, but it was not dramatic and likely reflects natural variation in the population.

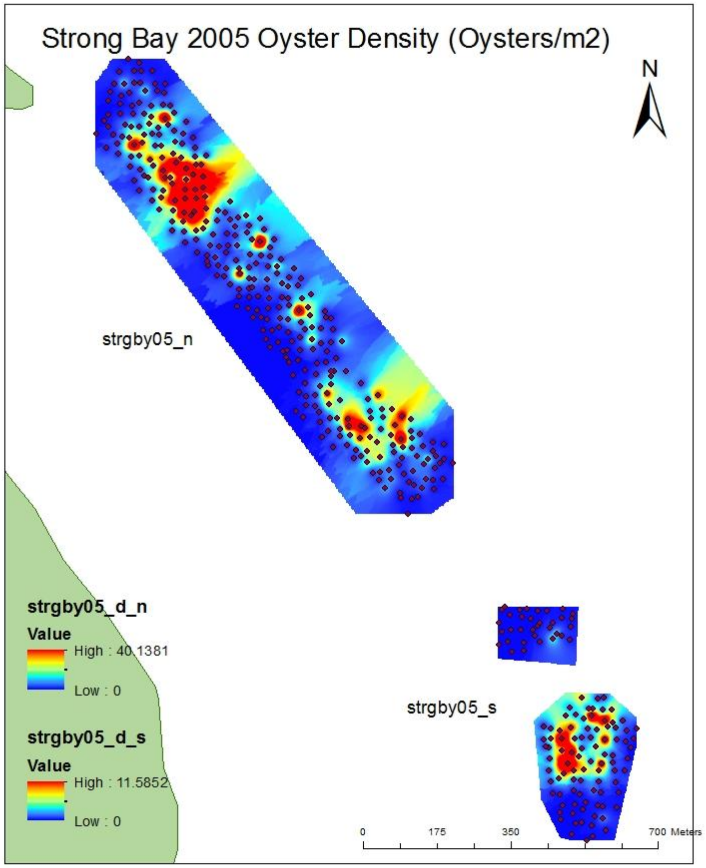



6a

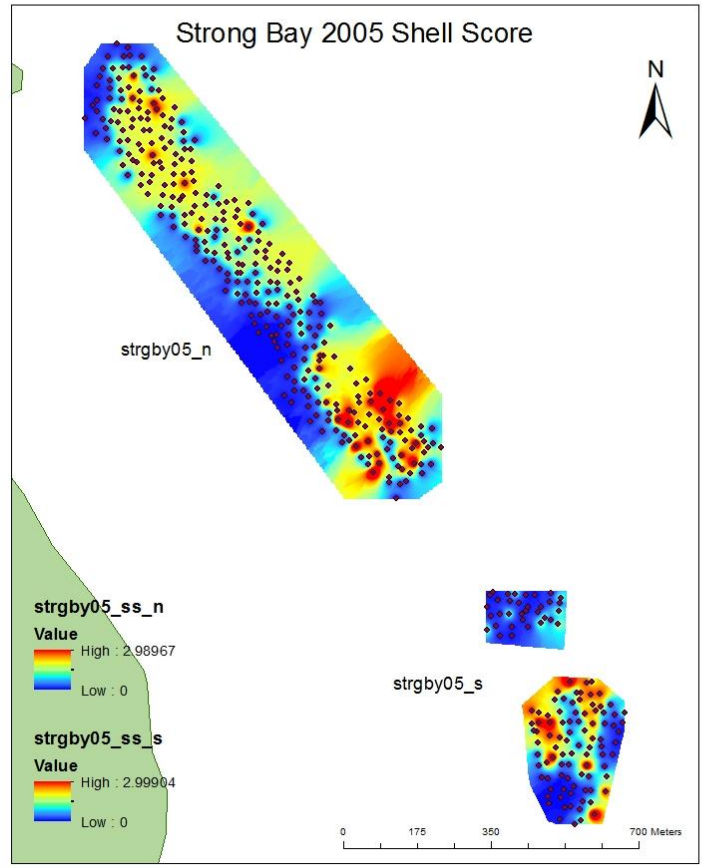



6b

Figure 5.6. Oyster density (6a) and shell score (6b) plots at Strong Bay, an oyster bar in the Chester River planted in 2008. Oyster densities and shell scores were low at this bar; only 3% of the area surveyed had oyster densities greater than 5oy/$m^2$, despite 40% shell coverage, indicating that not all areas with shell had oysters present.

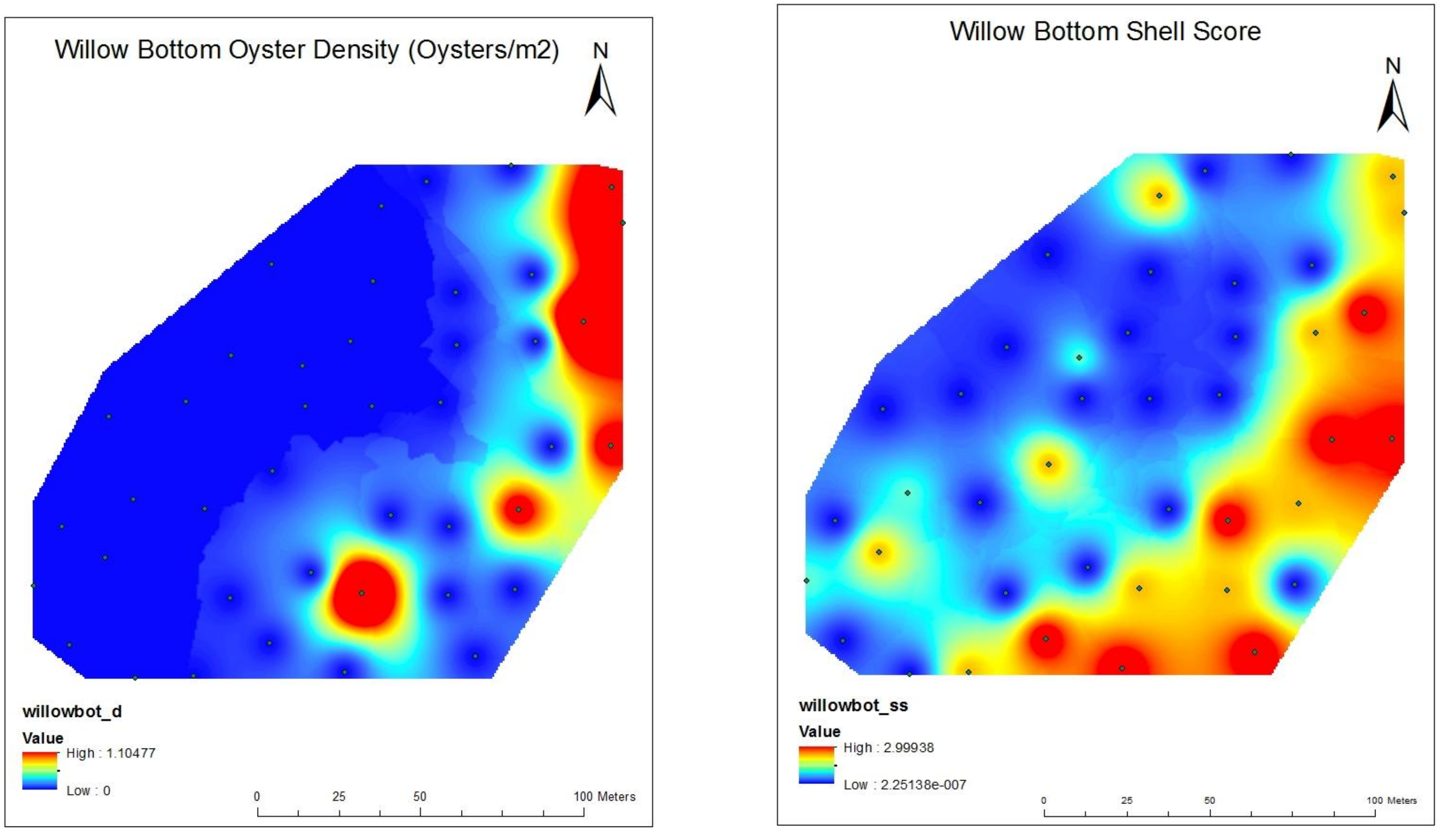



7a



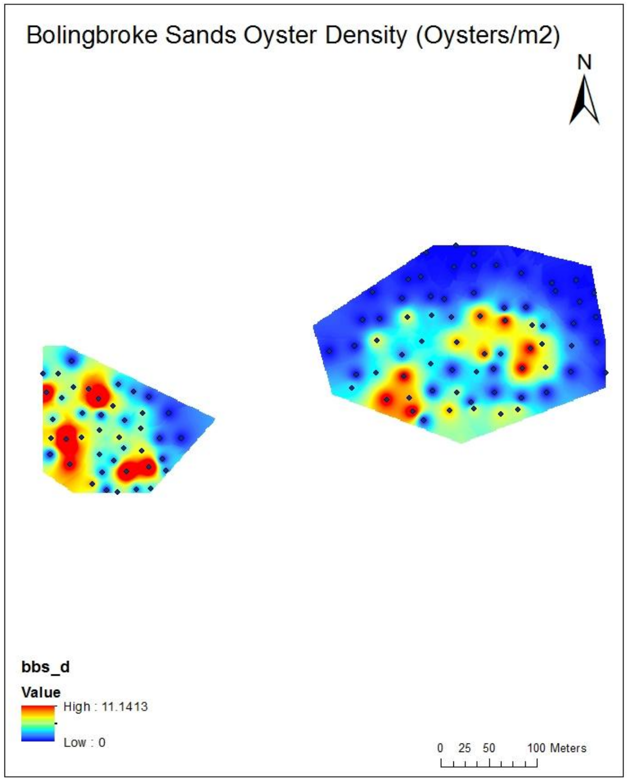

7b

Figure 5.7. Oyster density (7a) and shell score (7b) plots at Strong Bay, an oyster bar in the Chester River planted in 2005. Overall, in areas of high oyster density, shell score was also high. However, only 12% of the bar had oyster densities greater than 5oy/$m^2$ while 60% of the bar had shell coverage, indicating that not all areas with shell had oysters present.

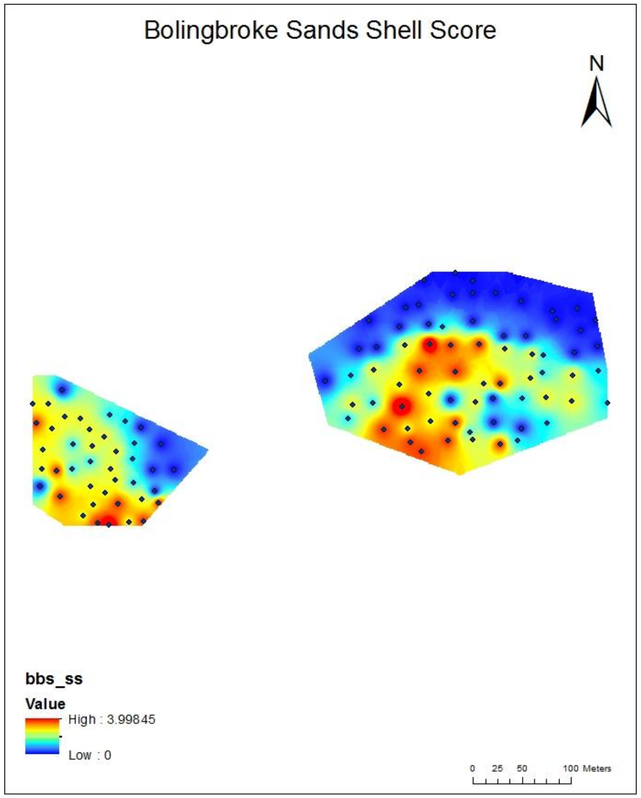



8a 8b

Figure 5.8. Oyster density (8a) and shell score (8b) plots at Willow Bottom, an oyster bar in the Chester River planted in 2007. Although shell score and oyster density correlate spatially at this bar, oyster and shell coverage are both poor overall. None of the bar has oyster density greater than 5oy/$m^2$ and only 13% of the bar had any shell coverage. A decline in oyster density and shell coverage was observed at Willow Bottom between the 2010 and 2011 surveys, but it was not dramatic and likely reflects natural variation in the population.

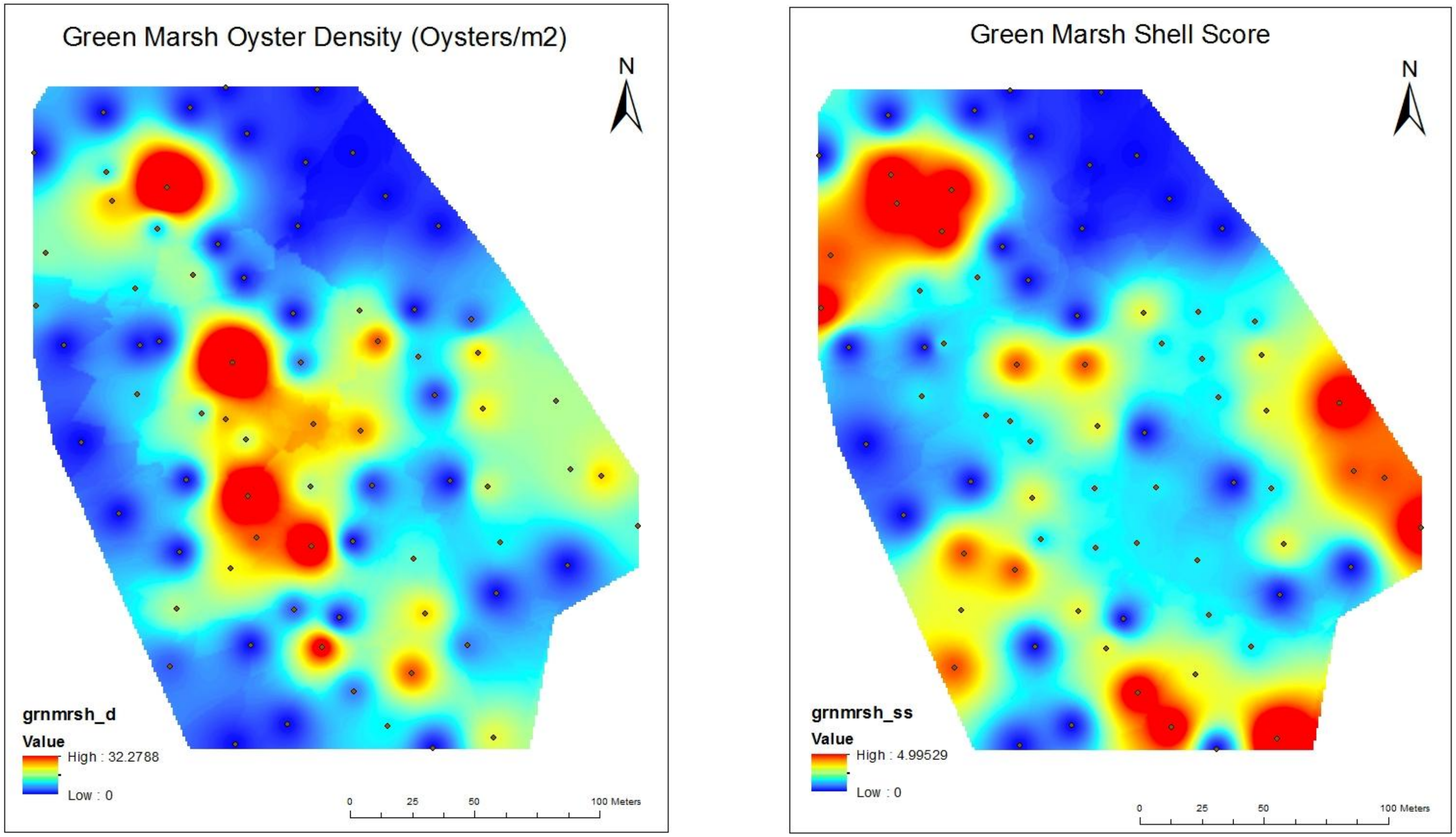



9a




9b

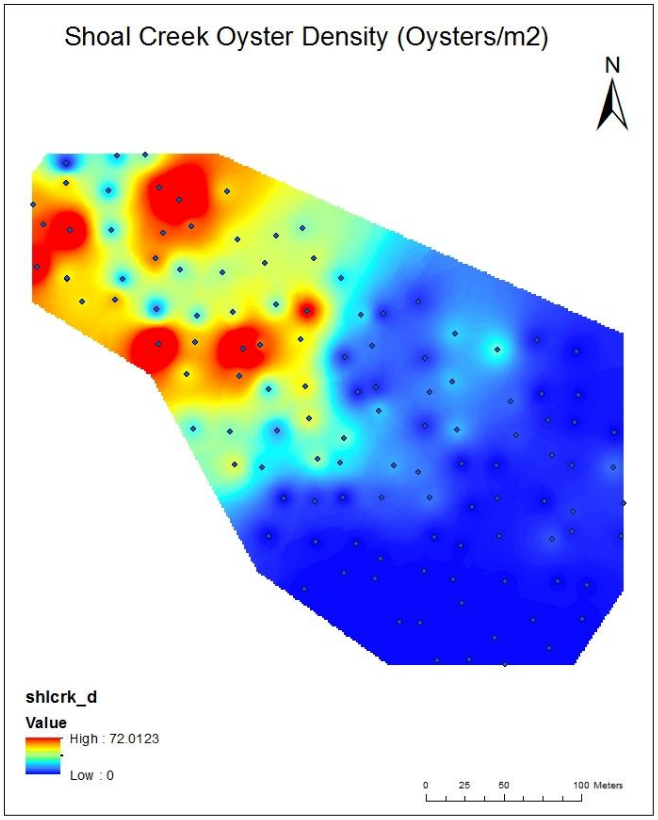
Figure 5.9. Oyster density (9a) and shell score (9b) plots at Bolingbroke Sands an oyster bar in the Choptank River planted in 2008. Areas of high oyster density also had high shell scores, however not all areas of high shell score yielded high oyster density. Only 3% of the bar had oyster densities greater than 5oy/$m^2$, while 50% of the bar had shell coverage, indicating that not all areas with shell had oysters present.

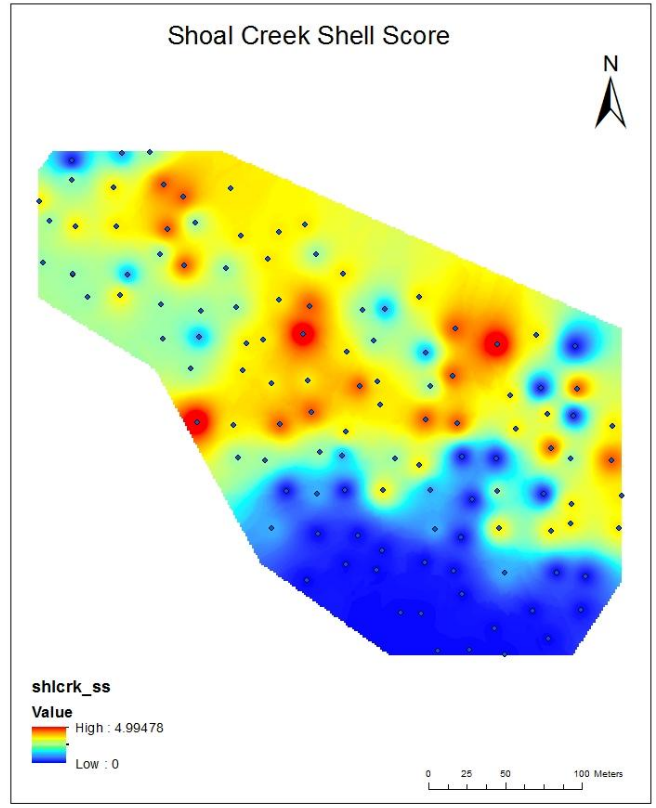



10a

10b

Figure 5.10. Oyster density (10a) and shell score (10b) plots at Green Marsh, an oyster bar in the Choptank River planted in 2008. Areas of highest oyster density did not occur in areas of highest shell score, however some shell coverage was present where all oysters were found. Seventeen percent of the bar had oyster densities greater than 5oy/$m^2$ and 33% of the bar had shell coverage, indicating that not all areas with shell had oysters present. A significant amount of rock was also found at this site that is not classified under shell coverage and therefore some of the areas without shell could have hard substrate in the form of rocks.

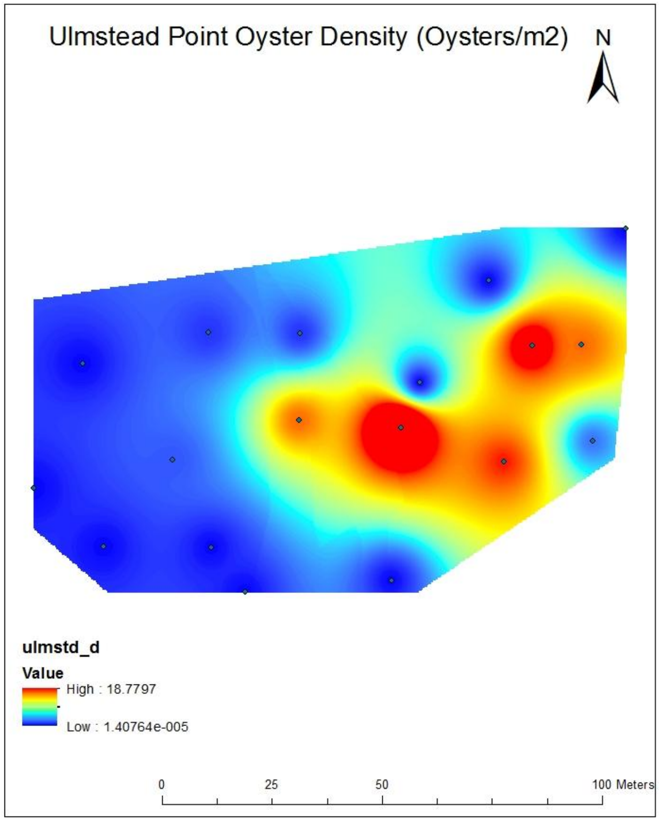


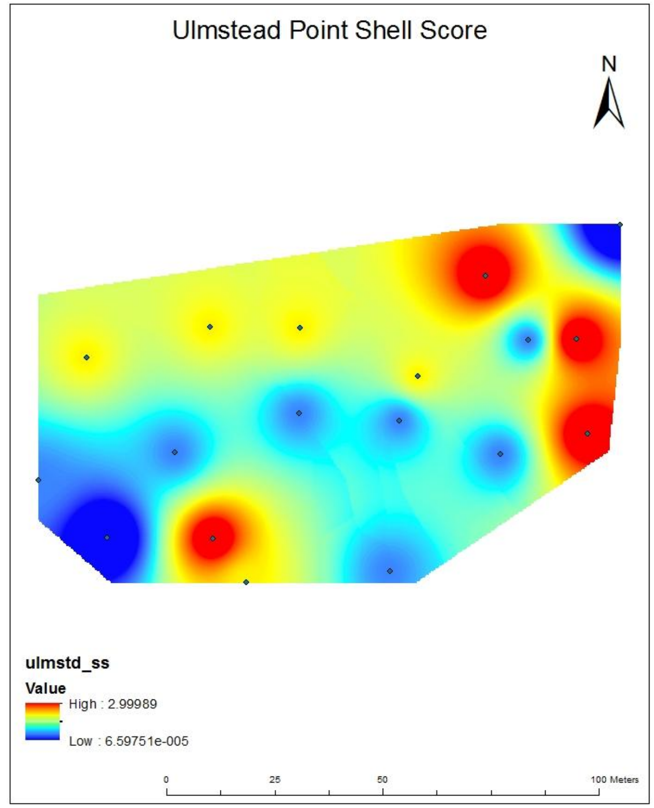

11a

11b

Figure 5.11. Oyster density (11a) and shell score (11b) plots at Shoal Creek, an oyster bar in the Choptank River planted in 2005 and 2008. Overall, in areas of high oyster density, shell score was also high. However, 39% of the bar had oyster densities greater than 5oy/$m^2$ while 59% of the bar had shell coverage, indicating that not all areas with shell had oysters present.

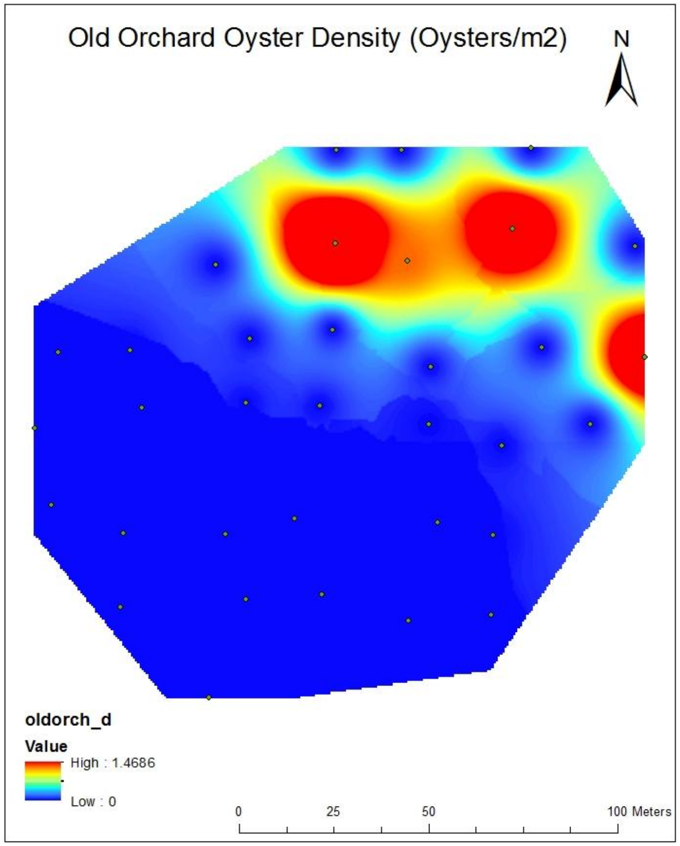



12a

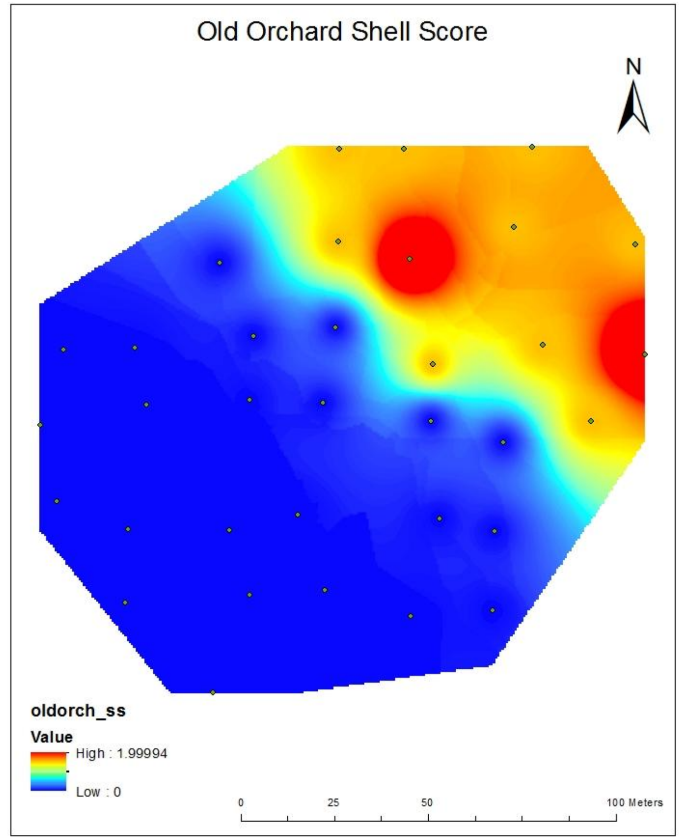



12b

Figure 5.12. Oyster density (12a) and shell score (12b) plots at Ulmstead Point, an oyster bar in the Magothy River planted in 2006. The 2011 survey indicated only 3% of the bar had oyster densities greater than 5oy/$m^2$ and only 11% shell coverage while the 2010 survey indicated 69% of the bar with oyster densities greater than 5oy/$m^2$ and 80% shell coverage. The source of this decline in oyster density and shell is unknown as disease prevalence and intensity declined between survey years, although the oysters with high disease in 2010 could have died over the winter and therefore were not observed in the 2011 survey.

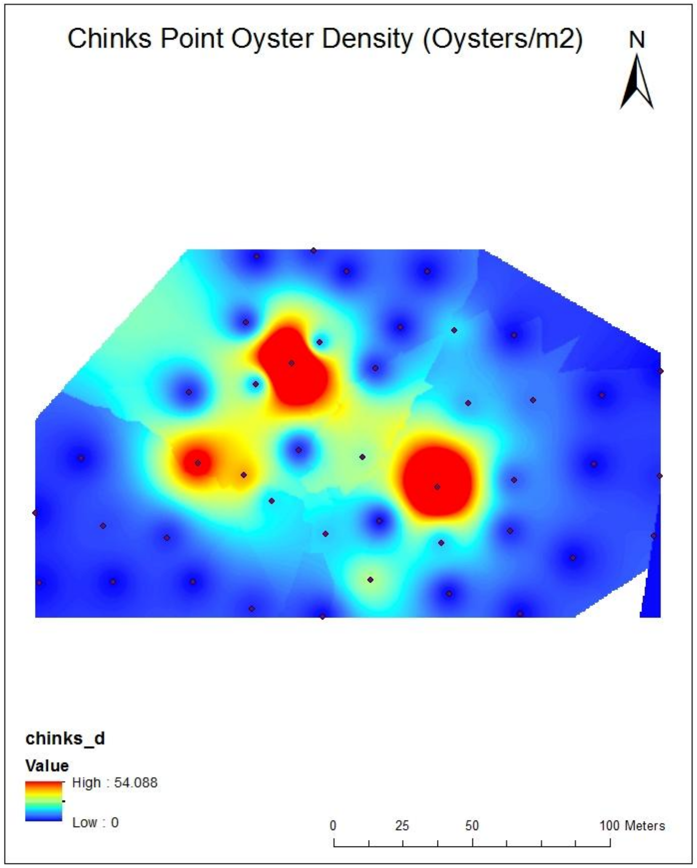



13a

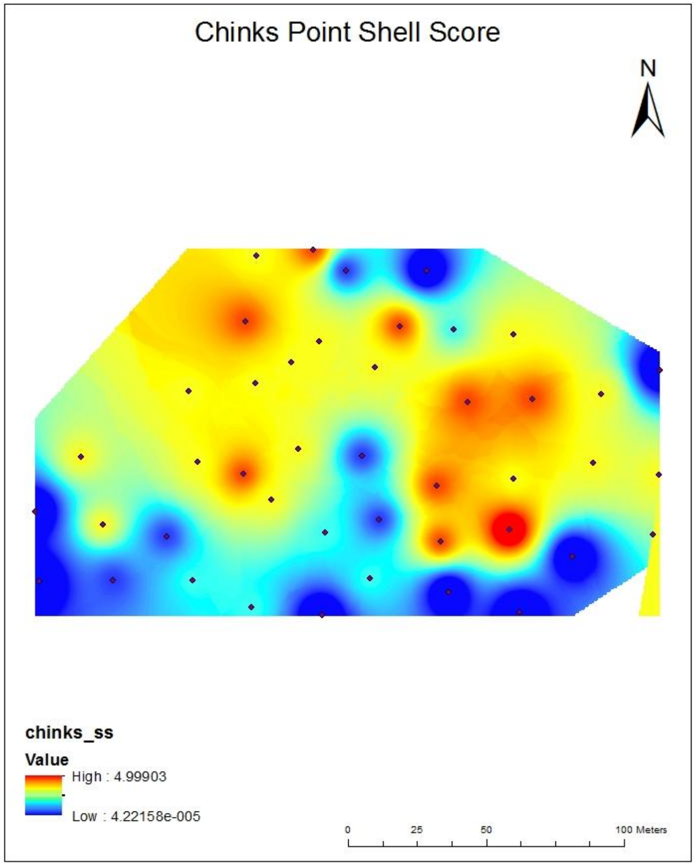



13b

Figure 5.13. Oyster density (13a) and shell score (13b) plots at Old Orchard, an oyster bar in the Miles River planted in 2008. Oyster densities and shell scores were low at this bar; none of the area surveyed had oyster densities greater than 5oy/$m^2$ and only 7% of the bar had any shell coverage.

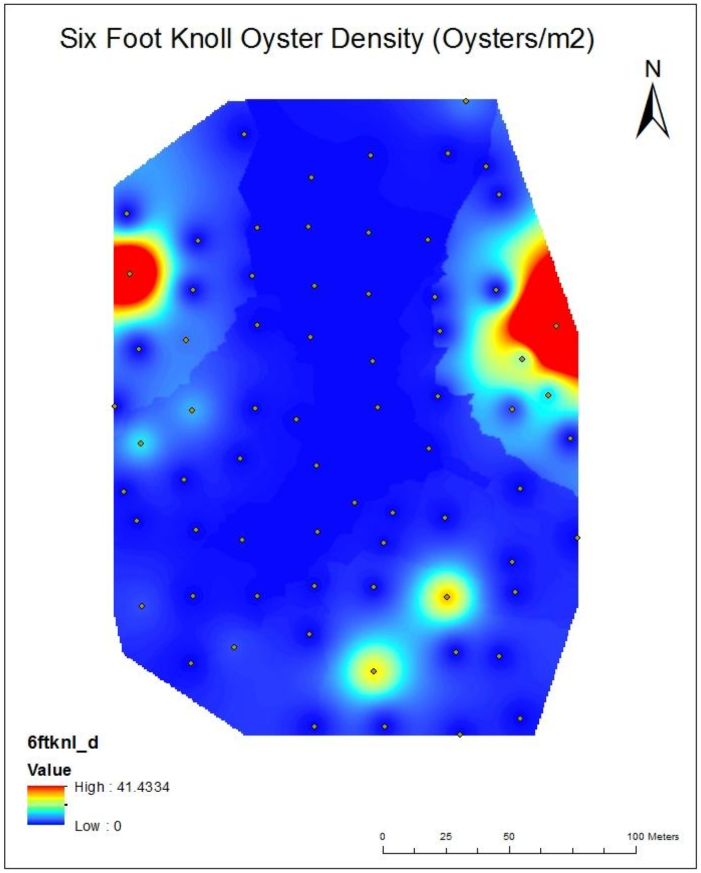



14a

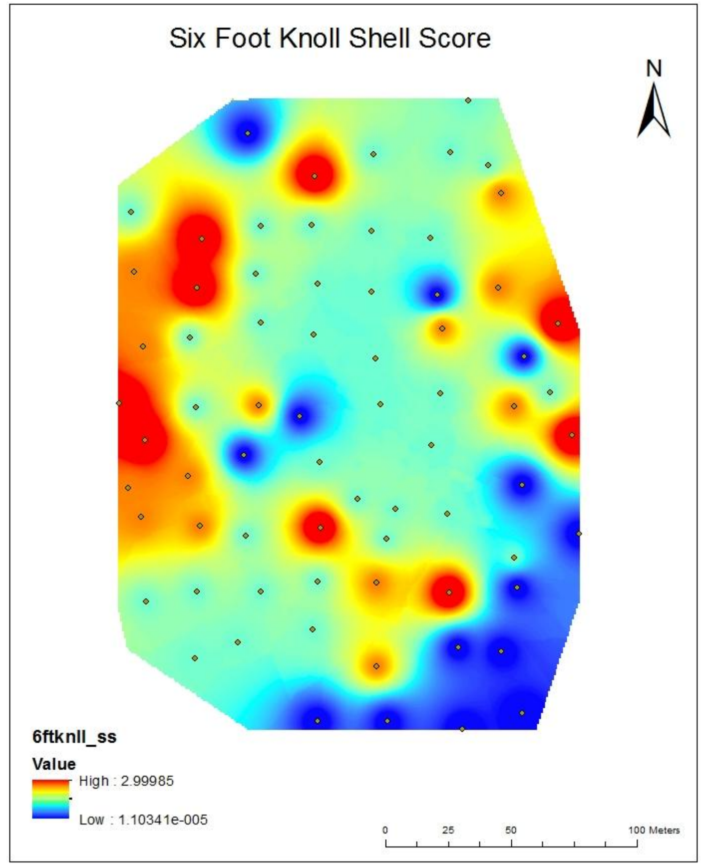



14b

Figure 5.14. Oyster density (14a) and shell score (14b) plots at Chinks Point, an oyster bar in the Severn River that was planted in 2008. Areas of high oyster density also had high shell scores, however not all high shell scores yielded high oyster densities. Overall oyster and shell coverage was low at this for; only 4% of the bar had oyster densities greater than 5oy/$m^2$ and only 24% of the bar had shell coverage.




15a




15b

Figure 5.15. Oyster density (15a) and shell score (15b) plots at Six Foot Knoll, an oyster bar in the Upper Bay that was planted in 2008. Areas of high oyster density also had high shell scores, however not all high shell scores yielded high oyster densities. However only 1% of the bar had live oyster densities greater than 5 oysters/$m^2$ despite 39% of the bar having shell coverage. Of all oysters (live and dead) measured at this bar, 61% were boxes.

Conclusions:

Overall, oyster density and shell score appear to be related in that, in areas of high oyster density shell score was also high. A majority of the plots, however, show that areas of high shell score did not yield high oyster density. This suggests that high shell score is not always associated with the presence of live oysters, although areas with high oyster density tend to also have high shell coverage. Unsurprisingly, bars with high populations also had high oyster biomass. Mean oyster density in 2011 was four oy/$m^2$, but less than 9% of the area surveyed achieved greater than that density. Only 39% of the area surveyed had any shell coverage again indicating that not only is shell coverage greater than oyster coverage on the bars sampled. In bars where the same area was surveyed in 2010 and 2011, shell coverage and oyster density went down or did not change significantly from 2010 to 2011. Some of the decline in oyster density could be attributed to Dermo prevalence; however it is likely that most of the variance in oyster density and shell coverage is a reflection of the natural variation in these variables in the Chesapeake Bay system.

Considering that just under 40% of the area surveyed had any shell, and oysters were not found in areas without shell, we suggest that future patent tong sampling be limited to areas where shell has been found in the past. The Maryland Geological Survey and NOAA Chesapeake Bay Office have extensive bottom survey data that can be used for this purpose. This will reduced the area necessary to sample by about half, allowing for a greater number of bars to be sampled in the future. Although an extensive restoration program has been undertaken by the ORP, it is clear that restored bars do not have complete shell or oyster coverage, indicating that higher density restoration efforts are necessary to create more successfully restored habitat and therefore more successful oyster populations. Similarly, oyster density and biomass data show that these bars are not meeting the metrics of success described above. We suspect that the low numbers are largely due to spat-on-shell planted on less than adequate bottom (i.e.: not exposed shell). The target areas for planting have been revised since these bars were planted, and survival seems to be improving (see Section IV).

In November and December of 2011 the Paynter Lab, in conjunction with the ORP, undertook an extensive patent tong survey of Harris Creek and the Little Choptank River. A detailed report of the findings of this survey will be presented in a separate report to the ORP. The purpose of this survey was twofold; to evaluate the accuracy of the bottom imaging software to detect different bottom types and to determine the oyster population and shell distribution in each tributary. The results of this survey will help to determine the usefulness of bottom imaging data in determining accurate locations of good oyster bottom. The data from the survey will also help to understand the variability in oyster density and size as well as shell coverage at a tributary scale and will be used to design large-scale patent tong surveys in the future.

Additionally, long term patent tong data was evaluated from Coppers Hill, Drum Point, Willow Bottom, and Ulmstead Point. These four bars have been monitored annually since 2007 and the data for these sites is available in Section VI.

## Section VI: Long-Term Patent Tong Monitoring 2007-2011

In order to obtain a temporally sound representation of oyster population dynamics over time following a spat on shell planting, four individual oyster bars were monitored for five consecutive years (2007-2011). Figure 6.1 shows the four long-term monitoring sites. Site locations are indicated by red dots, river names in bold black and site names in yellow boxes. These bars, their location, harvest status and planting dates are outlined in Table 6.1 below. Rivers are further divided into sections as follows, L: lower, M: middle, and U: upriver.

Table 6.1. Oyster bars targeted for long-term monitoring. Rivers are further divided into sections as follows, L: lower, M: middle, and U: upriver.

| River | Section | Bar Name | Harvest Status | Planting Dates |
|---|---|---|---|---|
| Chester | U | Coppers Hill | Managed Reserve | 9/25/07, 4/28/08 |
| | M | Drum Point | Managed Reserve | 6/26/2007 |
| | M | Willow Bottom | Managed Reserve | 5/30/2007 |
| Magothy | U | Ulmstead Point | Sanctuary | 8/8/2006 |

Sampling occurred at these bars using an extensive patent tong survey throughout the planted area. A grid of 25m x 25m cells was overlaid on the planted area and each grid cell was sampled with hydraulic patent tongs. Number and shell height (mm) of live and dead (box) oysters were recorded at each grab. The density of oysters at each point was calculated using the area of the tongs and a population estimate was generated using this density data. The biomass of oysters found at each site was calculated using the following equation: Biomass (g) =0.00003*(Shell Height (mm) ^2.3512) (Liddel 2007). This equation was used to calculate the total biomass in each surveyed cell; cell data was then totaled to determine each bar's biomass. The density of oysters at each patent tong survey point was recorded using GIS in 2008-2011. These spatial data allowed for a density plot to be generated for each year to illustrate the spatial distribution of oysters at each site for 2008-2011. Results for individual sites are presented below.

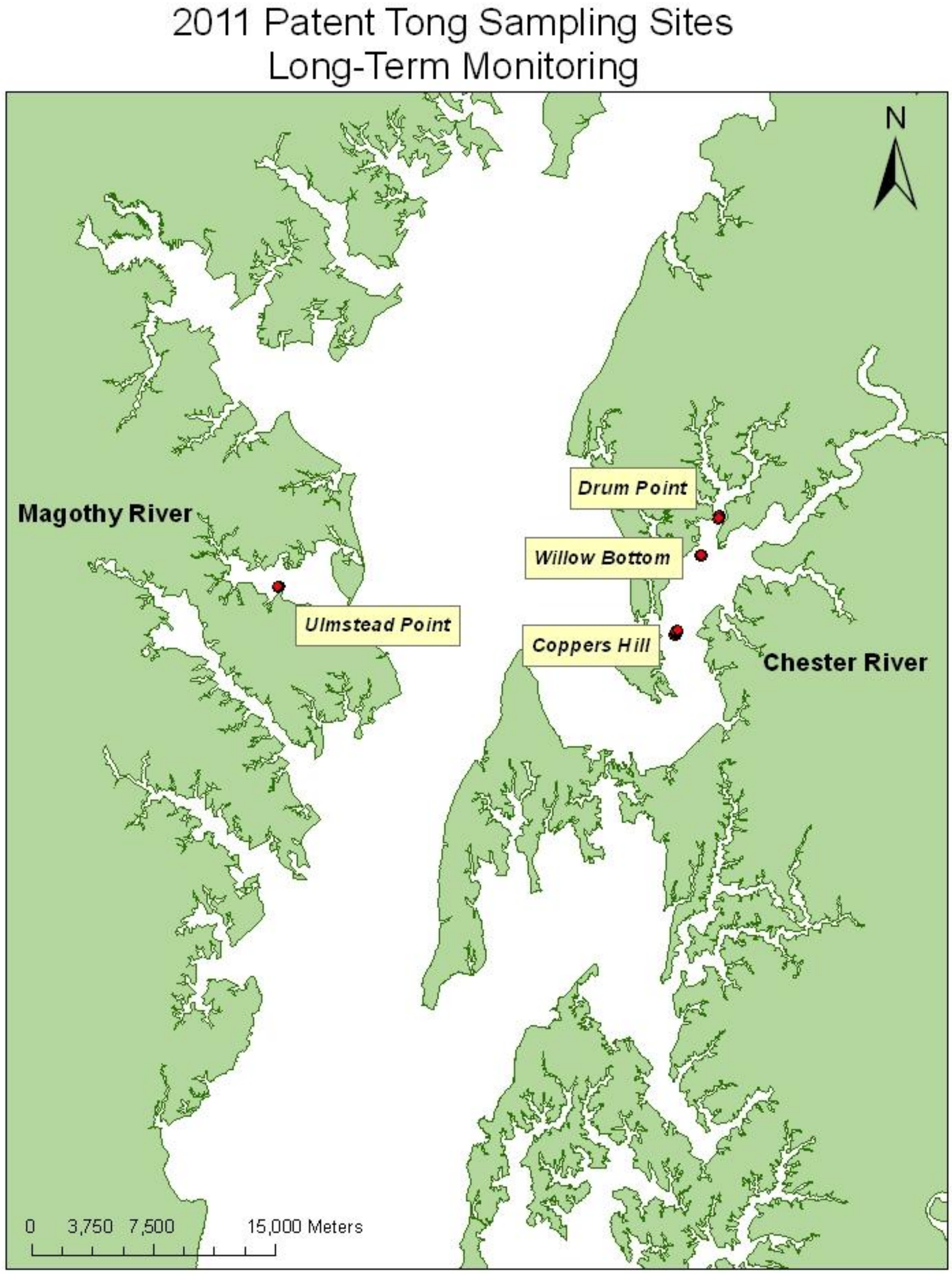



Figure 6.1. Map of long-term monitoring oyster bars. Bar locations are indicated by red dots with bar names in yellow.

**Coppers Hill**

Coppers Hill is a managed reserve bar located in the Chester River that was planted in both 2007 and 2008. However, the patent tong survey for 2007 was conducted before the planting occurred. The size distribution of oysters sampled at Coppers Hill indicated a small number of adult oysters in 2007, high numbers of spat in 2008 followed by a decline in the amount of spat but an increase in their size in 2009, with an amplification of that pattern in 2010 (Fig. 6.2). In 2010, Coppers Hill was open for harvest, and the effects are reflected in the data. The 2011 survey revealed very little growth in size, and a large drop in the number of adult oysters. The biomass of oysters at Coppers Hill was also reflective of the planting, growth, and harvest activities at the bar from 2007-2011 (Fig. 6.3). The low biomass in 2007 reflected the low number of oysters surveyed; however, 2007 oysters were larger than the spat surveyed in 2008, also indicated by the fairly small increase in biomass in 2008. 2008 oysters were many, but small, as the bar was planted after the survey in 2007 and again in 2008. Together, figures 6.2 and 6.3 show that a high abundance of oysters did not necessarily entail high biomass. Data from 2009 showed a very slight increase in biomass, which could be reflective of high spat mortality after the 2008 planting. In 2010, as oyster size increased biomass also grew. After the open harvest in 2010, biomass drastically decreased. The total biomass for each year was consistent with the size distribution of oysters in each year, indicating the patent tong survey detected the size distribution and relative amounts of oysters on Coppers Hill before and after planting.

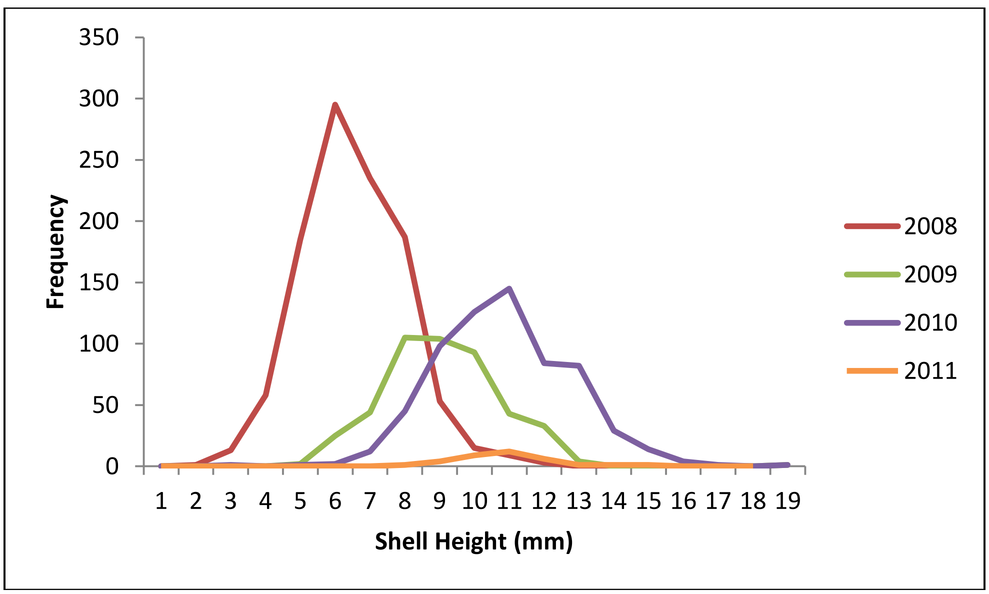



Figure 6.2. Size frequency of oysters sampled at Coppers Hill during 2007-2011 patent tong surveys. Coppers Hill was planted in 2007 (after patent tong survey) and 2008. The size frequencies indicate the patent tong survey detected the size distribution and relative amounts of oysters on Coppers Hill before and after planting.

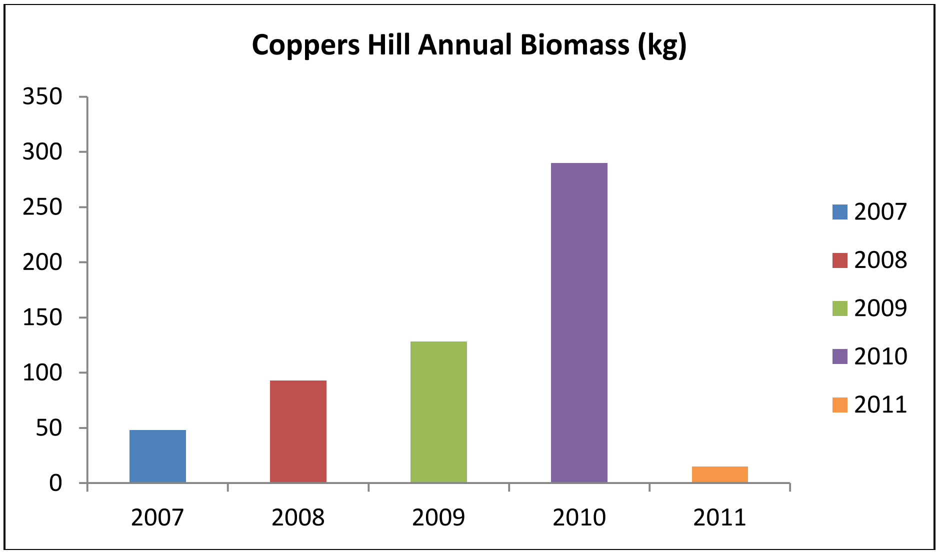



Figure 6.3. Biomass of oysters at Coppers Hill during 2007-2011 patent tong surveys. The biomass of oysters at Coppers Hill was consistent with the size distribution of oysters in each year.

The survey statistics for Coppers Hill are presented in Table 6.2 below. Similar to the trends observed in the size frequency distribution and total biomass data, the increase in live count and decline in mean shell height from 2007 to 2008 was indicative of the 2008 planting. Since the patent tong survey for 2007 was conducted before the 2007 planting, the low live count and relatively high mortality (as box count % of live) was not unexpected for the large, older population that was sampled. The oyster density, population estimates and biomass estimates follow a similar pattern, with 2007 having lower mean density, population and biomass than both 2008 and 2009. The 2009 patent tong survey showed an increase in mean shell height paired with declines in live count, mortality, mean density and population. The 2010 survey indicated a small increase in live count, mortality, mean density, population and biomass. We believe these increases are reflective of the natural variability present in the system as it reaches a sustainable post-planting population. After the bar opened for harvest, the 2011 survey showed a large drop in the number of live oysters, with still relatively few boxes, suggesting that the decreased oyster density, population, and biomass were due to harvest rather than natural mortality. Intensity of Dermo (*Perkinsus marinus*) was low across all years measured, also suggesting that the decrease in oysters was due to harvest.

Table 6.2. Patent tong survey statistics for Coppers Hill.

| Sampling Year | Mean Shell Height (mm) | Live Count | Box Count | Box Count (% of Total) | Mean Density (oysters/m$^2$) | Population Abundance | Biomass Sum (kg) | Dermo Prevalence (%) | Dermo Weighted Intensity |
|---|---|---|---|---|---|---|---|---|---|
| **2007** | 102 | 86 | 28 | 25 | 1 | 29,696 | 48 | NA | NA |
| **2008** | 51 | 803 | 57 | 7 | 13 | 277,279 | 93 | NA | NA |
| **2009** | 77 | 462 | 8 | 2 | 7 | 159,530 | 128 | 10 | 0.17 |
| **2010** | 94 | 626 | 19 | 3 | 9 | 216,160 | 290 | 20 | 0.17 |
| **2011** | 63 | 34 | 3 | 8 | <1 | 11,740 | 15 | 50 | 0.22 |

The density plots for Coppers Hill are presented in Figure 6.3 below. Oyster density in 2008 reached as high as 125 oysters/m$^2$, mostly concentrated in the middle and eastern portion of the planting; however a majority of the site had no oysters present (Fig. 6.4a). In contrast, in 2009 oyster density reached a maximum of 62 oysters/m$^2$, mostly concentrated in the southern half of the planting (Fig. 6.4b). This decline in density and shift in the location of oysters was indicative of activity that occurred on this bar between the 2008 and 2009 patent tong surveys. The 2010 survey found oysters in the same general location as the 2009 survey, but at slightly higher densities (106 oysters/m$^2$). In 2011, oyster density was at its lowest, with less than one oyster per square meter and highest densities at the northern portion of the bar.

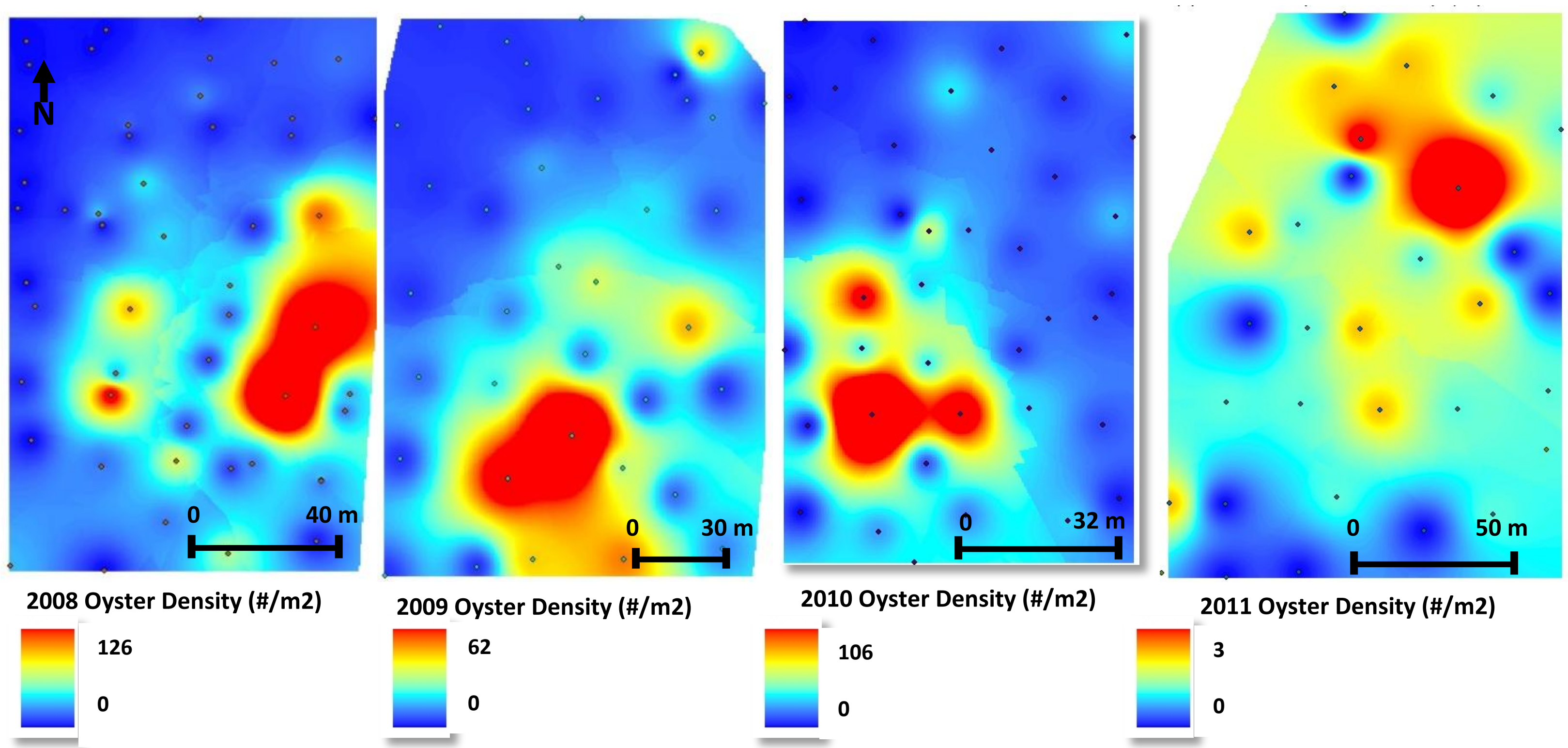



Figure 6.4. Coppers Hill oyster density plots from 2008, 2009, 2010, and 2011 patent tong surveys. Maximum oyster density was higher in 2008 (126 oysters/$m^2$) than in 2009 (62 oysters/$m^2$) and the location of oysters shifted south and west between 2008 and 2009. The decline in density and shift in the location of oyster from 2008 to 2009 is indicative of possible harvest on this bar between the 2008 and 2009 patent tong surveys. The consistency in the location and increase in maximum density of oysters from 2009 to 2010 (106 oysters/$m^2$) indicates the bar was relatively undisturbed between the 2009 and 2010 surveys. Oyster density in 2011 showed highest density at the northern end of the bar, however the maximum density was only 3 oysters/$m^2$, reflective of the open harvest in 2010 and 2011.

**Drum Point**

Drum Point is a managed reserve bar located in the Chester River that was planted in 2007. The 2007 patent tong survey was conducted before the planting occurred. The size distribution of oysters sampled at Drum Point indicated a small number of adult oysters in 2007, high numbers of spat in 2008 (indicative of the 2007 planting) followed by a decline in the amount of spat but an increase in oyster size in 2009 and a continued increase in oyster size and number in 2010 (Fig. 6.5). The 2011 survey showed a slight decrease in oyster number, but with size frequencies similar to 2010.This pattern of size distributions indicates that the patent tong survey detected the size distribution and relative amounts of oysters on Drum Point before and after planting.

Biomass data paralleled the size frequency data (Fig. 6.6). 2007 was represented pre-planting, with low numbers of old oysters yielding a low biomass. In 2008, after the 2007 planting, biomass increased only slightly as the bar was now occupied by many small oysters (whose individual biomass is low relative to an older oyster). In 2009, biomass remained fairly constant, as many young oysters died and those that survived grew larger. As population numbers below will show, biomass remained steady with a fairly large drop in population, reiterating the idea that biomass was greatly amplified as oysters aged/grew, easily compensating for natural mortality. In 2010 and 2011, biomass increased slightly, as surviving oysters continued to grow.

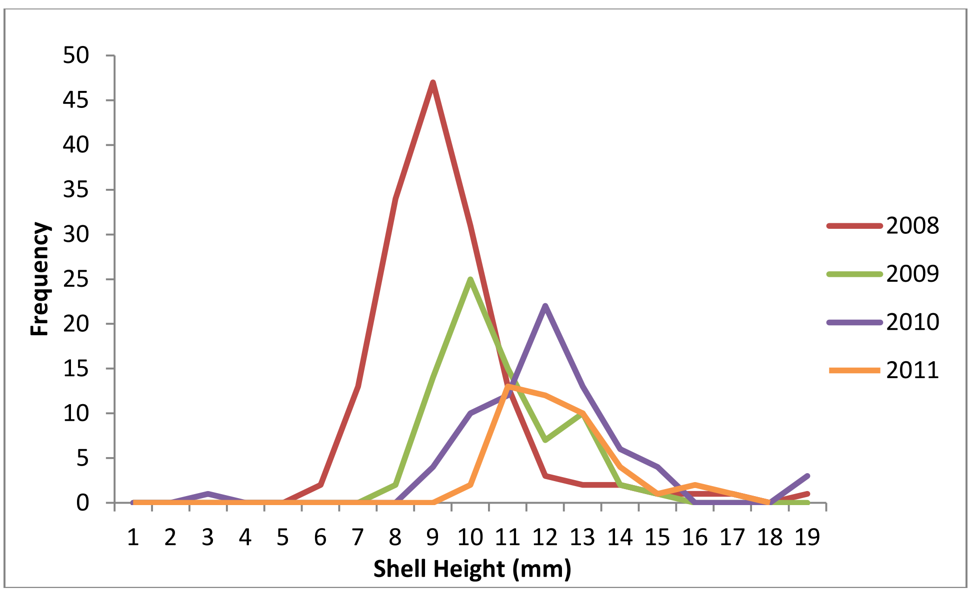



Figure 6.5. Size frequency of oysters sampled at Drum Point during 2007-2011 patent tong surveys. Drum Point was planted in 2007 (after patent tong survey). The size frequencies indicate the patent tong survey detected the size distribution and relative amounts of oysters on Drum Point before and after planting.

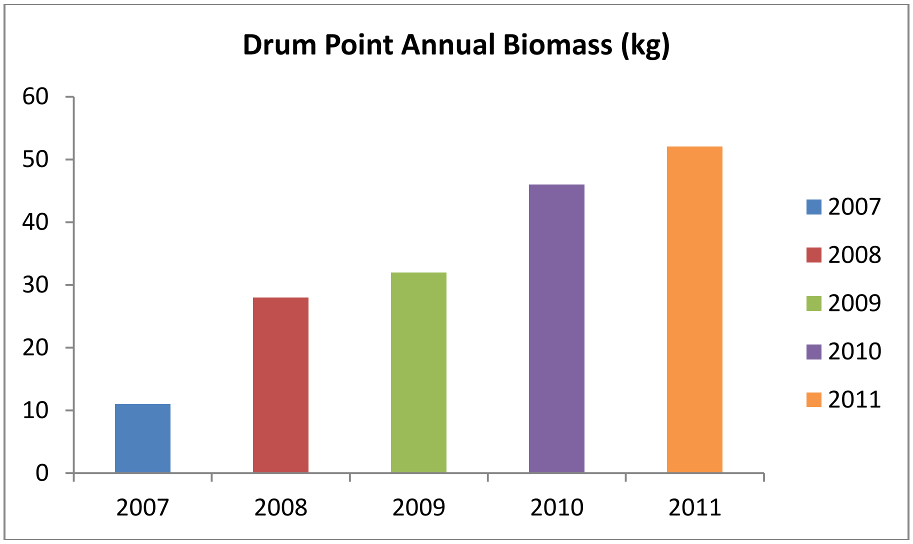



Figure 6.6. Biomass of oysters at Drum Point during 2007-2011 patent tong surveys. The biomass of oysters at Drum Point was consistent with the size distribution of oysters in each year.

The survey statistics for Drum Point are presented in Table 6.3 below. Similar to the trends in the size frequency distribution and biomass data, the increase in live count and decline in mean shell height from 2007 to 2008 was indicative of the 2008 planting. Since the patent tong survey for 2007 was conducted before the 2007 planting, the low live count and relatively high mortality (as box count % of live) is not unexpected for the large, older population that was sampled. The oyster density and population estimates follow a similar pattern, with 2007 having lower mean density and population than both 2008 and 2009. The 2009 patent tong survey shows an increase in mean shell height paired with decline in live count, mortality, mean density and population. The 2010 survey indicated an increase in live count, mortality, mean density and population. While the overall population decreased in 2011, an outcome of the 2010 open harvest at Drum Point, bar biomass differed only slightly from 2010. Total biomass remained steady despite a fairly large drop in population, underscoring that biomass was greatly amplified as oysters aged/grew, easily compensating for natural mortality. Dermo intensity was low in all three years measured, suggesting that disease played little role in the dynamics at this bar.

Table 6.3. Patent tong survey statistics for Drum Point.

| Sampling Year | Mean Shell Height (mm) | Live Count | Box Count | Box Count (% of Total) | Mean Density (oysters /m$^2$) | Population Abundance | Biomass Sum (kg) | Dermo Prevalence (%) | Dermo Weighted Intensity |
|---|---|---|---|---|---|---|---|---|---|
| **2007** | 123 | 13 | 8 | 38 | <1 | 4,316 | 11 | NA | NA |
| **2008** | 80 | 97 | 7 | 7 | 1 | 33,494 | 28 | NA | NA |
| **2009** | 92 | 26 | 2 | 7 | <1 | 8,978 | 32 | 48 | 0.57 |
| **2010** | 107 | 73 | 2 | 3 | 1 | 25,207 | 46 | 10 | 0.01 |
| **2011** | 104 | 45 | 2 | 4 | 1 | 15,539 | 52 | 23 | 0.04 |

The density plots for Drum Point are presented in Figure 6.7 below. Oyster density in 2008 reached a maximum 12 oysters/m$^2$, mostly concentrated in the north and eastern portion of the planting. In contrast, in 2009 oyster density reached a maximum of 6 oysters/m$^2$, spread throughout the planting . This decline in density and shift in the location of oyster is indicative of activity that occurred on this bar between the 2008 and 2009 patent tong surveys. The 2010 survey indicated another shift in the location of oysters on Drum Point, although at such low maximum densities (9 oysters/m$^2$), the patent tong survey could have missed other areas of relative high density on the bar. The density plot from 2011 shows areas of highest density similar to 2010, with similar maximum densities (7 oysters/m$^2$).

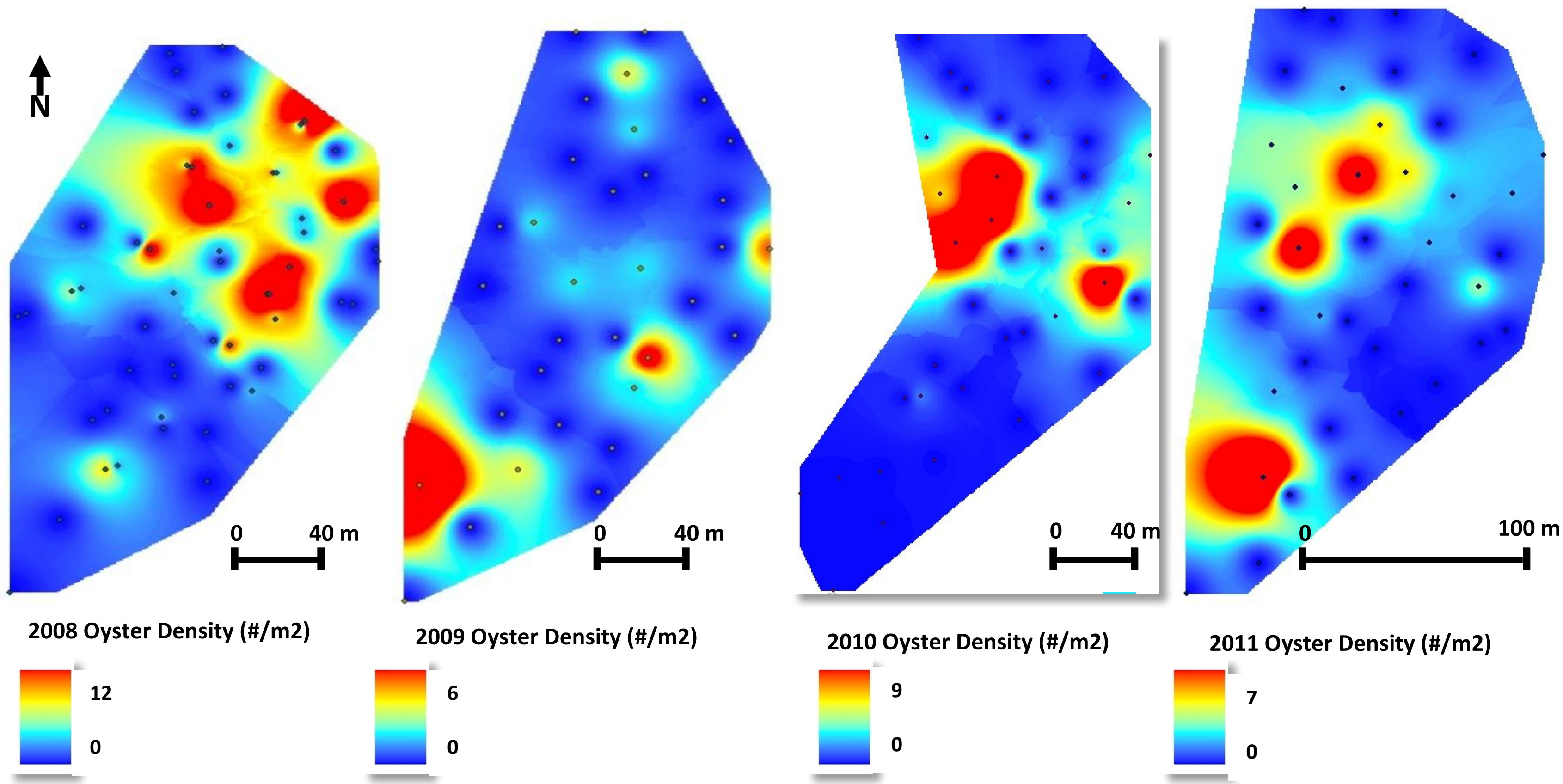



Figure 6.7. Drum Point oyster density plots from 2008, 2009, 2010 and 2011 patent tong surveys. Maximum oyster density was higher in 2008 (12 oysters/$m^2$) than in 2009 (6 oysters/$m^2$) and the location of oysters shifted between 2008 and 2009. The decline in density and shift in the location of oyster from 2008 to 2009 is indicative of possible harvest on this bar between the 2008 and 2009 patent tong surveys. Maximum oyster density remained low in 2010 (9 oysters/$m^2$) and 2011 (7 oysters/$m^2$) and although the density plot indicates a shift in the location of oysters, the low density of oysters at the bar make it difficult for the patent tongs to accurately capture all areas of relative high density on the bar.

**Willow Bottom**

Willow Bottom is a managed reserve bar located in the Chester River that was planted in 2007. The patent tong survey for 2007 was conducted before the planting occurred and no oysters were found in that survey. The size distribution of oysters sampled at Willow Bottom indicated consistency in the number of oysters sampled in 2008 and 2009 paired with a shift to larger oysters from 2008 to 2009, with the 2010 size distribution data indicating a decline in the number of oysters but an increase in surviving animals' shell heights (Fig. 6.8). In 2010, the bar was opened for harvest and the 2011 data shows this through lower oyster numbers with little to no growth. This pattern of size distributions indicates high survival from year two to year three post-planting and also points to significant growth between years pre-harvest.

Biomass data at Willow Bottom complements the size frequency data. Figure 6.9 showed no biomass for 2007, as no oysters were found. 2008's high number of spat after the 2007 planting had much lower biomass than in 2009, indicating the large oyster growth that occurred between 2008 and 2009. In 2010, oyster growth was coupled with some mortality, and biomass remained constant, although population abundance decreased (Table 6.4). Due to harvest in 2010, the overall biomass decreased in 2011.

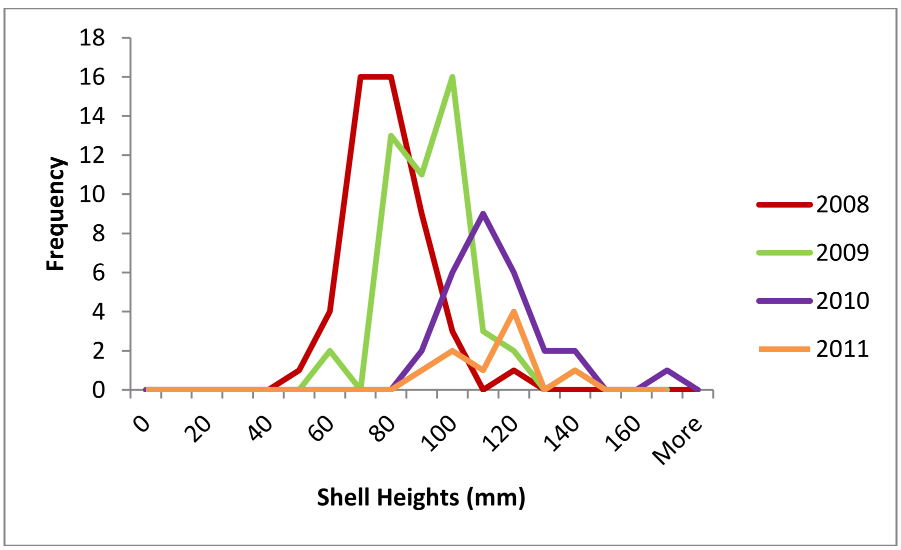



Figure 6.8. Size frequency of oysters sampled at Willow Bottom during 2007-2011 patent tong surveys. Willow Bottom was planted in 2007 after the patent tong survey and no oysters were found during the survey that year. The size frequencies indicate high survival from year two to year three post-planting and significant growth between pre-harvest (2010) years at Willow Bottom.

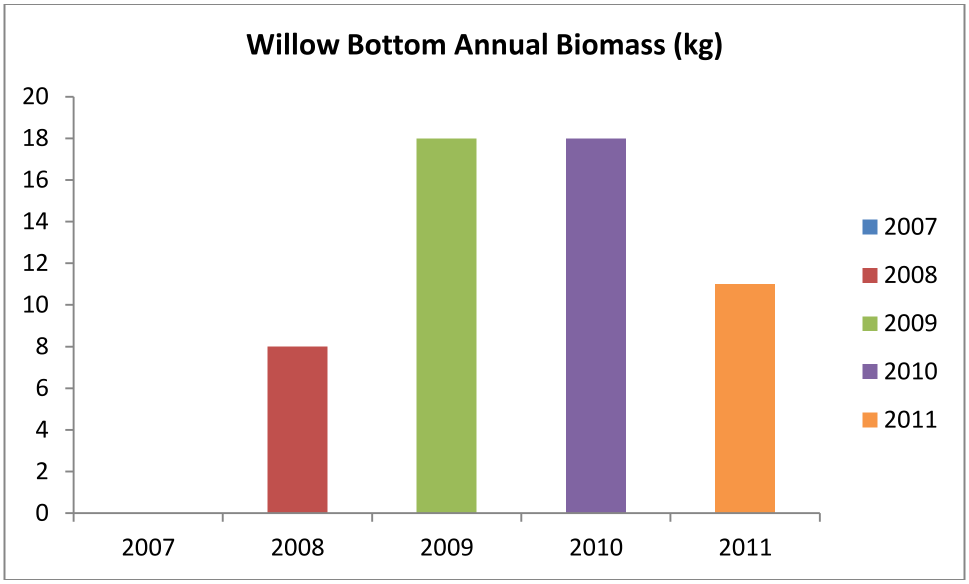



Figure 6.9. Biomass of oysters at Willow Bottom during 2007-2011 patent tong surveys. The biomass of oysters at Willow Bottom is consistent with the size distribution of oysters in each year.

The survey statistics for Willow Bottom are presented in Table 6.4 below. The highest live count and population was observed in 2009, with an unexpected decline in live count and population in 2010. Low spat mortality (as box count % of live) was observed when oysters were found at the site. Although the size frequency distributions indicated some mortality between 2009 and 2010, no dead oysters were found in the 2010 survey, indicating that oysters were either more spread out throughout the bar in 2010 or the survey did not capture the amount of dead oysters on the bar accurately. However, the low live counts and populations observed at Willow Bottom during the entire survey period may prevent the patent tong from accurately capturing oyster densities. In 2010, Willow Bottom was open for harvest, and while this likely led to a decrease in population in the 2011 survey, the relatively high box count suggests natural mortality also affected the population. Total biomass increased from 2008 to 2009, indicating that growth outpaced death between these two years. Biomass remained fairly consistent from 2009 to 2010, showing that the existing population may be stabilizing 3 years after planting, however the decrease in 2011 counters that trend if the loss was due to natural mortality rather than harvest. Despite these fluctuations, the overall oyster population at Willow Bottom has been very low during the entire survey period, and it is unlikely an effect of disease as dermo intensity was also low at this bar.

Table 6.4. Patent tong survey statistics for Willow Bottom.

| Sampling Year | Mean Shell Height (mm) | Live Count | Box Count | Box Count (% of Total) | Mean Density (oysters/ $m^2$) | Population Abundance | Biomass Sum (kg) | Dermo Prevalence (%) | Dermo Weighted Intensity |
|---|---|---|---|---|---|---|---|---|---|
| **2007** | N/A | 0 | 0 | N/A | 0 | 0 | 0 | NA | NA |
| **2008** | 74 | 16 | 0 | 0 | <1 | 5,352 | 8 | NA | NA |
| **2009** | 87 | 47 | 1 | 2 | <1 | 16,229 | 18 | 31 | 0.19 |
| **2010** | 110 | 28 | 0 | 0 | <1 | 9,668 | 18 | 59 | 0.26 |
| **2011** | 111 | 9 | 3 | 25 | <1 | 3,308 | 11 | NA | NA |

The density plots for Willow Bottom are presented in Figure 6.10 below. Maximum oyster density was low in all years (4 oysters/$m^2$ in 2008, 8 oysters/$m^2$ in 2009, 9 oysters/$m^2$ in 2010, and 9 oysters/$m^2$ in 2011). Spatially, oysters were spread throughout the planting in 2008 and concentrated to the eastern half in 2009-2011. The increase in density and the shift in spatial distribution of oysters from 2008 to 2009 may be indicative of activity on this bar in the period between the two surveys.

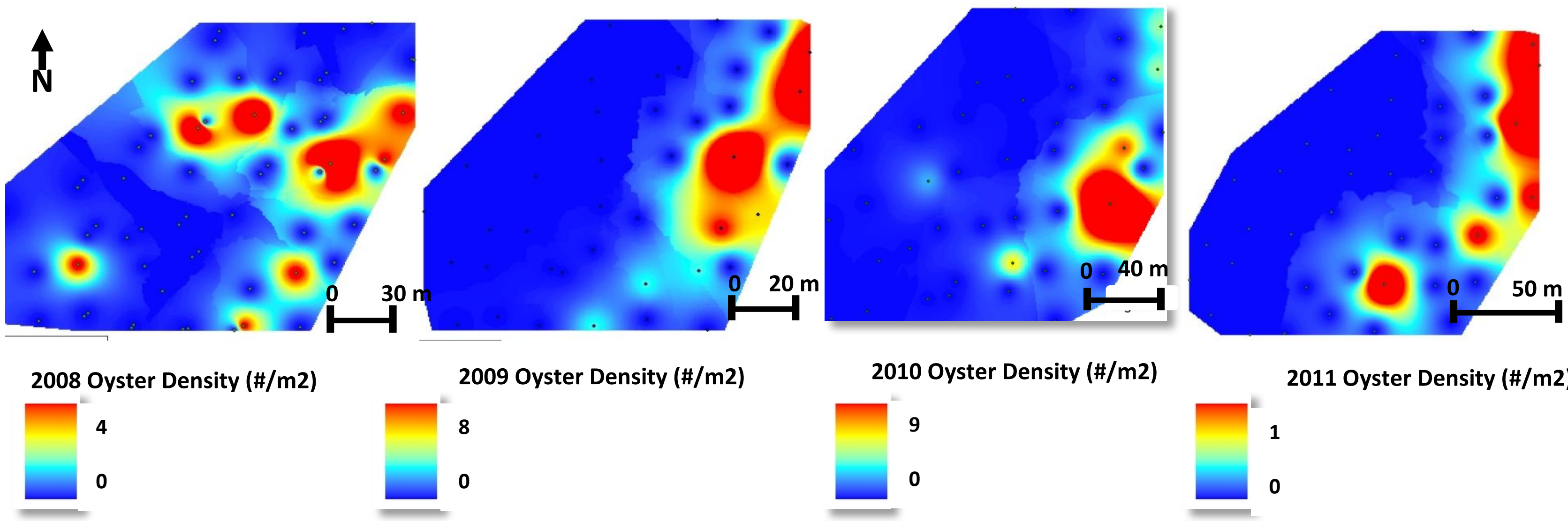



Figure 6.10. Willow Bottom oyster density plots from 2008, 2009, 2010, and 2011 patent tong surveys. Oyster density was low throughout 2008 to 2011 and location shifted eastward from 2008 (4 oysters/$m^2$) to 2009(8 oysters/$m^2$). The shift in location may be indicative of activity on this bar between surveys. In 2010, oyster density (9 oysters/$m^2$) and location remained consistent, suggesting the bar was undisturbed between 2009 and 2010, while overall density dropped in 2011 (1 oyster/$m^2$).

**Ulmstead Point**

Ulmstead Point is an oyster sanctuary located in the Magothy River that was planted in 2006. The size distribution of oysters sampled at Ulmstead Point indicated a high frequency of spat in 2007, a decline in the amount of spat but an increase in oyster size in 2008 and 2009 followed by no change in the size frequency or amount of oysters in 2010 (Fig. 6.11). In 2011, the size distribution and frequency of oysters dropped off greatly. This pattern of size distributions indicates significant mortality post-planting combined with growth of the surviving oysters. In addition, such low oyster numbers in 2011 suggest possible harvest or large natural mortality between the 2010 and 2011 surveys. These patterns also show that the patent tong survey detected the size distribution and relative amounts of oysters on Ulmstead Point after planting.

Biomass data for Ulmstead Point closely matches the size frequency data (Fig. 6.12). After the 2006 planting, 2007 oysters were many but small spat, yielding a low biomass. In 2008, spat mortality coupled with growth of surviving oysters is reflected through a very slight increase in biomass. In 2009, biomass increased, and the size frequency plot matches this increase in size. The following year showed no change in biomass, and the size frequency plot again coincides as oyster size remained the same. While the size frequency plot showed very few oysters in 2011, the oysters present were large, resulting in only a slight decrease in overall biomass.

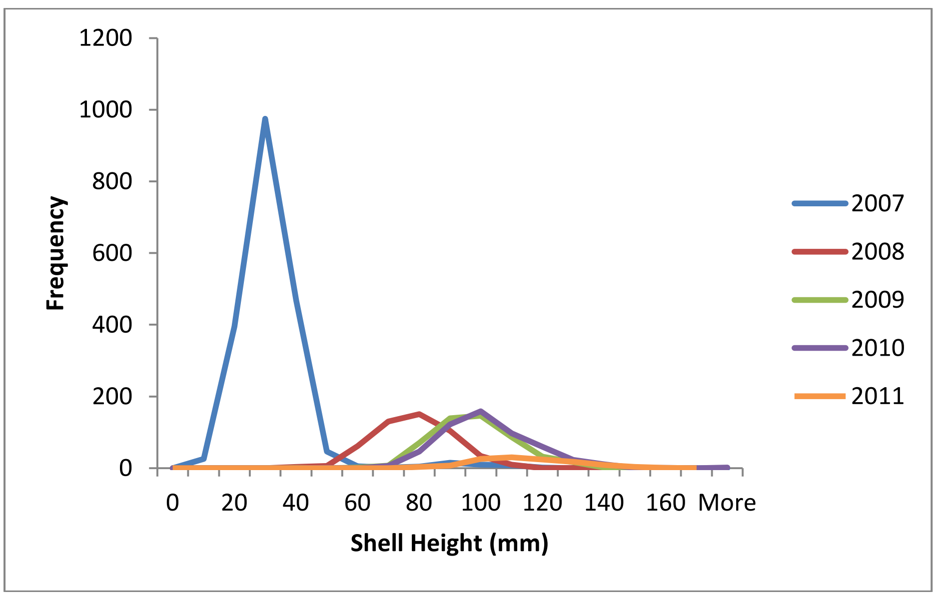



Figure 6.11. Size frequency of oysters sampled at Ulmstead Point during 2007-2011 patent tong surveys. Ulmstead Point was planted in 2006. The size frequencies indicate the patent tong survey detected significant mortality paired with growth of the surviving oysters and also adequately represented the size distribution and relative amounts of oysters on Ulmstead Point after planting.

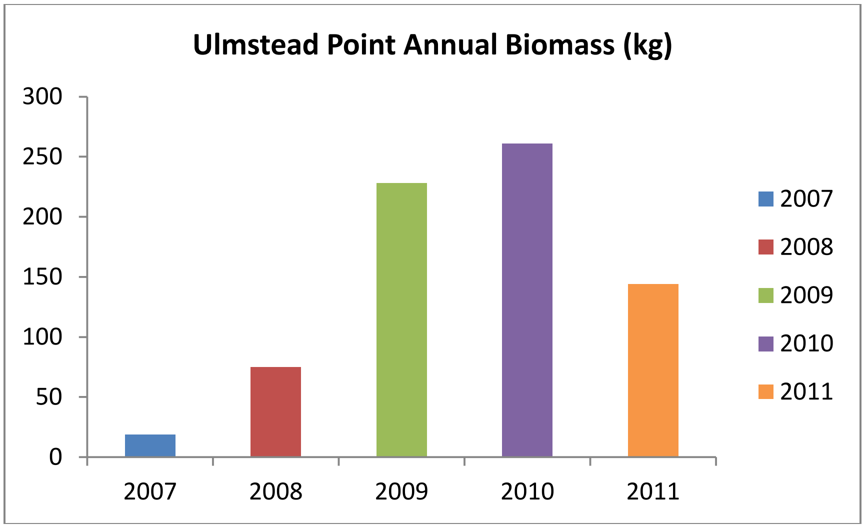



Figure 6.12. Biomass of oysters at Ulmstead Point during 2007-2011 patent tong surveys. The biomass of oysters at Ulmstead Point is consistent with the size distribution of oysters in each year.

The survey statistics for Ulmstead Point are presented in Table 6.5 below. Similar to the trends in the size frequency distribution, the highest live count and smallest shell heights were observed in 2007, a decline in live count and an increase in mean shell height in 2008, an unexpected increase in live count and mean shell height in 2009 with oyster size and population leveling off in 2010. High spat mortality (as box count % of live) was observed in the first year post planting and dramatically declined in the following years post planting. The oyster density and population estimates follow a similar pattern, with 2007 having higher mean density and population than 2008-2011. The 2008 patent tong survey showed a decline in live count, mortality, mean density, population and biomass, however, the 2009 survey indicated an increase in these metrics from the year before. The 2010 survey data indicated that the population is leveling off in the fourth year post-planting to contain a steady density, population and biomass of animals. In 2011, however, the oyster population experienced a sizeable drop. As the data below show, the 2011 survey returned a relatively high percentage of boxes when compared to previous years, suggesting that the decreased oyster population at Ulmstead Point may have been due to natural mortality rather than harvest. However, the number of boxes found does not account entirely for the reduction in live oysters. These data could also reflect illegal harvest. Record-low salinities throughout the bay in 2011 may have affected oyster survival at this bar, in addition to a fairly soft bottom in this region of the Magothy River. It is unlikely that disease greatly affected the oysters at this bar, as intensity was low in 2010 and 2011.

Table 6.5. Patent tong survey statistics for Ulmstead Point.

| Sampling Year | Mean Shell Height (mm) | Live Count | Box Count | Box Count (% of Total) | Mean Density (oysters/ $m^2$) | Population Abundance | Biomass Sum (kg) | Dermo Prevalence (%) | Dermo Weighted Intensity |
|---|---|---|---|---|---|---|---|---|---|
| **2007** | 27 | 625 | 161 | 20 | 20 | 225,138 | 19 | NA | NA |
| **2008** | 75 | 281 | 19 | 6 | 10 | 96,858 | 75 | NA | NA |
| **2009** | 94 | 512 | 1 | <1 | 19 | 176,796 | 228 | NA | NA |
| **2010** | 98 | 518 | 10 | 2 | 15 | 178, 867 | 261 | 20 | 0.21 |
| **2011** | 106 | 121 | 26 | 18 | 4 | 41.782 | 144 | 3.7 | 0.04 |

The density plots for Ulmstead Point are presented in Figure 6.13 below. Oyster density in 2008 reached maximums of 50 oysters/$m^2$, spread throughout the planting. In 2009 oyster density reached a maximum of 80 oysters/$m^2$, also spread throughout the planting. 2010 oyster density reached a maximum of 94 oysters/$m^2$ consistently spread throughout the planting. In 2011, oysters were densest in similar regions of the bar, however maximum densities were much lower (7 oysters/$m^2$). The consistency in the density and spatial distribution of oysters on this sanctuary may be evidence of the undisturbed nature of this bar, also suggesting the population decline in 2011 may have been due to natural mortality.

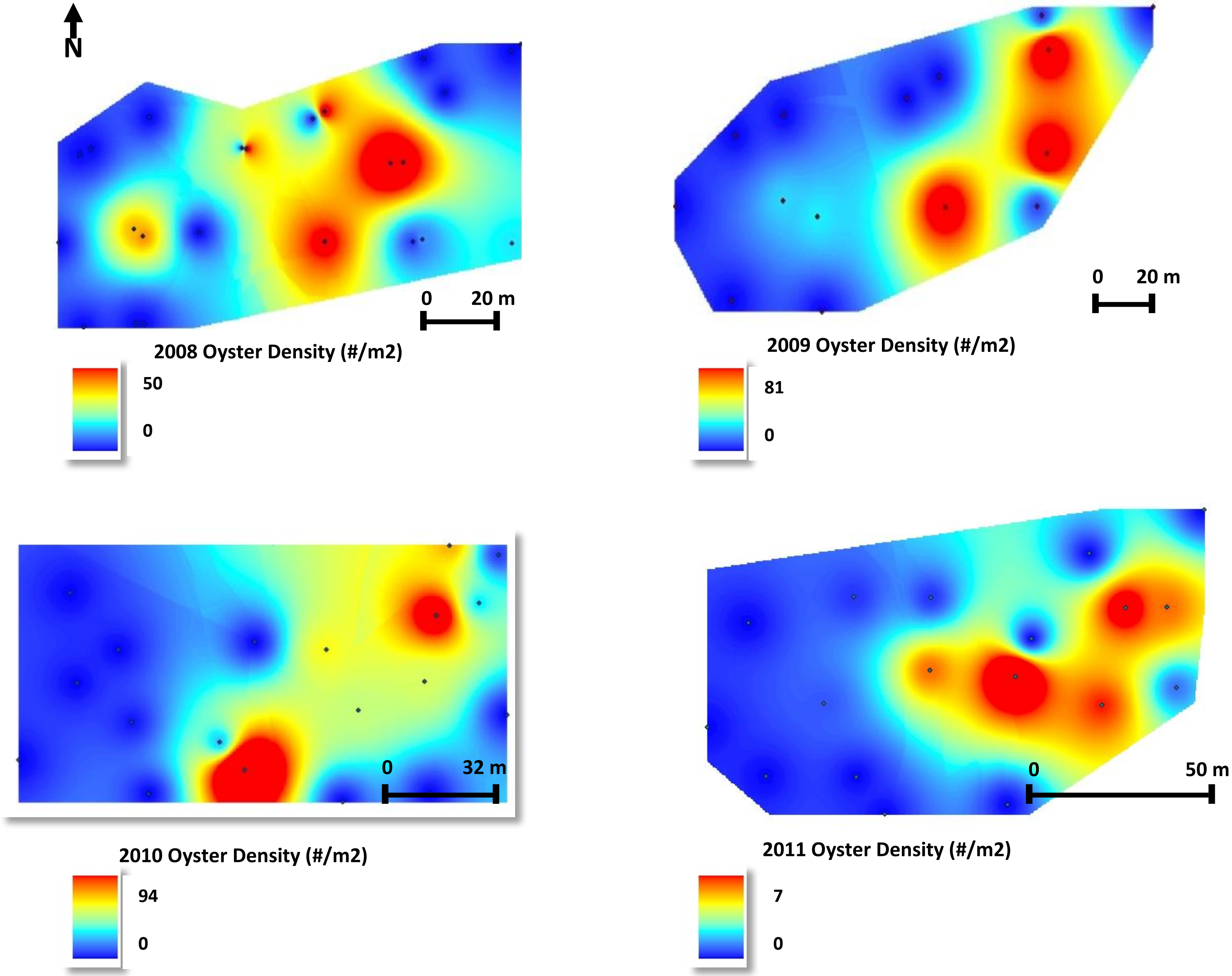

N
0
20 m
2008 Oyster Density (#/m2)
50
0
0
20 m
2009 Oyster Density (#/m2)
81
0
0
32 m
2010 Oyster Density (#/m2)
94
0
0
50 m
2011 Oyster Density (#/m2)
7
0

Figure 6.13. Ulmstead Point oyster density plots from 2008, 2009, 2010 and 2011 patent tong surveys. Oyster density and location remained consistent between 2008-2010, with maximum density increasing slightly from year to year: 2008 (50 oysters/$m^2$), 2009 (81 oysters/$m^2$), and 2010 (94 oysters/$m^2$) until 2011 (7 oysters/$m^2$). The consistency in density and location of oyster from 2008 through 2011may be indicative of the undisturbed nature of this bar.

**Conclusions**

The long term patent tong data for these four sites indicate that patent tongs are appropriately characterizing the addition, growth and distribution of oysters on managed reserves and sanctuaries. The frequency distributions of shell height reflected the addition of oysters by a shift in the mean size and number of oysters present. The frequency distributions also reflected the growth of oysters post-planting, through a drop in numbers of oysters paired with an increase in mean shell height. Although a large amount of variability exists in the population estimates, the bars sampled generally declined after the first year of sampling post-planting and then remained relatively consistent in the years following (see Figure 6.14 below). The opening of the managed reserve bars for harvest is clearly shown through the population declines of Coppers Hill, Drum Point, and Willow Bottom in 2011, however data suggests that natural mortality (through the proportion of box to live oysters) also played a part in the decline of the oyster population at Willow Bottom and at the sanctuary bar Ulmstead Point.

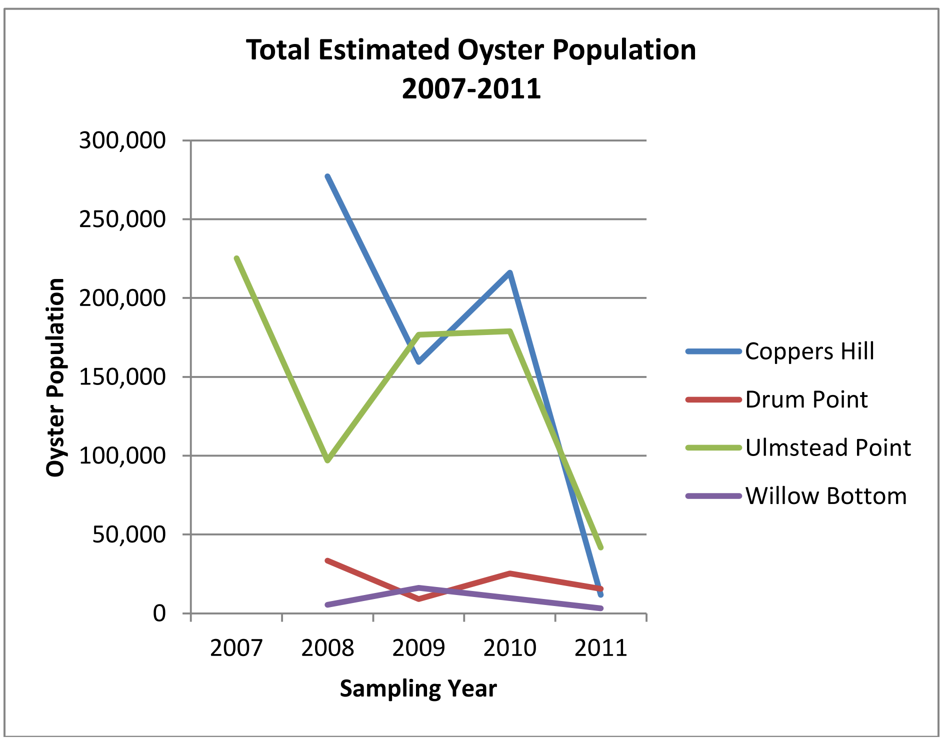



Figure 6.14. Oyster population at each bar sampled by sampling year. Although a large amount of variability exists in the population estimates, the bars sampled generally declined after the

first year of sampling post-planting and then remained relatively consistent until 2011 (after three of the four bars were opened for harvest).

Biomass data show an increase in biomass over time at each bar and complemented the size frequency data, emphasizing at all four bars the influence that oyster size has on biomass relative to population size (see Figure 6.15 below). At each bar, changes in population abundance might have been offset by increasing biomass, as surviving oysters continued to grow. The summary statistics and population estimates accurately reflected the activities occurring on bars between sampling events, whether a planting occurred, the bar was opened for harvest, or the bar remained unchanged. The density plots were able to display not only the changes in the density of oysters between years, but also in their distribution. These shifts in distribution and density may be a tool for managers to use to detect illegal activity on oyster bars. On bars that remained unchanged post-planting, survey data indicate a leveling-off of oyster density and distribution three to four years post planting.

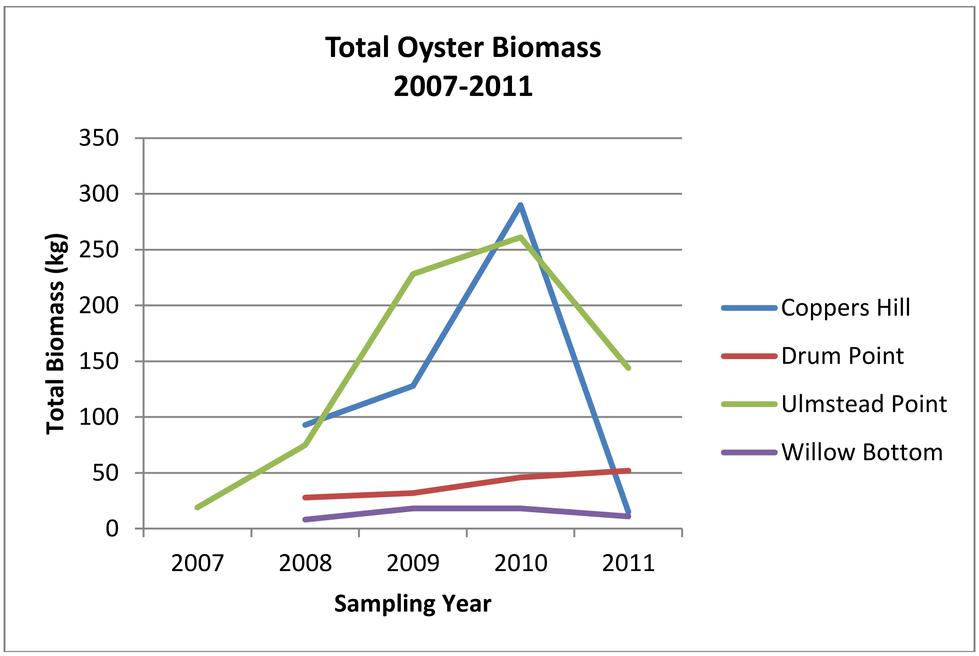



Figure 6.15. Total oyster biomass (in kg) at each bar sampled by sampling year. Biomass increased at each bar through time prior to an open harvest, despite a drop in average oyster size, emphasizing the influence that oyster size has on biomass at each bar sampled.

On oyster bars with low oyster densities (i.e. less than 10 oysters/$m^2$), and thus low populations, the distribution of animals was patchy and therefore changes in the population estimates and spatial distribution of animals was heavily influenced by one or two patent tong samples. Across all four bars, dermo intensity remained low each year, and thus disease was likely not a large factor contributing to mortality at any of these sites. Although data from this survey are generally capturing the nature of undisturbed oyster bars to equalize their oyster densities, populations, and spatial distributions over time post-planting, it is important to survey small bars such as these at the fine scales currently being sampled by the Paynter Lab in order to accurately portray oyster population dynamics on these bars.  This concludes the annual monitoring of these four bars.  Four newly planted bars will be sampled in 2012 for long-term annual monitoring for the next five years.

References

Liddel, M.K.  "A von Bertalanffy Model for the Estimation of Oyster (*Crassostrea virginica*) Growth on Restored Oyster Reefs in the Chesapeake Bay".  Ph.D. dissertation, University of Maryland, College Park, 2007

## Section VII: Research

### An ontogenetic comparison of relative fecundity and egg quality of female *Crassostrea virginica* from northern Chesapeake Bay.

**Research Questions:** Does relative fecundity and/or egg quality change with oyster age? Does relative fecundity and/or egg quality change with the location an oyster lives in within the Chesapeake Bay?

**Methods:** Young and old oysters were collected from the Choptank and Magothy rivers and spawned at Horn Point Oyster Hatchery. Figure 7.1 shows the sampling sites for the 2010 and 2011 sampling seasons. Sample sites are indicated in red. Site name, age (in parenthesis) and year in which the site was sampled are indicated next to each site in yellow. In 2010, oysters were collected from their sites of origin. In 2011, oysters were kept in the same location off of the Horn Point Oyster Hatchery dock for 9 months prior to spawning, in order to control for site differences detected in 2010. Total number of eggs produced, shell height (mm), dry weight (g) and *Perkinsus marinus* infection intensity were recorded for each individual that spawned. Total lipid content (% wet weight) and fatty acid composition were also determined for the eggs of all individuals that spawned.

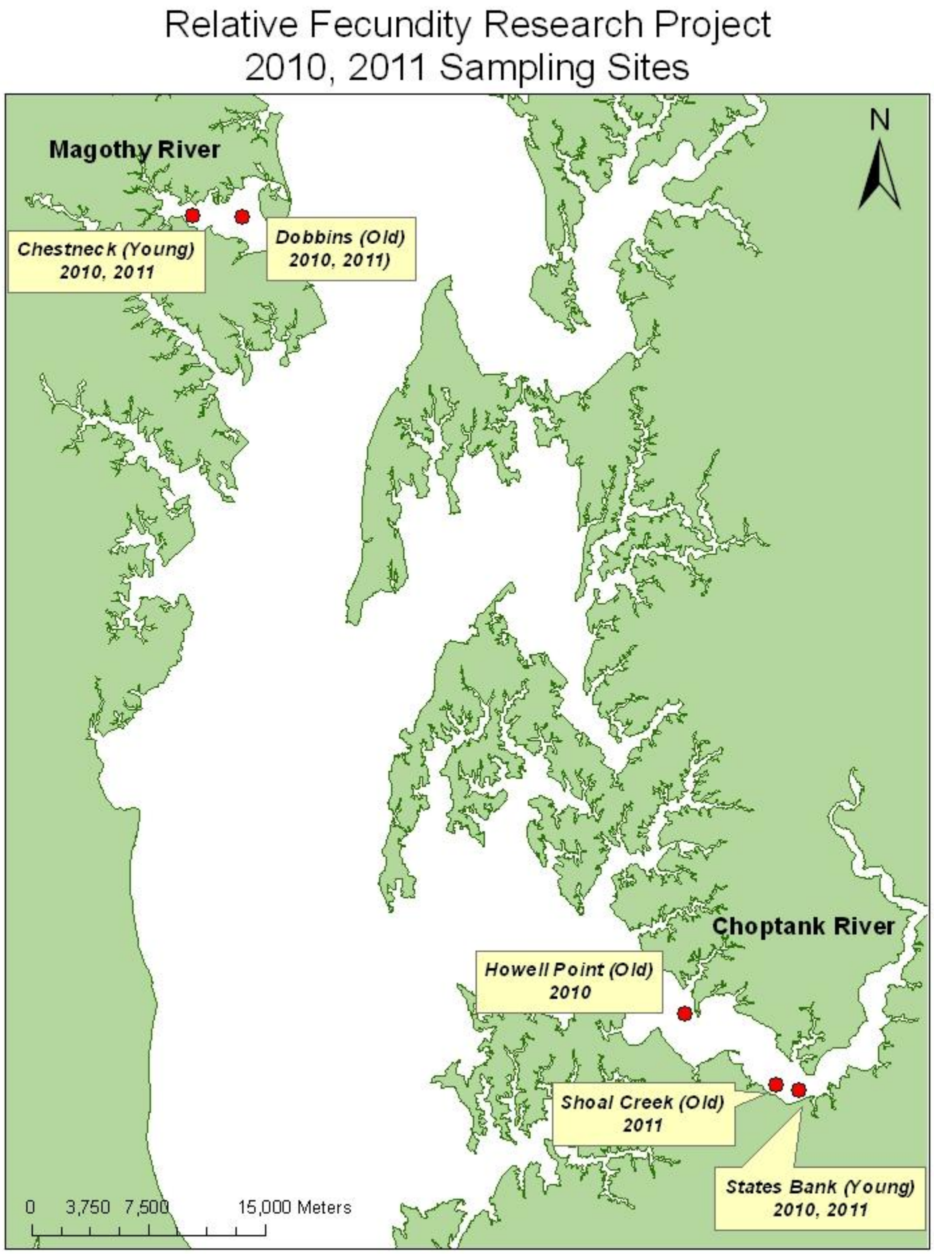



Figure 7.1. Sampling sites for 2010 and 2011 sampling seasons. Sample sites are indicated in red. Site name, age (in parenthesis) and year in which the site was sampled are indicated next to each site in yellow.

**Results:**

Overall metrics

Data from 32 and 69 female oysters from 4 sites in the northern Chesapeake Bay collected in 2010 and 2011, respectively are presented below. Table 7.1 outlines the mean values for all metrics collected on the oysters by collection site and year collected. There was no significant difference in raw count by age class in both 2010 and 2011 (P>0.05 for all comparisons). In 2010, oysters from Dobbins produced significantly less eggs than oysters from all other sites (P=0.04). In 2011, the oysters from Shoal Creek produced significantly more eggs than oysters from Dobbins and States Bank (P=0.007). In 2010, oysters from the Magothy river produced significantly less eggs than oysters from the Choptank river (P = 0.04), but in 2011 there was no difference in the number of eggs produced by river (P>0.05). In both 2010 and 2011, oysters from Dobbins were significantly bigger (greater shell height) than oysters from all other sites (2010: P=0.02, 2011: P<0.0001) and therefore oysters from the Magothy river were significantly bigger than oysters from the Choptank river (2010: P=0.03, 2011: P<0.0001). There was no significant difference in shell height by age class in 2010 (P>0.05), but in 2011 older oysters were significantly larger than younger oysters (P=0.009). There was no significant relationship between raw count and shell height in both 2010 and 2011 (P>0.05 for both years).

There was no difference in dry weight (g) by collection site or river in both 2010 and 2011 (P>0.05 for both comparisons). In 2010, there was no difference in dry weight by age class (P>0.05), but in 2011 old oysters were significantly heavier (greater dry weight) than young oysters (P=0.04). There was no difference in *Perkinsus marinus* prevalence by collection site, river, and age class in 2010 (P>0.05 for all comparisons). In 2011, there was no difference in *P. marinus* prevalence by river, but there were differences by site and age class (P<0.05 for all comparisons). However, it is important to note that the dermo levels seen on our samples were not high enough to elicit a physiological response in *C. virginica*.

Egg Total Lipid Content

The egg total lipid content (ETLC; % wet weight) of all oysters was determined from 4 sites in the northern Chesapeake Bay in 2010 and 2011. Table 7.2 outlines the mean ETLC for oysters by age, collection site and river. In 2010, oysters from Dobbins had significantly more ETLC than oysters from all other sites (P=0.008) but this pattern did not hold during 2011 and no significant difference was observed in ETLC during that year (P>0.05). There was no significant difference in ETLC by river or age class in either year (P>0.05 for all comparisons). In 2010, there was a significant negative relationship between ETLC and raw count (P=0.004, $R^2$=0.25), a relationship that was heavily influenced by the oysters from Dobbins (see Figure 7.2). In 2011, there was a significant positive relationship between ETLC and raw count (P=0.006, $R^2$=0.11).

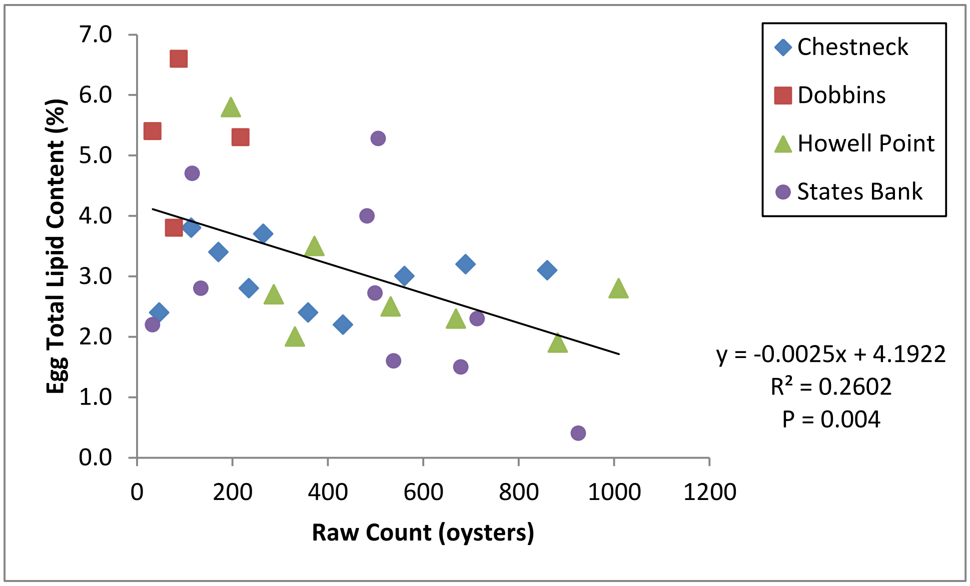



Figure 7.2. ETLC by raw count for female oysters spawned in 2010. There was a significant negative relationship between ETLC and raw count (P=0.004, $R^2$=0.26), however this relationship was largely driven by the four animals spawned from Dobbins (red squares).

Table 7.1. Mean metrics for female oysters by site and year collected. SEM = standard error of the mean. Dermo WP = *Perkinsus marinus* weighted prevalence.

| River | Site | Year | Age | n | Raw Count | Shell Height (mm) | SEM | Dry Weight (g) | SEM | Dermo WP | SEM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Magothy | Chestneck | 2010 | 4 | 10 | 373.3 | 105.1 | 5.77 | 1.43 | 0.14 | 0.2 | 0.11 |
| | Chestneck | 2011 | 5 | 20 | 303.23 | 110.8 | 4.09 | 1.99 | 0.17 | 0.3 | 0.08 |
| | Dobbins | 2010 | 11 | 4 | 104 | 127 | 5.83 | 2.16 | 0.31 | 1 | 0.68 |
| | Dobbins | 2011 | 12 | 12 | 240.94 | 134.08 | 5.81 | 2.67 | 0.35 | 1.08 | 0.29 |
| Choptank | States Bank | 2010 | 3 | 10 | 462.5 | 100.9 | 5.27 | 1.35 | 0.23 | 0.25 | 0.13 |
| | States Bank | 2011 | 4 | 20 | 237.63 | 100.55 | 2.68 | 1.91 | 0.11 | 0.25 | 0.16 |
| | Howell Point | 2010 | 9 | 8 | 535 | 92.13 | 5.84 | 1.77 | 0.37 | 0.25 | 0.16 |
| | Shoal Creek | 2011 | 10 | 17 | 378.67 | 107.71 | 4.3 | 2.19 | 0.16 | 0.44 | 0.19 |

Table 7.2. Mean egg total lipid content (ETLC; % wet weight) by age class, collection site and river.

| 2010 | | | | 2011 | | | |
|---|---|---|---|---|---|---|---|
| **Age Class** | **n** | **% Lipid** | **SEM** | **Age Class** | **n** | **% Lipid** | **SEM** |
| Old | 12 | 3.72 | 0.47 | Old | 29 | 4.86 | 0.21 |
| Young | 20 | 2.88 | 0.25 | Young | 40 | 4.99 | 0.24 |
| **Site (Age)** | **n** | **% Lipid** | **SEM** | **Site (Age)** | **n** | **% Lipid** | **SEM** |
| Chest Neck (4) | 10 | 3.00 | 0.17 | Chest Neck (5) | 20 | 4.79 | 0.27 |
| Dobbins (11) | 4 | 5.28 | 0.57 | Dobbins (12) | 12 | 5.04 | 0.29 |
| States Bank (3) | 10 | 2.75 | 0.48 | States Bank (4) | 20 | 5.19 | 0.39 |
| Howell Point (9) | 8 | 2.94 | 0.45 | Shoal Creek (10) | 17 | 4.74 | 0.30 |
| **River** | **n** | **% Lipid** | **SEM** | **River** | **n** | **% Lipid** | **SEM** |
| Choptank | 18 | 2.83 | 0.32 | Choptank | 37 | 4.98 | 0.25 |
| Magothy | 14 | 3.65 | 0.34 | Magothy | 32 | 4.88 | 0.20 |

*Egg Fatty Acid Composition*

Eggs from individual female oysters were analyzed for fatty acid composition using gas chromatography. In 2010, significant differences were found in the fatty acid composition of eggs by site (global R = 0.368, Figure 7.3), and the SIMPER analysis indicated that polyunsaturated fatty acids (18:2n-6 and 22:6n-3, specifically) being the most influential in separating the fatty acid signatures between sites. Eggs from oysters from sites within the same river had more similar fatty acid signatures than eggs from oysters from different rivers, indicating a possible difference in diet between rivers. However, in 2011, no significant site differences were observed in the fatty acid composition of oyster eggs (global R = 0.046). This is likely due to the similar environments the oysters were exposed to while they were developing their eggs over the fall and winter. See Figure 7.4.

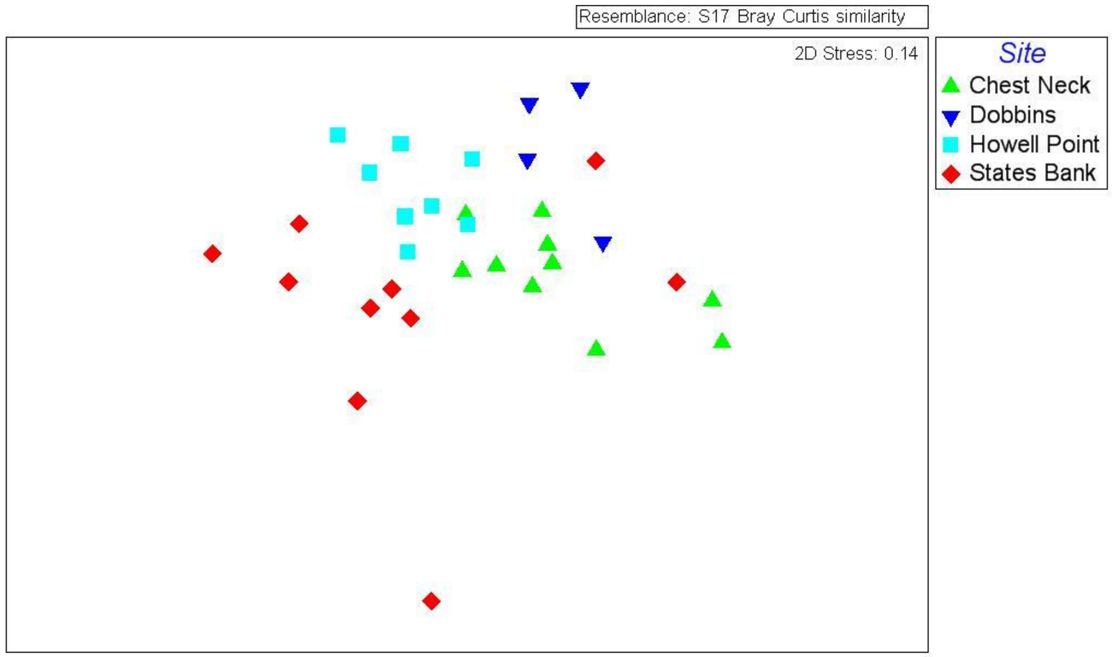



Figure 7.3. MDS plot of the fatty acid signatures of eggs by site in 2010. The ANOSIM revealed significant differences in the fatty acid signatures of eggs by site. The SIMPER analysis indicated that polyunsaturated fatty acids (18:2n-6 and 22:6n-3, specifically) being the most influential in separating the fatty acid signatures between sites.

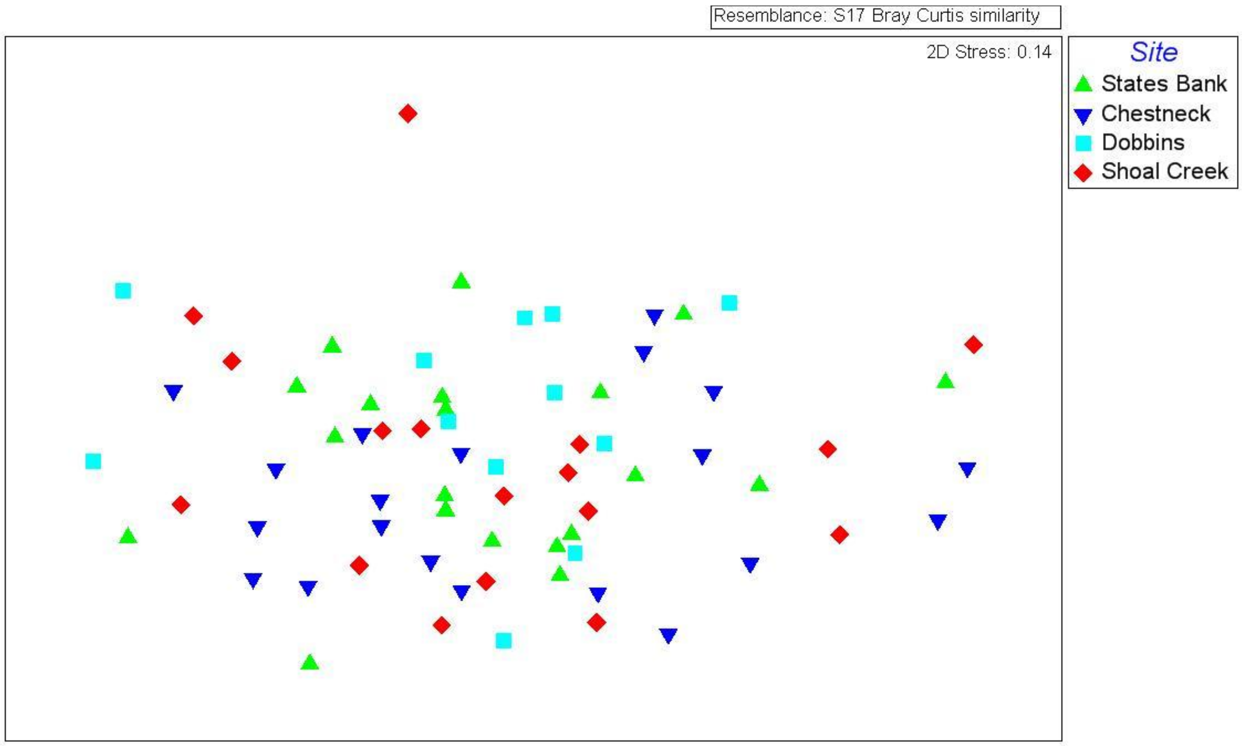


Figure 7.4. MDS plot of the fatty acid signatures of eggs by site in 2011. The ANOSIM revealed no significant differences in the fatty acid signatures of eggs by site. This lack of significance relative to the animals sampled in 2010 is likely due to the similar environments, and therefore diets the oysters were exposed to during egg development prior to the 2011 sampling event.

Although no significant differences were found in the fatty acid signatures of eggs by oyster age class, the MDS plot does indicate some similarity within age classes in 2010 (Figure 7.5). However, no obvious pattern was observed in the eggs from oysters sampled in 2011 (Figure 7.6). No significant relationship was found between the fatty acid signatures of eggs and oyster size or river.

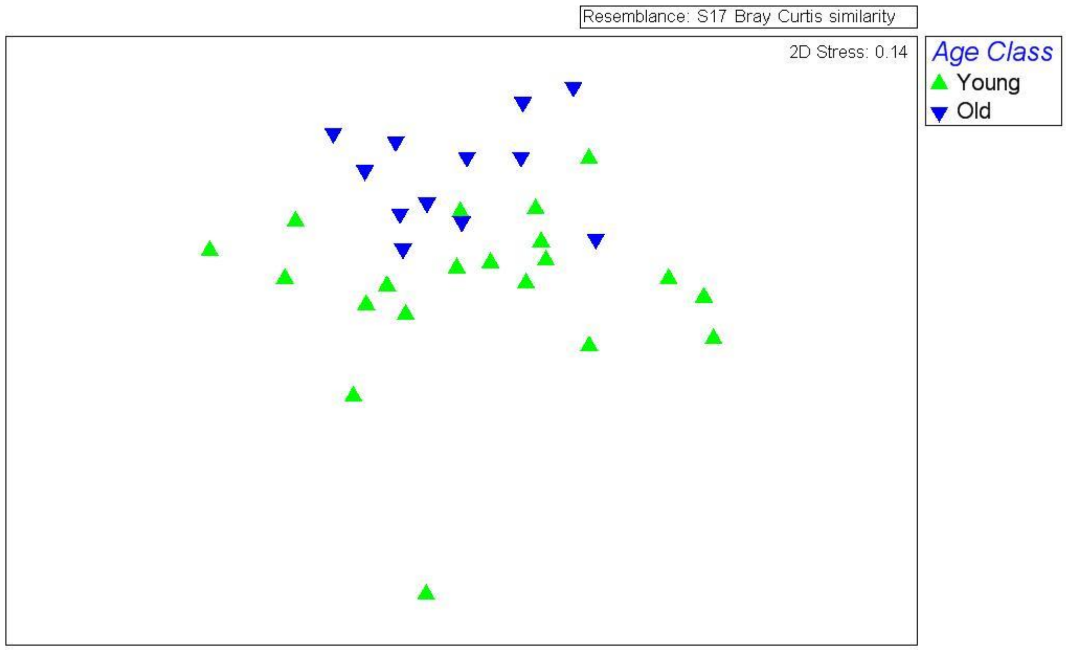



Figure 7.5. MDS plot of fatty acid signature of eggs by oyster age class in 2010. Although the ANOSIM found no significant differences in the fatty acid signatures of eggs by oyster age class, the MDS plot indicates there is some separation of fatty acid signatures based on oyster age.

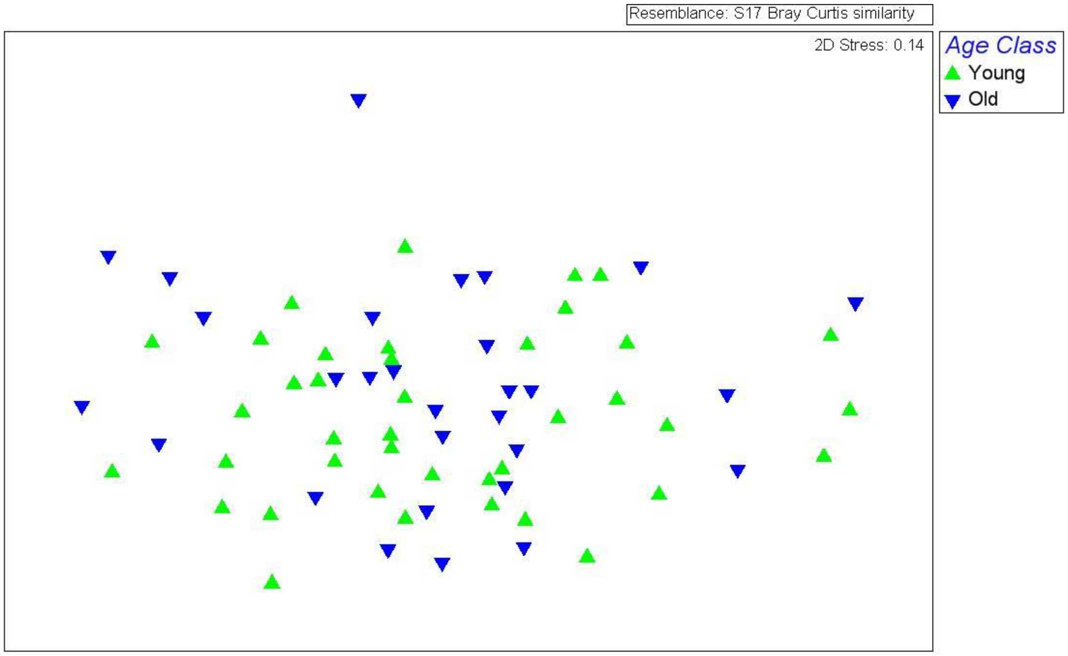


Figure 7.6. MDS plot of fatty acid signature of eggs by oyster age class in 2011. Contrary to the trend in 2010, there was no apparent relationship between oyster age and the fatty acid composition of eggs in 2011.

**Conclusions**

In summary, there was variation present in number of eggs spawned, shell height and dry weight and *P. marinus* prevalence in oysters from different sites, rivers and of different ages. However, the main source of this variation is the older animals from the Magothy river that were spawned in 2010. Also, no significant relationship was found between the size of the oyster and egg number in either year, indicating that oyster age, rather than oyster size, may play a role in the number of eggs an oyster produces. The apparent relationship between oyster age and egg total lipid content in 2010 was not confirmed in 2011 and the trends observed in 2010 were likely a result of data from four animals from the Dobbins oyster bar that successfully spawning in 2010. The 2011 Dobbins animals preformed much better, with 12 animals successfully spawning, and the site/age trends from 2010 were not present in 2011.

The overwintering of animals in the same location between the 2010 and 2011 spawning events eliminated differences in the fatty acid composition of eggs that were apparent in 2010. In 2010, the fatty acid signature of eggs differed by site, with eggs from oysters from the same river having more similar fatty acid signatures than eggs from oysters from different rivers. However, once the animals were kept in the same environment and therefore were exposed to the same food source, these differences disappeared. These results indicate that the fatty acid composition of oyster eggs is highly correlated to diet of the oyster making the eggs. Since fatty acid signatures are generally used to indicate diet, it would not be surprising that when the animals were exposed to similar diets, their fatty acid signature would be similar. However, this study focused on the fatty acid composition of the oyster eggs, not the oyster tissues themselves. It was therefore surprising to observe the differences in fatty acid signatures of the oyster eggs by site when the oysters were exposed to different environments and the similarity of the fatty acids once the environmental variation was removed. These findings call into question the idea that reproductive outputs have singular formulas within a species and bring to light the effect of the environment on not only the animals themselves, but also their offspring.

Future work should include collection of more oysters from different sites throughout the northern Chesapeake Bay to solidify trends spatially and inter-annually. A study to examine the fertilization success, success to D-hinge and/or settlement success should be done to determine the effects of the differences found in egg quality. Additionally, a study to examine the phyto-and zooplankton abundance and fatty acid composition in the rivers should be done to determine the source of the differences observed in the fatty acid composition of the oyster eggs in 2010.

## Section VIII: Lessons Learned

**Bar Rehabilitation:**
The 2011 bar rehabilitation monitoring was incomplete due to the lack of sites in which both pre and post rehabilitation surveys were conducted. For the two sites in which pre and post data were available, only one site showed marginal bottom type improvement. We believe this is due to patchy placement of shell resulting from the technique used for bar rehabilitation, such that divers may miss areas of high shell concentration. In order to improve on this, we hope to have better coordination of this effort in 2012 so that more pre and post rehabilitation data could be collected and more broad conclusions can be made.

**Ground-truthing:**
The use of side scan sonar (SSS) during site selection for groundtruthing was critical in our ability to select sites that would have the best bottom for planting. Steve Allen was crucial in this effort by helping Paynter Lab staff in choosing good sites to survey. The coordination of the use of SSS (provided by the Maryland Geological Survey and NOAA Chesapeake Bay Office) and thoughtful site selection by the ORP set our divers (as well as plantings) up for success in 2011. We will continue this coordinated effort in 2012.

**Post-planting Monitoring:**
Survival was up from an average of 13% in 2008-2010 to 27% in 2011. We believe this is directly tied to excellent site selection for planting on the part of the ORP, especially considering the low salinities experienced in 2011. We also believe that the overplanting of sites that was started in 2010 and continued into 2011 played a role in the high spat survival observed in 2011. Data from our spat survival and growth rate study (data will be presented in a separate report) indicate that spat planted on bottom with good shell coverage survived better than spat planted on sand or mud, further underscoring the importance of a shell base in spat survival. In 2012 we would like to continue sampling using quadrats in order to be able to relate spat density to survival. We would also like to use the data collected in the spat survival and growth rate experiment in 2011 to refine the parameters for the study in 2012, in order to continue to understand the effect of bottom type and spat size on survival. Assuming that a large area of dense shell bottom is available to us, we hope to conduct a large-scale experiment in 2012 similar to the spat size and growth rate experiment in order to test the large-scale trends in spat survival on different bottom types. We would also like to conduct a predator exclusion experiment in 2012 to understand how the size of different predators of oysters effects the survival of spat on restored bars.

**Patent Tong Survey:**
Overall, oyster density was related to shell score in that areas with high shell coverage also had high oyster densities, although there was some variation around this trend. Many plots showed that areas of high shell score did not yield high oyster density. This suggested that high shell score was not always associated with the presence of live oysters, although areas with high oyster density tended to also have high shell coverage. Average live oyster density on all bars sampled was 4 oysters/$m^2$, a density much lower than the recommended 15 oysters/$m^2$ metric

set by the NOAA/DNR/VMRC-led effort to define metrics of restoration success. Similarly, when taking into account expected annual mortality, oyster populations observed on patent tonged bars were generally less than 20% of the expected population. We believe the high mortality observed on restored bars is due to two main factors: poor bottom quality and illegal harvest of protected oysters. As seen in our post-planting monitoring data, when oysters are planted on suitable bottom, survival is higher. The extensive patent tong surveys conducted in Harris Creek and the Little Choptank River (data will be presented in a separate report) further underscore the importance of a shell base in the survival of oysters. That survey showed that shell score was significantly positively related to oyster density throughout both tributaries. However, the presence of good bottom will be a hurdle to overcome, as much of each river contained bottom unsuitable for restoration. We hope that as good bottom is identified and populations are restored on bottom with more shell coverage in the future, observed oyster populations in the patent tong survey will more closely match the expected populations.

In 2012, we will be changing our long-term monitoring bars to new bars that were planted in 2011. The extensive patent tong surveys conducted in Harris Creek and the Little Choptank River surveyed three sites that were planted in 2011, and those sites will become the new long-term monitoring bars from 2012 onwards. We hope to confirm the trends we observed in the first long-term monitoring survey without the complication of harvest, since these bars exist in tributaries that are entirely sanctuaries and therefore should never be open to harvest. In 2012 we hope to use the data from our first extensive patent tong survey to refine the survey technique and collect more data on oyster density and shell coverage on a tributary scale. Additionally, with the help of Jim Wesson at the VMRC, we will be quantifying the ratio of black to brown shell (buried: surface) present in patent tong grabs in 2012.

**Overall**

In 2012 we observed the highest spat survival in four years of post-planting monitoring. We believe that this high survival is directly related to the placement of spat-on-shell onto bottom with good shell coverage. The coordination of the efforts of the Maryland Geological Survey, NOAA Chesapeake Bay Office, the ORP and the Paynter Lab allowed for the implementation of the most up-to-date data on the suitability of areas for planting. This coordination is critical to the success of oyster restoration and we believe that the results of the 2012 planting year underscore the importance of such management.

Our experimental results also indicate the importance of good shell coverage for oyster survival. Our next challenge will be to identify areas with good shell coverage for planting, since our survey data do indicate the lack of large areas of bottom with a continuous, dense shell base. Refining our tools for identifying good bottom as well as understanding the expected survival of oysters planted on marginal bottom will help to create successful restoration projects in the future. In addition to expanding on the spat survival and growth rate experiment as well as the extensive patent tong surveys in 2012, we hope to conduct a predator exclusion experiment and a laboratory experiment to understand how spat density affects the predation of mud crabs, in order to more fully understand the factors affecting oyster survival in the Chesapeake Bay.