Oyster Restoration Monitoring 2010

submitted to the

Oyster Recovery Partnership

February, 2011

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Executive Summary

Monitoring activities undertaken by the Paynter Laboratory at the University of Maryland in 2010 can be broken down into four categories: pre-planting ground-truthing (GT), post-planting monitoring (PPM), patent tong surveying, and research. GT involves the assessment of bottom quality prior to planting spat-on-shell by the Partnership. 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 oyster on various bars as well as to sample the oysters for size and *Perkinsus marinus* prevalence. The research we conducted this year included preliminary crab exclusion experiments, an assessment of egg quality from four groups of oysters, and collaboration with scientists from the Horn Point Laboratory, UMCES, conducting a nutrient-reef metabolism study in the Choptank River. We also published a manuscript describing the growth and disease prevalence in oysters collected from many of the ORP-restored reefs and presented scientific papers at several national meetings.

This was the first year that GT (Section I) was undertaken using guidance from side scan sonar (SSS) to identify target areas before diving. This proved to be highly productive as it improved our efficiency in locating bottom suitable for planting very quickly. In previous years, target areas were “guesses” and often times contained marginal or bad bottom (little or no shell, mud, soft sand). We assessed 19 bars identifying acceptable planting areas within most bars.

PPM (Section II) again showed that the mean survivorship of spat planted was around 13%, which was similar to survivorship estimated in previous years. Sixteen bars were sampled and survival ranged from 0.4 to 33.9%. Although a strong negative correlation between initial spat/shell count and survival was shown in 2009, in 2010 no such relationship was found. We also sampled areas of high spat density (spat/m2) and low spat density to test whether density was related to survival. Some ecological theories suggest predation may cause higher mortality in areas of high prey (spat) abundance. However, our sampling showed no such correlation existed in 2010. We also attempted to correlate growth rate (mm/day) with survival since good growth may indicate better environmental conditions and lower mortality. Again, no correlation was found. Thus, we will continue to examine the cause(s) of early spat mortality in the future in order to better understand the dynamics of survival on restored oyster bars.

Patent tong surveys (Section III) 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. Fifteen bars were surveyed with oyster densities ranging from 0 to 107 oysters/m^2. Population estimates continue to reflect low overall survival on most restored reefs; less than 10% of the planted spat (when accounting for first year mortality) were present in the patent tong surveys conducted in 2010. However, three reefs (Ulmstead, Coppers Hill and Emory Hollow) showed much higher survival. ORP has begun adjusting for this low abundance by increasing the number of spat planted/acre.

Dermo weighted prevalences (WP, a measure of disease intensity) in most populations were low except those at Bolingbroke Sands (WP=1.73) in the Choptank River and at Spaniards Point (WP=1.05) in the Chester River. The WP in the oysters at Bolingbroke Sands may indicate significant disease mortality on that bar in 2011.

Long-term population surveys (Section IV) have been conducted annually at Coppers Hill, Drum Point, Ulmstead Point and Willow Bottom. These surveys show annual changes in size (length and biomass) and abundance on each bar. The results of these surveys showed very low, decreasing oyster abundances at Willow Bottom and Drum Point although they showed increasing biomass since they were planted. Ulmstead Point and Coppers Hill showed high abundances and healthy biomass increases since planting.

We have begun to use biomass as the most meaningful measure of oyster growth on restored reefs since it best represents the “amount” of oyster on the reef that will be spawning and providing ecosystem services.

Research and analyses of the data we have collected have yielded some interesting observations and conclusions (Section V). In general, we are refining our approach to oyster restoration and understanding better what to expect over time with hatchery-produced restoration efforts. We are stymied by the high spat mortality rates within eight weeks after planting. This mortality may be entirely natural and something restoration programs simply must accept. However, observations from the hatchery, including samples of planted shells hung from the dock, indicate mortality is not as high on those shells. Since lower mortality has been observed at the hatchery than in the field, we hope to pinpoint the causes of this observed decline in mortality and apply them to the spat that get planted on the reefs. Accurately estimating the populations of oysters on restored bars is another challenge to successful restoration. The hyper-variability in abundances of many of the populations scattered over wide areas leads to very high variability in our population estimates. We continue to analyze our survey data to determine the best ways to estimate abundances and survivorship.

Some of our work was published in the Journal of Shellfish Research in 2010 (Vol. 29, No. 2, 309–317, 2010) and presented at several national meetings including four papers at the National Shellfisheries meeting in San Diego, CA, two papers at the Benthic Ecology meeting in Wilmington, NC, and three papers at the International Conference on Shellfish Restoration in Charleston, SC.

In summary, this report describes our findings in detail and presents data and analyses that provide a pathway to adaptive management in oyster restoration.

ANNUAL SUMMARY TO THE OYSTER RECOVERY PARTNERSHIP 2010

Field Summary

- Experimental Work:
    - Predator exclusion experiment
        - Conducted 6/8-6/23/10
        - Purpose: to determine which predators most affect spat survival
        - Treatments: Live well (control), Completely open cage, 1" mesh cage, ¼" mesh cage, fine mesh cage.
        - Spat on shell were collected from the hatchery and 15 shells were placed in each cage.
        - 2 replicates per treatment were deployed (array of 8) on Glebe Bay for 2 weeks.
        - Preliminary data analysis shows ¼" mesh had higher survival than the 1" mesh cage, indicating large predators (mud crabs) may be responsible for spat mortality.
    - Oyster reproductive senescence experiment
        - Conducted 6/18-6/30/10
        - Purpose: to determine the effect of oyster age on relative fecundity and egg quality.
        - 200 oysters were collected from 4 locations: Dobbins (11y), Chest Neck Point (4y), Howell Point (9y) and States Bank (3y).
        - About 100 oysters from each site were mass-spawned, with 98 females over the 4 sites successfully spawning.
        - Egg count, shell height (mm), total mass (g) and wet tissue mass (g) were collected for each individual on spawning day.
        - Each spawning female was sampled for dry weight and dermo prevalence.
        - Eggs from each spawning female were individually collected for lipid analysis.
    - Mirant tray study
        - Conducted in collaboration with Dr. Lisa Kellogg at Horn Point Laboratory.
        - Purpose: to establish the denitrification pathways and abilities of the oyster reef system.
        - Paynter Lab's main responsibilities were field support for the project.
    - Army Corps of Engineers alternate substrate monitoring
        - Purpose: to compare oyster survival and community composition on different substrate types in the Chesapeake Bay.
- Days in Field:
    - Multiple types of work were conducted on many field days to take full advantage of ideal weather conditions, creating less total* days on the water than work completed. (See Table 1.)

Table 1. Total days on the water for each activity completed.

Activity	Field Days
Experimental Work	14
Ground Truthing	13
Media Event	2
Oyster Size/Disease (Dive)	8
Patent Tong Surveys	21
Post-planting Monitoring	9
Total Field Days*	54*

Lab Summary

- Pre-planting ground truthing survey completed.
  - See Section I.
  - 2010 was the first year that Side Scan Sonar (SSS) data were available for many of the sites that were surveyed.
  - 2010 survey data show that diver surveys of different bottom types confirm bottom-typing suggested by the SSS data.
  - These results underscore the importance of complete SSS coverage for all ground-truthing surveys.
- Post-planting monitoring survey completed.
  - See Section II.
  - Average 2010 spat survival was 12.67%, which was similar to 2009 survival (11.99%).
  - 2010 data do not suggest a trend with initial number of spat on shell and survival of spat 4-8 weeks post-planting.
  - 2010 data also do not suggest a trend with the density of spat/shells and spat survival.
  - These results suggest that the variation observed in spat survival is not related to the initial spat on shell number or density, indicating some other factor affecting spat survival among sites.
  - The Paynter Lab is currently developing a protocol to test additional factors affecting spat survival in 2011.
- Patent tong survey of sanctuaries and managed reserves completed.
  - See Section III.
  - 13 bars were monitored in the 2010 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.
- *Perkinsus marinus* (Dermo) monitoring completed.
  - Table 2 compares Dermo prevalence and intensity from 2008-2010.

        - Although sites were not consistent between years, these data show that 2010 had the highest prevalence and intensity of any year surveyed, but all years were relatively low and not different from each other.
    - See Table 3 below for a summary of the 2010 data.
    - Mean prevalence was 35.85% and mean intensity was 0.41.
    - These data suggest Dermo was not high in surveyed bars in 2010 and was probably not a large factor in oyster survival.

Table 2. Mean *Perkinsus marinus* prevalence and intensity from 2008-2010, with mean salinity per year.

Year	**Mean Prevalence (%)**	**SD**	**Range**	**Mean Intensity**	**SD**	**Range**	**Mean Salinity (‰)**
2008	29.98	25.86	0 - 93	0.28	0.46	0 - 2.07	N/A
2009	26.07	23.18	0 - 90	0.32	0.47	0 - 1.77	12.3
2010	35.86	32.35	0 - 100	0.41	0.59	0 - 2.53	11.3

Table 3. 2010 *Perkinsus* marinus prevalence and intensity by site.

Region	Bar Name	Plant Year	Date Collected	How Collected	Average Shell Height (mm)	Average Total Weight (g)	Average Shell Weight (g)	Dermo Prevalence (%)	Dermo Weighted Intensity
MAGOTHY RIVER	BLACK	2008	08-Oct-10	PTONG	76.83	53.79	28.13	6.67	0.10
UPPER CHESTER RIVER	BLACK BUOY	2009	03-Dec-10	PTONG	118.47	313.80	263.91	33.33	0.14
UPPER CHESTER RIVER	BLACK BUOY	2009	03-Dec-10	PTONG	68.48	43.74	34.76	7.41	0.00
UPPER CHOPTANK RIVER	BOLINGBROKE SAND	2006	03-Dec-10	PTONG	104.69	202.65	178.53	100.00	1.73
SOUTH RIVER	BREWER	2006	21-Oct-10	Dive	89.76	137.72	110.73	100.00	2.53
EASTERN BAY NORTH	CABIN CREEK	2008	21-Sep-10	Dive	69.21	45.41	35.01	3.45	0.00
MAGOTHY RIVER	CHEST NECK POINT	2006	28-Oct-10	Dive	111.47	112.07	82.00	0.00	0.00
SEVERN RIVER	CHINKS POINT	2007	21-Oct-10	Dive	93.10	72.26	53.79	90.00	1.37
EASTERN BAY NORTH	COX NECK	2007	29-Nov-10	Dive	96.31	104.86	80.12	69.23	1.16
UPPER CHOPTANK RIVER	DIXON	2007	03-Nov-10	Dive	109.27	216.26	178.37	6.67	0.04
BROAD CREEK	DRUM POINT	2007	14-Sep-10	PTONG	95.57	165.64	137.55	10.00	0.01
CHOPTANK RIVER	DUER MEMORIAL	2006	28-Oct-10	Dive	6.07	115.50	129.44	56.67	0.35
SOUTH RIVER	DUVALL/ FERRY POINT	2007	01-Sep-10	Dive	89.21	90.69	72.96	85.19	1.60
SOUTH RIVER	DUVALL/ FERRY POINT	2006	01-Sep-10	Dive	76.63	60.14	44.55	58.62	0.84
UPPER CHESTER RIVER	EMORY HOLLOW	2008	20-Oct-10	PTONG	94.63	75.67	56.73	3.33	0.03
UPPER CHESTER RIVER	EMORY WHARF	2005, 2006	23-Nov-10	PTONG	137.30	192.76	143.11	26.67	0.27

Region	Bar Name	Plant Year	Date Collected	How Collected	Average Shell Height (mm)	Average Total Weight (g)	Average Shell Weight (g)	Dermo Prevalence (%)	Dermo Weighted Intensity
UPPER CHESTER RIVER	EMORY WHARF	2008	23-Nov-10	PTONG	86.43	92.22	72.05	83.33	0.65
MIDDLE CHOPTAN K RIVER	GREEN MARSH	2008	03-Nov-10	Dive	95.50	77.34	57.05	14.81	0.01
MIDDLE CHOPTAN K RIVER	GREEN MARSH	2003	03-Nov-10	Dive	128.70	319.66	261.81	66.67	1.24
LOWER CHESTER RIVER	HICKORY THICKET	2006	20-Aug-10	Dive	106.14	108.00	83.10	31.58	0.12
LOWER CHESTER RIVER	HICKORY THICKET	2008	20-Aug-10	Dive	66.23	29.22	22.98	26.67	0.20
LOWER CHESTER RIVER	HICKORY THICKET	2007	20-Aug-10	Dive	82.57	85.47	55.50	11.11	0.04
LOWER CHESTER RIVER	HICKORY THICKET	2006	16-Sep-10	PTONG	104.28	115.12	93.34	12.00	0.04
EASTERN BAY NORTH	MILL HILL	2008	29-Nov-10	Dive	87.19	51.15	38.06	12.50	0.13
MILES RIVER	OLD ORCHARD	2008	29-Nov-10	Dive	80.38	99.01	84.34	0.00	0.00
MAGOTH Y RIVER	PARK	2008	08-Oct-10	PTONG	78.40	54.76	40.43	10.71	0.04
UPPER CHESTER RIVER	PINEY POINT	2007	17-Aug-10	PTONG	83.20	112.06	99.02	20.00	0.17
UPPER CHESTER RIVER	POSSUM POINT	2005, 2006	23-Nov-10	PTONG	109.00	148.06	112.06	30.00	0.14
UPPER CHOPTAN K RIVER	SHOAL CREEK	2006	21-Sep-10	Dive	113.30	173.00	134.04	82.76	0.81
UPPER CHOPTAN K RIVER	SHOAL CREEK	2009	21-Sep-10	Dive	69.47	45.82	36.20	66.67	0.29
UPPER CHOPTAN K RIVER	SHOAL CREEK	2007	21-Sep-10	Dive	106.61	192.77	158.54	95.65	1.45
UPPER CHESTER RIVER	SPANIARD POINT	2006	31-Aug-10	PTONG	97.90	169.24	144.60	80.00	1.05

Region	Bar Name	Plant Year	Date Collected	How Collected	Average Shell Height (mm)	Average Total Weight (g)	Average Shell Weight (g)	Dermo Prevalence (%)	Dermo Weighted Intensity
UPPER CHOPTANK RIVER	STATES BANK	2007	21-Sep-10	Dive	95.07	202.47	172.39	50.00	0.15
LOWER CHESTER RIVER	STRONG BAY	2008	20-Aug-10	Dive	78.93	54.60	44.97	20.00	0.01
LOWER CHESTER RIVER	STRONG BAY	2007	20-Aug-10	Dive	105.32	99.19	80.89	38.71	0.17
LOWER CHESTER RIVER	STRONG BAY	2005	20-Aug-10	Dive	123.93	173.64	138.65	20.00	0.20
LOWER ANNE ARUNDEL SHORE	TOLLY POINT	2006	21-Oct-10	Dive	98.63	112.28	85.15	63.33	0.71
LOWER ANNE ARUNDEL SHORE	TOLLY POINT	2009	21-Oct-10	Dive	69.77	43.15	32.34	6.67	0.04
SEVERN RIVER	TRACES HOLLOW	2010	15-Nov-10	Dive	27.13	SPAT	SPAT	0.00	0.00
MAGOTHY RIVER	UMPHASIS	2006	08-Oct-10	PTONG	98.00	102.26	78.89	20.00	0.21
SEVERN RIVER	WADE	2010	15-Nov-10	Dive	11.27	SPAT	SPAT	10.71	0.07
SEVERN RIVER	WADE	2010	15-Nov-10	Dive	13.63	SPAT	SPAT	10.00	0.01
SEVERN RIVER	WADE	2010	15-Nov-10	Dive	13.40	SPAT	SPAT	3.33	0.00
SEVERN RIVER	WEEMS UPPER	2010	15-Nov-10	Dive	36.46	SPAT	SPAT	10.71	0.07
UPPER CHESTER RIVER	WILLOW BOTTOM	2007	14-Sep-10	PTONG	98.79	156.31	130.71	58.62	0.26

- Water quality was measured at each site using a YSI.
    - Variables collected include surface and bottom temperature, salinity, and dissolved oxygen.
    - Table 4 shows bottom and surface salinity at sites, arranged by river/region and date collected while Table 5 gives the average bottom salinity for each region.
    - With salinity values ranging from 5.32 ‰ (Tolly Point Surface) to 16.8 ‰ (Cook’s Point Bottom) and an average bottom salinity of 11.33 ‰ with a standard deviation of 1.81, overall 2010 salinity values were not unusually high nor low, nor did they fluctuate greatly throughout the year.

Table 4. Salinity (‰) at each site in 2010.

Date Surveyed	Site	Region	Surface Salinity (‰)	Bottom Salinity (‰)
7/15/2010	9' Knoll	Chester	10.4	10.3
7/15/2010	Strong Bay	Chester	10.4	10.3
7/22/2010	Carpenter's Island	Chester	9.7	9.9
7/22/2010	Coppers Hill/Piney Point	Chester	9.4	9.6
7/22/2010	Hudson	Chester	8.4	8.6
8/17/2010	Coppers Hill/Piney Point	Chester	9.8	10.2
8/20/2010	Blunt	Chester	10.6	11.0
8/20/2010	Hickory Thicket	Chester	10.6	11.3
8/20/2010	Strong Bay	Chester	11.3	11.4
8/31/2010	Spaniard Point	Chester	9.4	10.1
9/14/2010	Drum Point	Chester	10.1	10.2
9/14/2010	Willow Bottom	Chester	10.8	10.8
9/16/2010	Hickory Thicket	Chester	13.4	13.5
10/20/2010	Emory Hollow	Chester	9.1	9.3
7/20/2010	Bolingbroke Sand	Choptank	9.4	9.7
8/26/2010	Sandy Hill	Choptank	11.5	11.7
9/21/2010	Cabin Creek	Choptank	9.4	10.3
9/21/2010	Cook's Point	Choptank	16.0	16.8
9/21/2010	Shoal Creek	Choptank	11.6	12.1
9/21/2010	States Bank	Choptank	11.9	12.4
11/3/2010	Dixon	Choptank	9.8	9.9
11/3/2010	Green Marsh	Choptank	11.8	12.2
11/3/2010	Sandy Hill	Choptank	12.6	13.4
11/3/2010	Shoal Creek	Choptank	11.3	12.1
11/3/2010	States Bank	Choptank	9.8	9.9
12/3/2010	Black Buoy	Choptank	12.2	12.0
12/3/2010	Bolingbroke Sand	Choptank	12.2	12.0
11/29/2010	Bugby	Eastern Bay	13.5	13.6
11/29/2010	Cox Neck	Eastern Bay	13.9	13.9
11/29/2010	Mill Hill	Eastern Bay	13.5	13.6
10/28/2010	Black	Magothy	10.2	10.3
10/28/2010	Chestneck	Magothy	10.1	10.2
10/28/2010	Dobbins	Magothy	10.4	10.5
10/28/2010	Duer	Magothy	10.1	10.2
10/28/2010	Park	Magothy	10.2	10.6
10/28/2010	Ulmstead	Magothy	10.2	10.3
11/29/2010	Old Orchard	Miles River	13.5	13.5
4/15/2010	Tolly Point	Severn	5.3	8.7
9/1/2010	Ferry Point	South	11.1	11.2
8/9/2010	Flag Pond/Calvert Cliffs	Upper Calvert Shore	14.7	15.7

Table 5. Mean bottom salinity and *Perkinsus marinus* prevalence and intensity in each river/region surveyed.

Region	Mean Prevalence	SD	Range	Mean Intensity	SD	Range	Ave Bottom Salinity (‰)
Chester	34.48	26.2	3-83	0.29	0.39	0-1.44	10.46
Choptank	56.82	35.10	7-100	0.65	0.65	0-1.73	11.89
Eastern Bay	28.39	35.65	3-69	0.43	0.64	0-1.16	13.70
Magothy	9.35	8.36	0-20	0.09	0.09	0-0.21	10.35
Miles	0.00	0	-	0.00	0	-	13.50
Severn	32.75	40.07	0-100	0.53	0.88	0-2.53	8.68
South	71.90	18.78	59-85	1.22	0.54	0-1.6	11.16
Upper Calvert Shore	-	-	-	-	-	-	15.68
ALL	33.38	23.45	-	0.46	0.46	-	11.33

- Research Projects
  - Oyster reproductive senescence project, year 1, completed.
    - Purpose: to determine the effect of oyster age on relative fecundity and egg quality.
    - The data suggest that female oyster egg quantity determines the quality of the eggs (fat content) produced by those oysters.
    - The data also suggest that fat composition of eggs differs by site, indicating a possible difference in food sources by river.
    - Year 2 animals have been collected and are currently being conditioned at Horn Point Oyster Hatchery.
    - Year 2 spawning will be conducted in early fall 2011.
  - Mud crab predation on oyster spat study completed.
    - Rebecca Kulp's undergraduate honors thesis project.
    - The study provided evidence for the large impact that mud crab (*E. depressus*) predation could have on post planting spat survival. The mean number of spat that *E. depressus* ate over the course of the study (96 hrs) was 23 spat and 37% of the spat available to them.
    - A manuscript of these data is currently in prep for Journal of Experimental Marine Biology and Ecology.
  - Oyster hardness and toughness study in progress.
    - Grace Chon's undergraduate honors thesis project.
    - Purpose: to compare hardness and toughness of *C. virginica* and *C. ariakensis* shells.
    - Collaboration with Dr. Lloyd at UMd (Materials Science), Dr. Lucas at George Washington University and Drs. Lawn and Lee at NIST.

- Publications and Presentations
  - 10 year study manuscript accepted to the Journal of Shellfish Research

        - Paynter KT, Politano V, Lane HA, Allen S, Meritt D. 2010. Growth rates and *Perkinsus marinus* prevalence in restored oyster populations in Maryland. J Shell Res. 29(2): 309-319.
    - National Shellfisheries Association/World Aquaculture Society 2010
        - Ken Paynter, Steve Allen and Donald Merritt. Hatchery-based oyster restoration in Maryland: Assessing success, a survey of projects up to 10 years old. Oral presentation.
        - Vincent Politano, Steve Allen and Ken Paynter. Patent tong surveys of Maryland oyster sanctuaries: Estimating hatchery-based oyster abundance and distribution. Oral presentation.
        - Sara Lombardi and Ken Paynter. Hemolymph pH of *Crassostrea virginica* and *Crassostrea ariakensis* after anoxic exposure. Oral presentation.
        - Karen Kesler, Vincent Politano and Ken Paynter. The investigation of species settlement and colonization of *Crassostrea virginica* live oyster clumps and dead shell clumps. Poster presentation.
    - Benthic Ecology Meeting 2010
        - Hillary Lane, Vincent Politano and Ken Paynter. Evidence for density-dependent survival in juvenile oysters (*Crassostrea virginica*) from Chesapeake Bay, Maryland. Oral presentation.
        - Rebecca Kulp, Vincent Politano, Hillary Lane and Ken Paynter. Determining the size vulnerability of juvenile *Crassostrea virginica* to mud crab predation on Chesapeake Bay oyster reefs. Poster presentation.
    - International Conference on Shellfish Restoration 2010
        - Hillary Lane, Vincent Politano, Stephanie Alexander, Emily Vlahovich, Heather Koopman, Donald Merritt and Ken Paynter. A comparison of relative fecundity and egg quality in oysters (*Crassostrea virginica*) of different ages from Northern Chesapeake Bay. Oral presentation.
        - Sara Lombardi and Ken Paynter. Differences in the gaping response and hemolymph pH of the Eastern oyster, *Crassostrea virginica*, and the Asian oyster, *Crassostrea ariakensis*, when exposed to hypoxic and anoxic environments. Oral presentation.
        - Karen Kesler, Vincent Politano, Hillary Lane and Ken Paynter. Differentiating the impact of physical and biotic components of the oyster, *Crassostrea virginica*, to the benthic reef community. Oral presentation.
- Conclusions/Lessons Learned:
    - Final conclusions regarding each activity (ground-truthing, post-planting monitoring, and patent tong surveys) can be found in Section V.
    - Also included are recommendations for future work/experiments.

SECTION I

Paynter Lab Ground Truthing 2010
Data Summary and Conclusions

In the Spring of 2010, twenty individual oyster bars were selected by the Oyster Recovery Partnership (ORP) for a pre-planting ground-truthing (GT) survey by the Paynter Lab. These bars were located in the Chester, Choptank, Severn, South and Magothy Rivers as well as in Eastern Bay. The purpose of the GT survey is 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. The Maryland Geological Survey (MGS) and NOAA Chesapeake Bay Office (NCBO) provided side scan sonar data of sites when available. In general, darker return 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. Fifty, 100 or 200 meter transect lines are deployed through the target area and amount of exposed shell, substrate type, penetration and oyster density are recorded by divers every two meters along the transect lines. The table below outlines the score for each category, with increasing metric values indicating bottom type improvement.

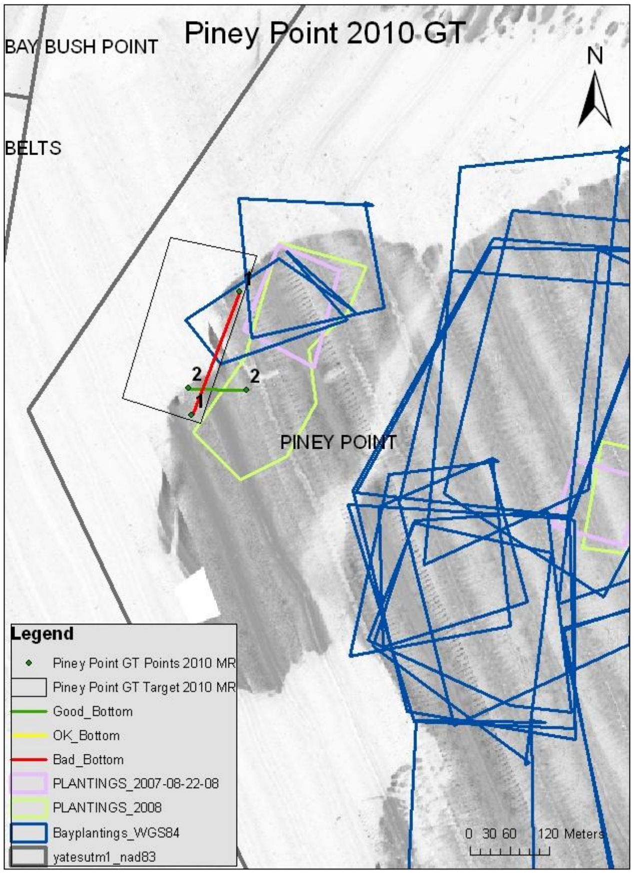
Exposed Shell	**Value**	**Substrate Type**	**Value**	**Penetration**	**Value**
Zero	0	Silt	0	Shoulder	0
Very Little / Patch	1	Mud	1	Elbow	1
Some	2	Sandy Mud	2	Wrist	2
Exposed	3	Sand	3	Finger	3
Oyster Bar	4	Rock / Bar Fill / Debris	4	Knuckle	4
		Shell Hash	5	Hard Bottom	5
		Loose Shell	6		
		Oyster	7		

- 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.

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

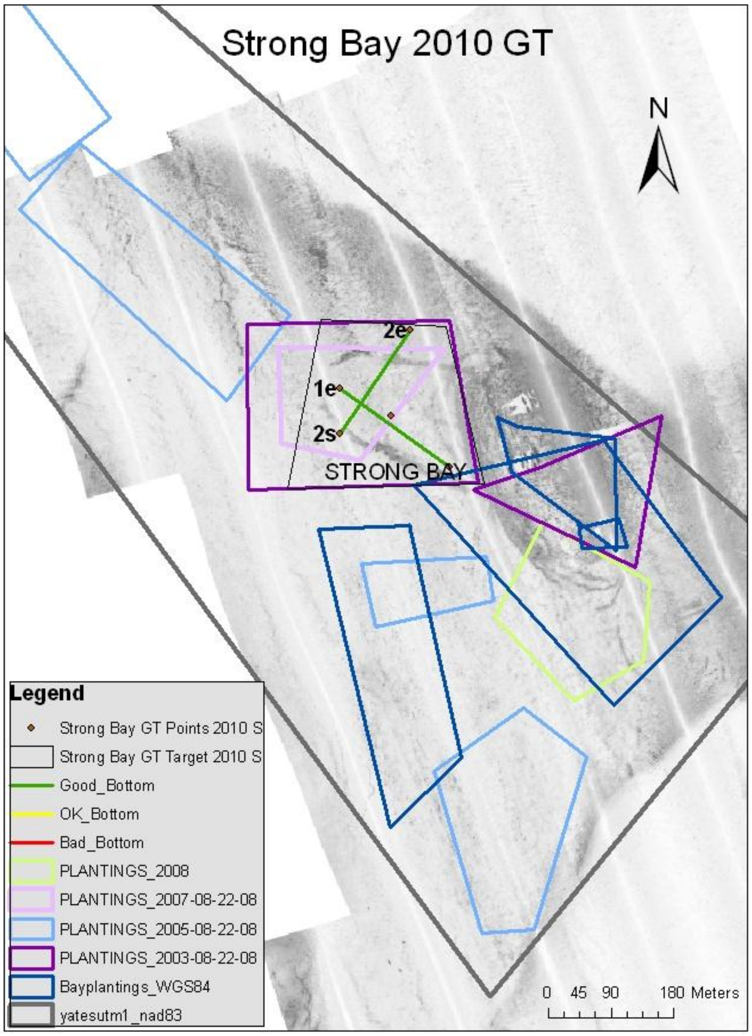
This report contains a detailed map of each site that was surveyed, the associated mode data as well as a summary of the conclusions gleaned from the collected data.



Since a new year class (YC) was the objective for the Piney Point 2010 planting, the target area was chosen because a large area of the target shared a boundary with the 2007 and 2008 plantings, despite much of the area having soft return on the side scan.

The target area was surveyed with the fish finder on the Paynter Lab boat prior to diver survey and only areas of hard return were surveyed by divers, explaining the lack of diver coverage in the western portion of the target plot. The bottom under transect 1 was deemed inappropriate for planting, due to the lack of exposed shell and the muddy bottom. The bottom under transect 2 was determined to be good bottom for planting because of the presence of exposed shell and hard bottom. At Piney Point, the diver survey found areas of hard bottom on top of hard return from the side scan sonar.

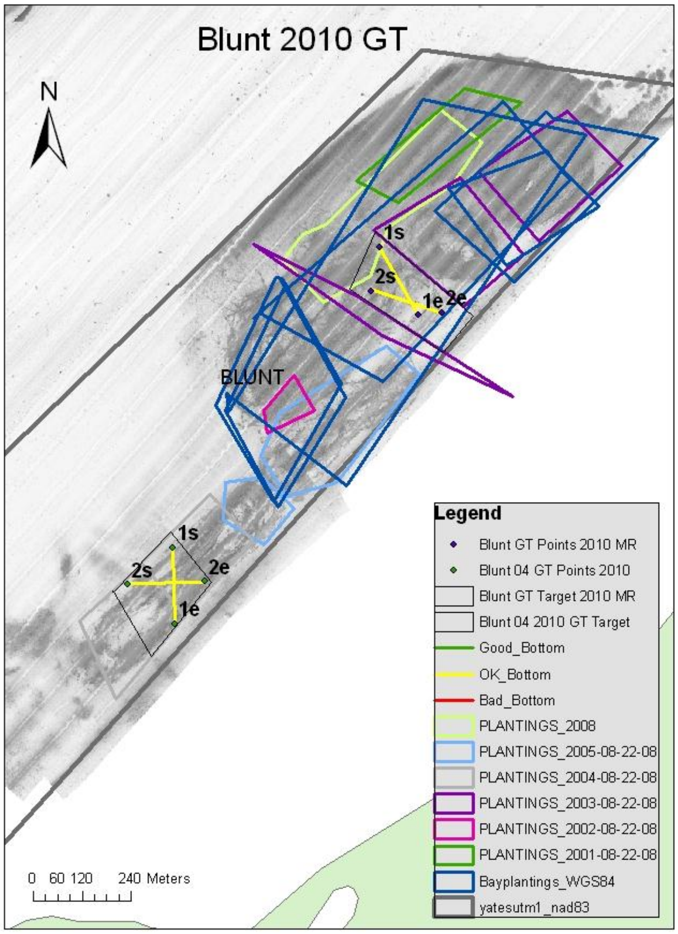
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
5/13/10	MR	New YC	1	100	Zero	Knuckle	Mud
5/13/10	MR	New YC	2	50	Exposed	Hard Bottom	Loose shell



Since the objective for the Strong Bay 2010 planting was an overplanting, the target area at Strong Bay was chosen to overlay both 2003 and 2007 plantings. Although areas of harder return were found southeast of the target, those areas were not large enough to accommodate the 10 acre area needed for GT.

The bottom under both transect 1 and 2 were deemed appropriate for planting due to the presence of exposed shell and hard bottom in both transects. Areas of dark side scan return were accompanied by hard bottom observations by divers at Strong Bay.

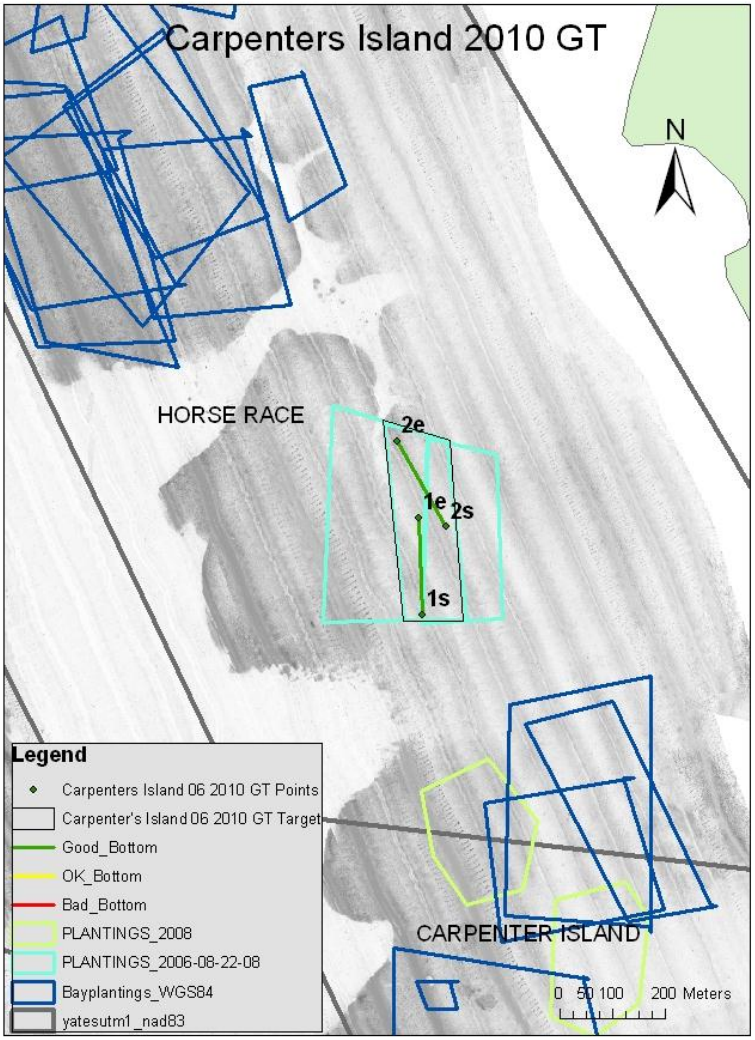
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
6/11/10	S	Overplant	1	100	Some	Hard Bottom	Loose Shell
6/11/10	S	Overplant	2	100	Exposed	Hard Bottom	Loose Shell



Since the objective for the Blunt 2010 planting was 2 sites, both with new year classes, the target areas were chosen in between plantings already on the bar. The northern site was chosen due to its proximity to other plantings. The southern site was chosen to explore a previously bar-cleaned area

The bottom under the transects in the northern target area were deemed OK for planting because although no exposed shell was found, relatively low penetration was observed on sandy bottom. Since this bar has been planted with success in the past, future plantings on these areas could also be successful. Divers observed softer bottom than expected when compared to the side scan return and Blunt. As expected, no oysters were observed on the bar-cleaned site.

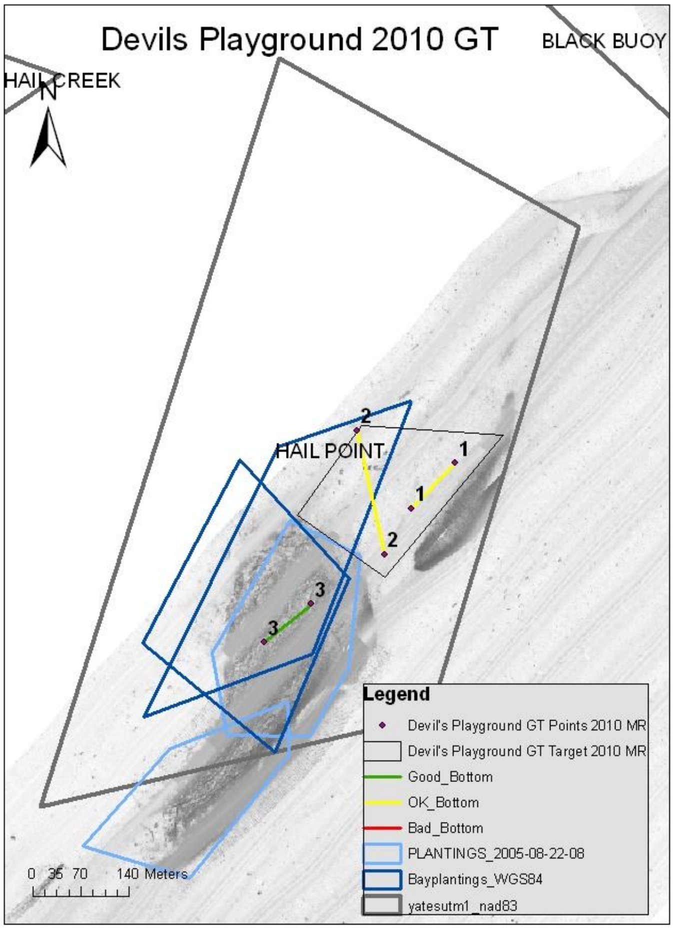
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
6/11/10	MR	New YC	1	100	Zero	Knuckle	Sand
6/11/10	MR	New YC	2	100	Zero	Knuckle	Sand
6/25/10	MR	New YC	1	100	Zero	Knuckle	Sand
6/25/10	MR	New YC	2	100	Zero	Knuckle	Sand



Since the objective at Carpenter's Island was an overplanting , a target area was chosen over an area of hard side scan return as well as a planting that occurred in 2006. However, during the diver survey, no evidence of animals from the 2006 planting was found.

The bottom under both transect lines at Carpenter's Island were deemed appropriate for planting due the high amount of exposed shell present covering the bottom. Areas of hard side scan return were accompanied by hard bottom observations by divers at Carpenter's Island.

Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
6/25/10	MR	Overplant	1	100	Exposed	Knuckle	Loose Shell
6/25/10	MR	Overplant	2	100	Exposed	Knuckle	Loose Shell

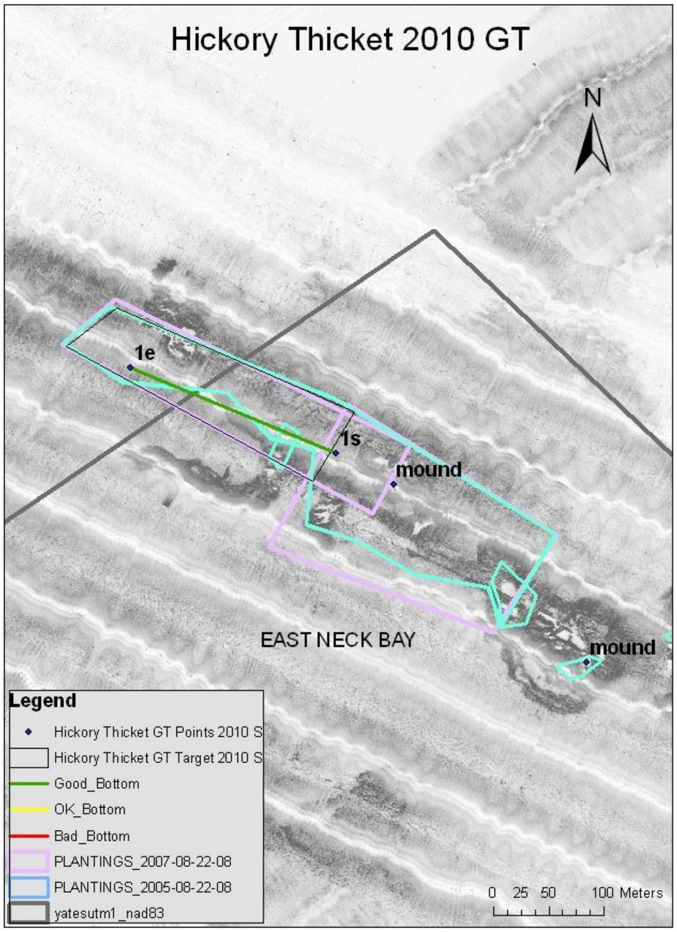


Since the objective for the Devil's Playground 2010 planting was a new year class, the target area was chosen in an area of hard side scan return that was flush with a 2005 planting and also still within the boundaries of the historical Yates bar. Since the bottom within the target area was only OK bottom, another area outside of the target was chosen for confirmation of the side scan return.

The bottom under transects 1 and 2 were deemed ok bottom, due to the lack of exposed shell, amount of penetration and sandy bottom observed during the survey. Transect 3 was conducted to confirm the hard return from the sonar was actually hard bottom. The diver survey at Devil's Playground confirmed the return from the side scan, with lighter return being over OK bottom and darker return being over good bottom.

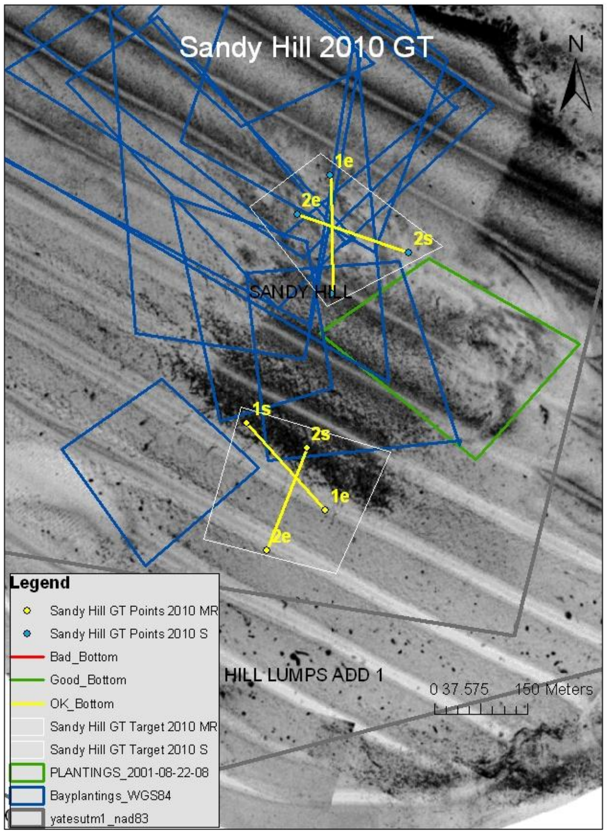
Date	**Bar Type**	**Objective**	**Transect #**	**# Points**	**Mode Exposed Shell**	**Mode Penetration**	**Mode Substrate**
5/13/10	MR	New YC	1	50	Zero	Knuckle	Sand
5/13/10	MR	New YC	2	100	Zero	Knuckle	Sand
5/13/10	MR	New YC	3	50	Exposed	Hard Bottom	Loose Shell

Since the objective for the Hickory Thicket 2010 planting was to overplant an existing planting, the target area was placed over the area of overlap between the 2005 and 2007 plantings.



The transect taken at Hickory Thicket indicated good bottom for planting due to presence of hard bottom and shell throughout the transect. Only one transect was taken due to the overwhelming presence of good bottom that coincided with hard side scan return. The side scan return at Hickory Thicket was confirmed by divers at this site.

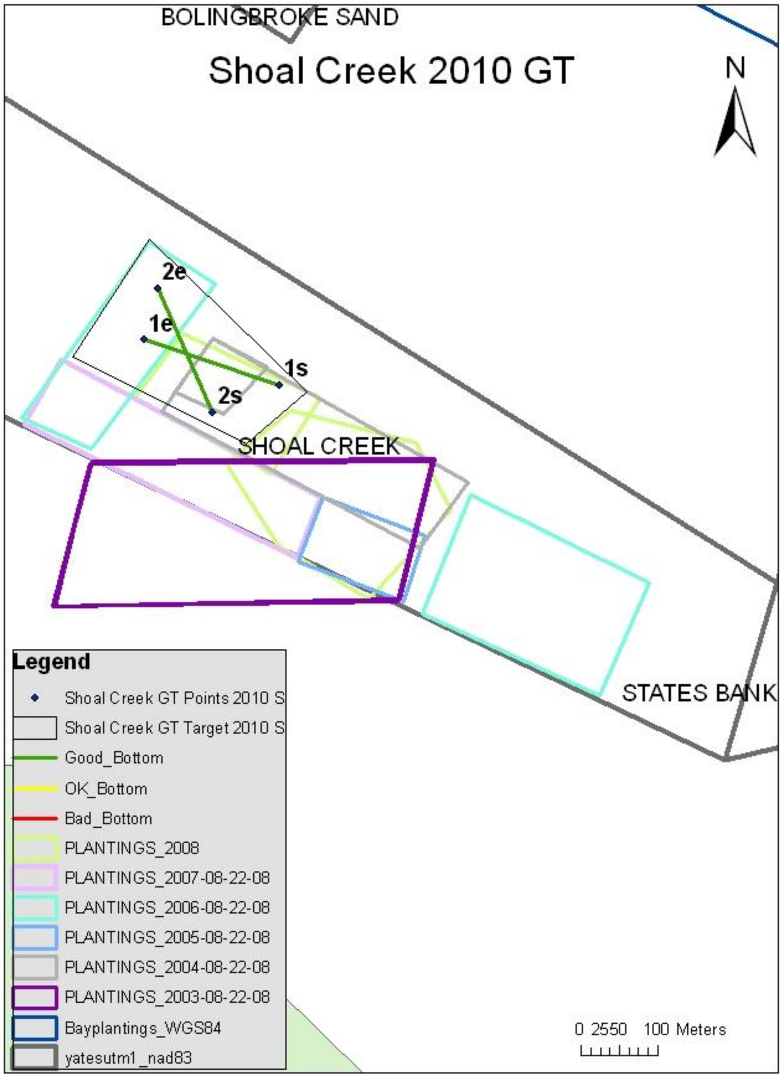
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
6/11/10	S	Overplant	1	100	Exposed	Hard Bottom	Loose Shell



Since the objective for the Sandy Hill 2010 planting at both the sanctuary (south) and the managed reserve (north) sites was a new year class, target areas were chosen based on proximity to previous plantings as well as hard side scan return.

One transect line at each site was deemed OK for planting while the other transect was not deemed good for planting. This was because each site had some areas with either shallower penetration or some exposed shell. However, since both plots had one transect that was not good for planting, these plots should not be a first choice to plant this season. The hard side scan return did not coincide with hard bottom at the Sandy Hill site.

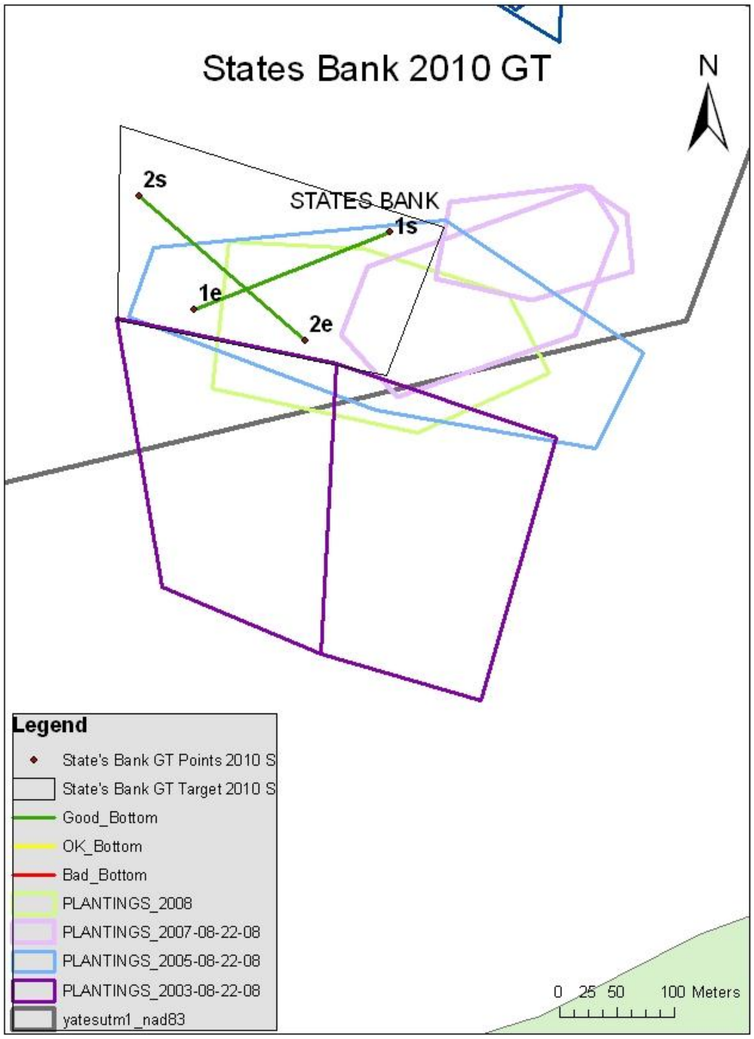
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
7/20/10	S	New YC	1	100	Zero	Knuckle	Sand
7/20/10	S	New YC	2	100	Zero	Finger	Sand
7/20/10	MR	New YC	1	100	Zero	Finger	Sand
7/20/10	MR	New YC	2	100	Exposed	Finger	Sand



Since the objective for the Shoal Creek 2010 planting was to overplant an existing planting, the target area was chosen over 2004, 2006 and 2008 plantings. No side scan data were available for Shoal Creek.

Both transects at Shoal Creek were deemed to be over good bottom based on the presence of shell and hard bottom. The target area at Shoal Creek is appropriate for planting.

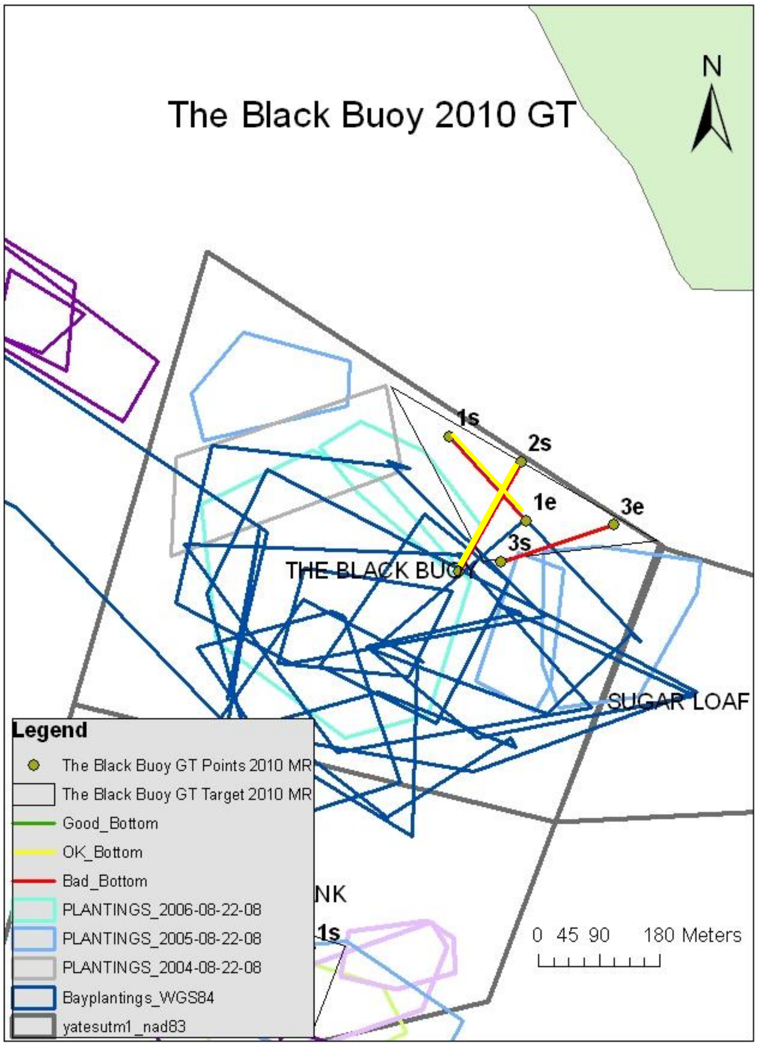
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
4/30/10	S	Overplant	1	100	Exposed	Hard Bottom	Loose Shell
4/30/10	S	Overplant	2	100	Exposed	Hard Bottom	Loose Shell



Since the objective for the States Bank 2010 planting was to overplant an existing planting, the target area was chosen over 2005, 2007 and 2008 plantings. The target was also placed next to a large 2003 planting. No side scan was available for States Bank.

Both transects at States Bank were deemed to be over good bottom based on the presence of shell and hard bottom. The target area at States Bank is appropriate for planting.

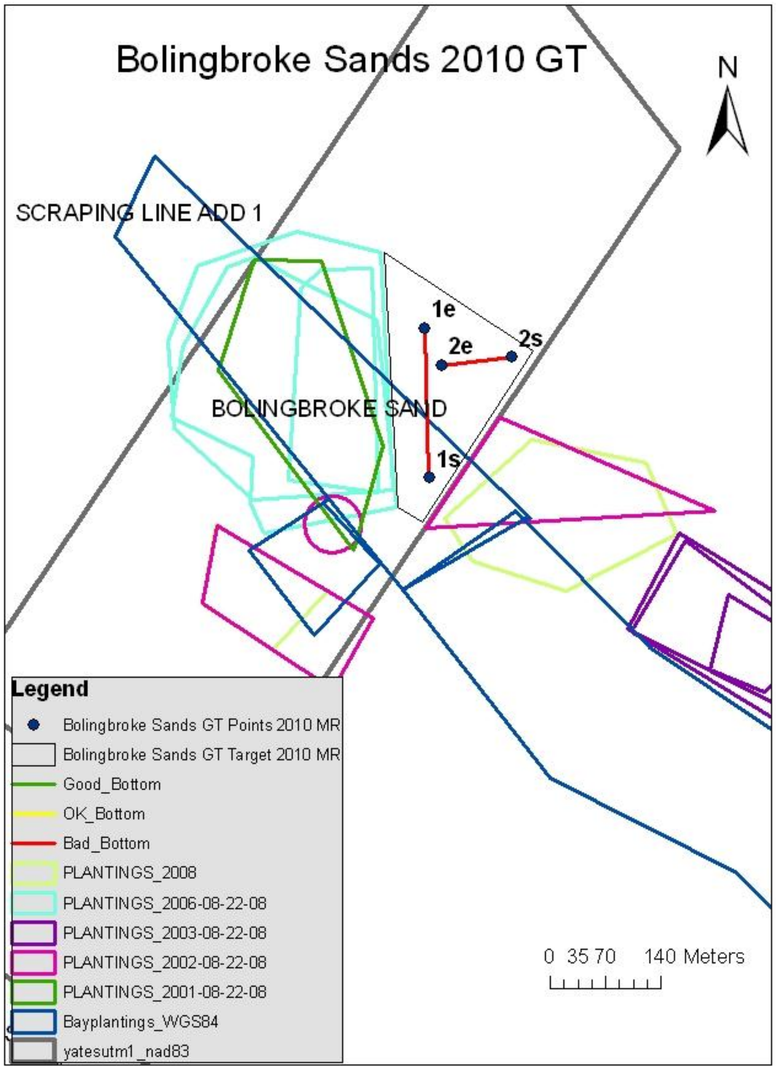
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
4/30/10	S	Overplant	1	100	Exposed	Hard Bottom	Loose Shell
4/30/10	S	Overplant	2	100	Exposed	Knuckle	Loose Shell



Since the objective for The Black Buoy 2010 planting was for a new year class, the target area was selected in close proximity to 2005 and 2006 plantings as well as areas of historical shell-only plantings (Bayplantings_WGS84 layer). No side scan was available for The Black Buoy.

The bottom under two transects at The Black Buoy was deemed OK for planting due to the low penetration values and slight presence of shell. However, one transect was not deemed good for planting, due to the absence of shell and deep penetration. Based on the GT data, only the northwestern portion of the plot is suitable for planting.

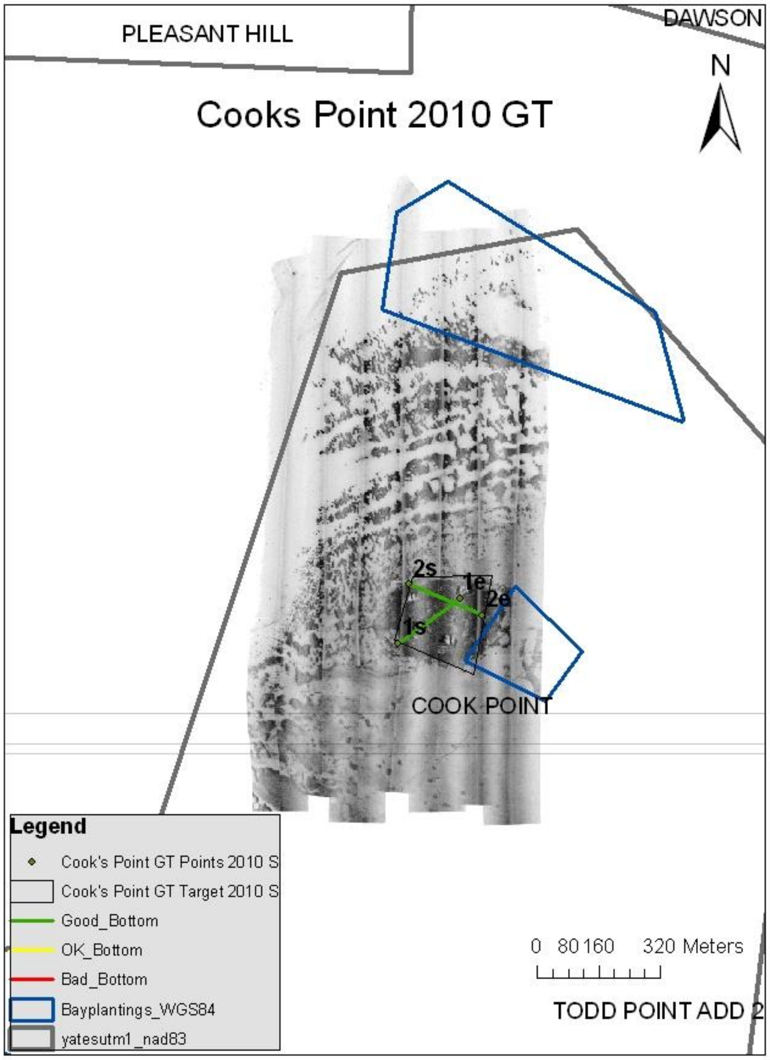
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
4/30/10	MR	New YC	1	50	Zero	Knuckle	Sand
4/30/10	MR	New YC	2	100	Some	Knuckle	Sand
4/30/10	MR	New YC	3	50	Zero	Finger	Sand



Since the objective for the Bolingbroke Sands 2010 planting was a new year class, the target area was chosen to be next to a high concentration of 2006 plantings as well as 2003 and 2008 plantings. No side scan was available for Bolingbroke Sands.

The bottom under the transect lines at Bolingbroke Sands was not deemed appropriate for planting, due the lack of exposed shell, relatively high penetration and sandy bottom.

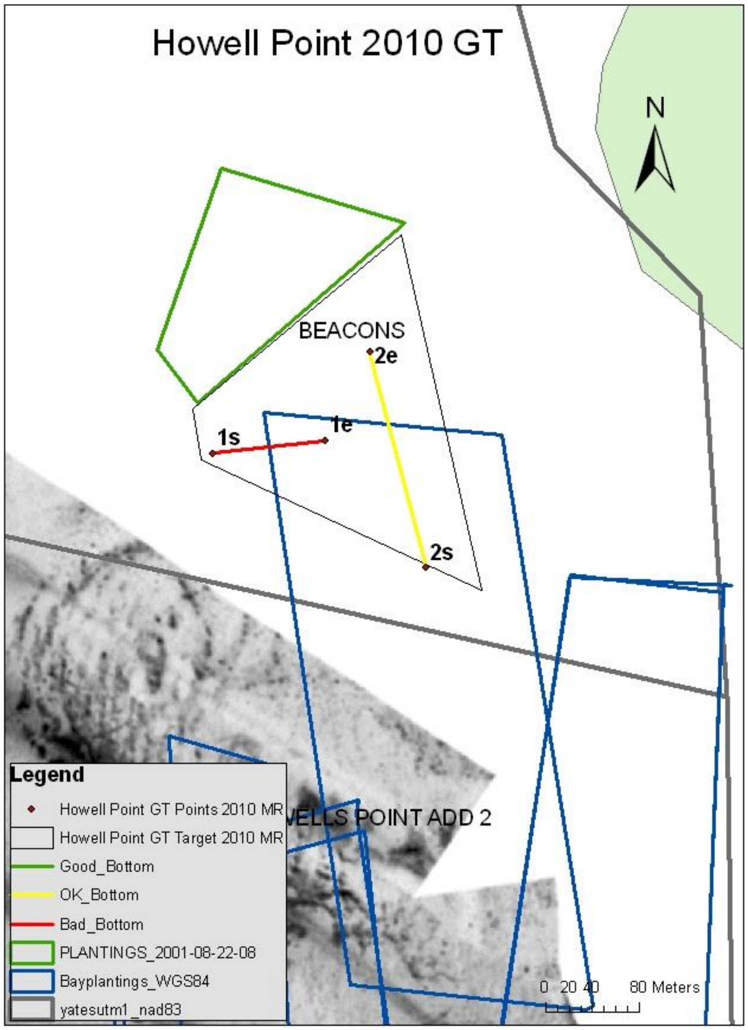
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
4/30/10	MR	New YC	1	100	Zero	Finger	Sand
4/30/10	MR	New YC	2	50	Zero	Finger	Sand



Since the objective for the Cooks Point 2010 planting was a new year class, the target area was placed over the area of hardest side scan return as well as adjacent to a historical shell-only planting.

The bottom under both transect lines at Cooks Point was deemed good for planting due to the presences of exposed shell and hard bottom. The diver survey confirmed the hard return from the side scan sonar survey.

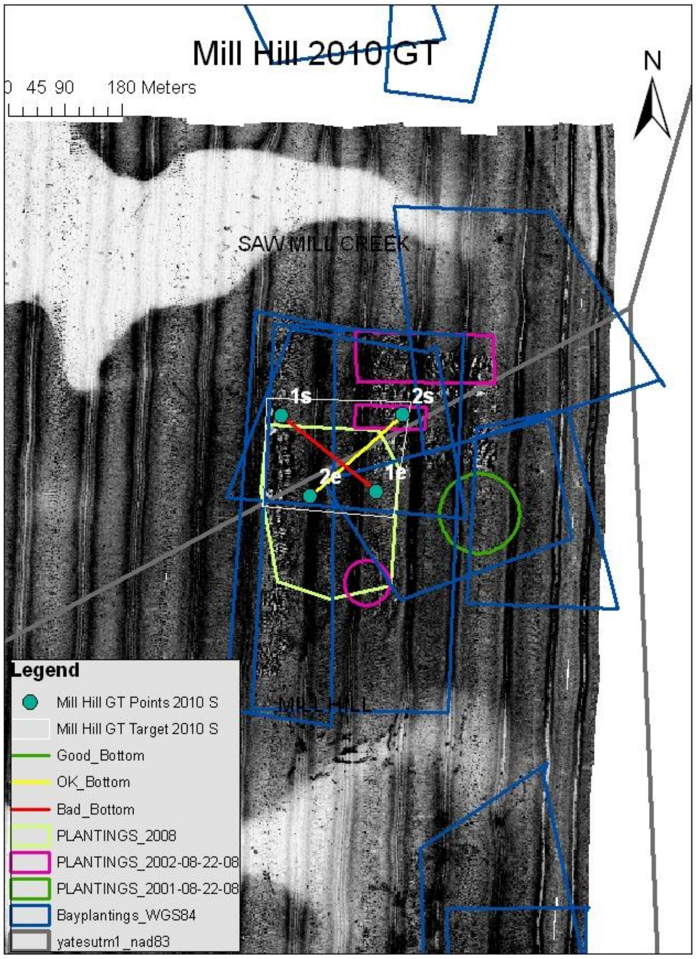
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
7/9/10	S	New YC	1	100	Exposed	Hard Bottom	Sand
7/9/10	S	New YC	2	100	Exposed	Hard Bottom	Loose Shell



Since the objective for the Howell Point 2010 planting was a new year class, the target area was chosen adjacent to the 2001 planting site and also on top of a historical shell-only planting. No side scan was available for the target area at Howell Point.

The bottom under transect one was deemed bad for planting due to the absence of shell, relatively deep penetration and sandy bottom. The bottom under transect two was better than that under transect one, with very little exposed shell and less penetration than transect one, but sandy bottom was still observed under the second transect.

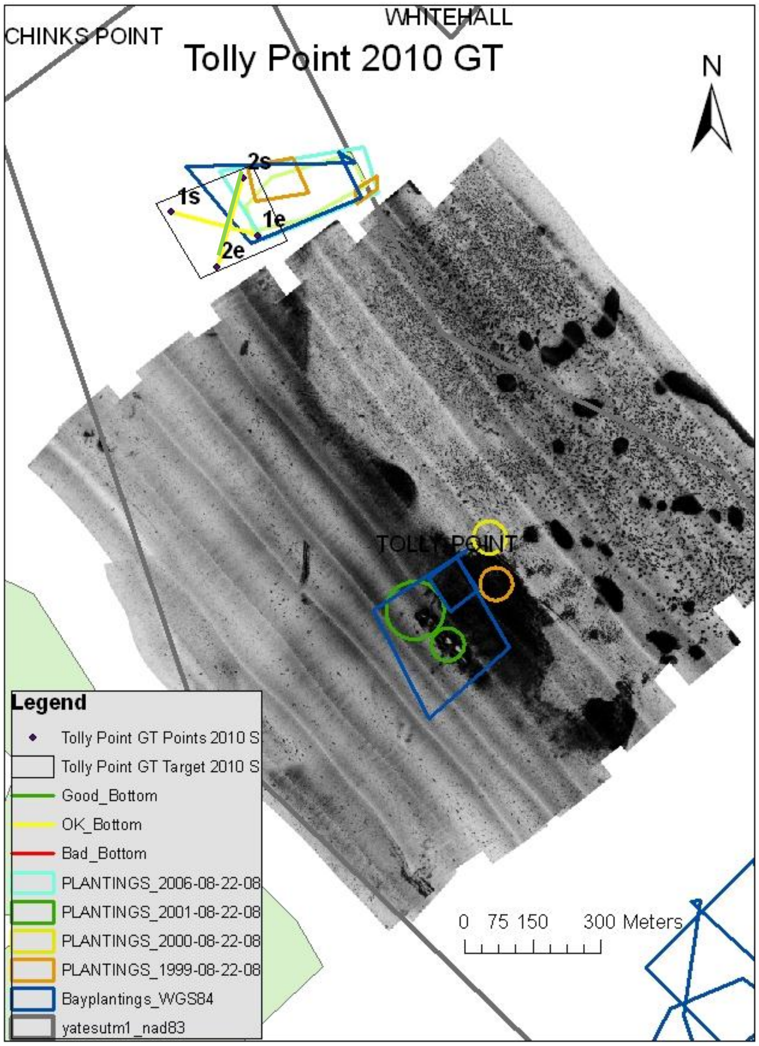
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
7/9/10	MR	New YC	1	50	Zero	Finger	Sand
7/9/10	MR	New YC	2	100	Very Little	Knuckle	Sand



Since the objective for the Mill Hill 2010 planting was an overplanting, the target area was chosen to overlay 2002 and 2008 plantings as well as the historical shell-only plantings. The target area was also chosen on an area of hard side scan return.

The bottom under transect one was deemed unsuitable for a planting due to the absence of shell, the relatively deep penetration and the sandy bottom. The bottom under transect two was slightly better than that under transect one, with some hard bottom, but still zero shell and sandy substrate. Since transect two overlapped transect one, the bottom of transect two may have been affected by the area under transect one. The hard side scan return observed at Mill Hill was not confirmed by diver surveys of that area.

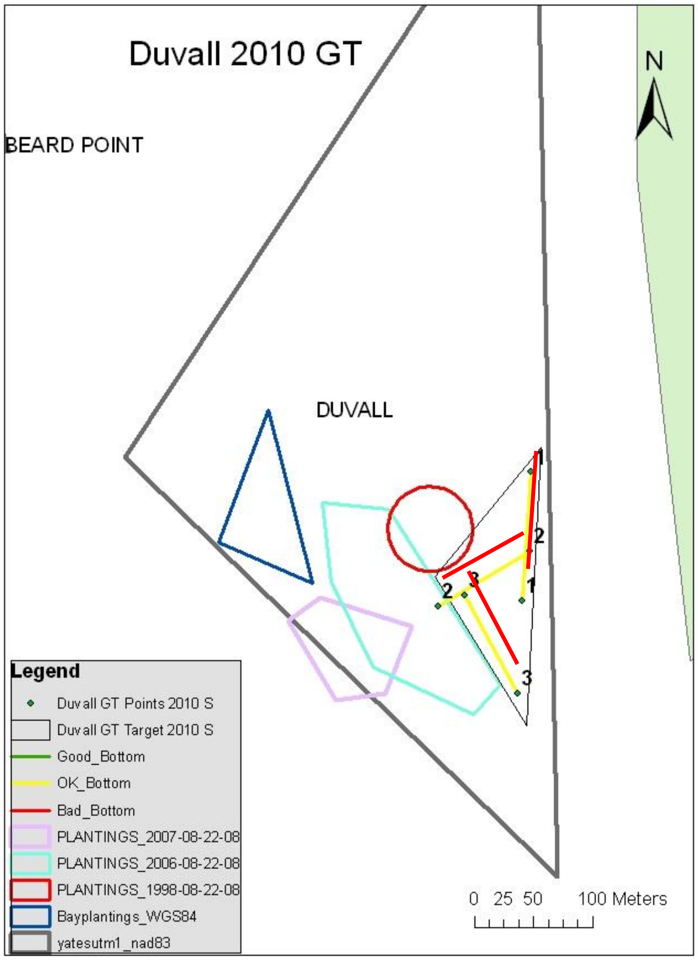
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
6/10/10	S	Overplant	1	100	Zero	Finger	Sand
6/10/10	S	Overplant	2	100	Zero	Hard Bottom	Sand



Since the objective for the Tolly Point 2010 planting was an overplanting, the target area was selected to overlap 1999, 2001 and 2006 plantings. Although side scan was available for the southern portion of the bar, previous diver surveys had determined that area to be unsuitable for planting, so a northern site was chosen.

The bottom under both tracklines at Tolly Point was deemed OK for planting, due to the low presence of shell on the bottom under transect one, the relatively high penetration and the partially sandy bottom.

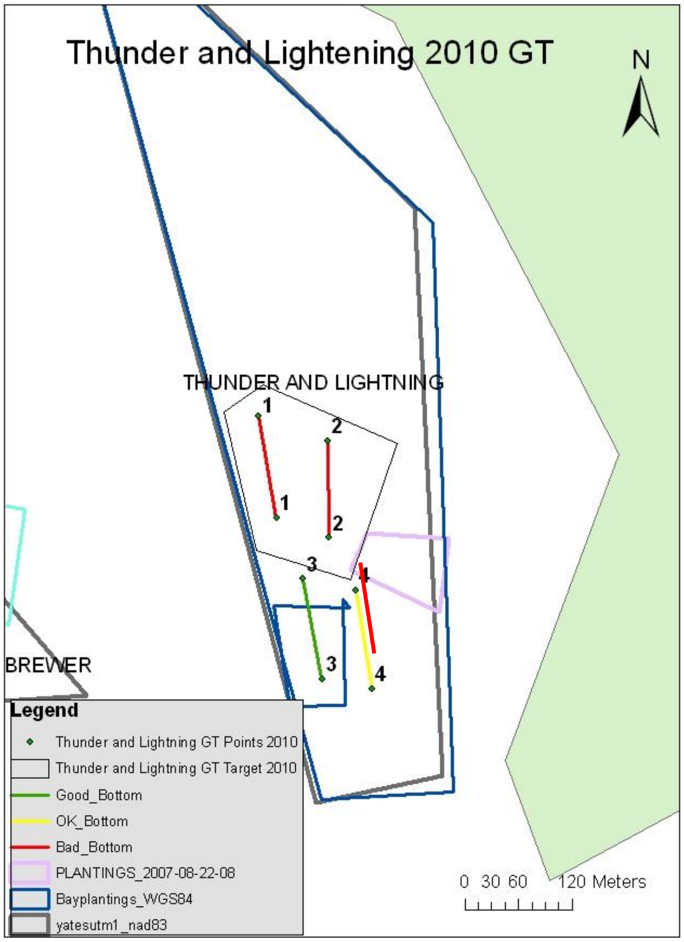
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
6/10/10	S	Overplant	1	100	Some	Knuckle	Sand
6/10/10	S	Overplant	2	100	Exposed	Knuckle	Loose Shell



Since the objective for the Duvall 2010 planting was to expand an existing sanctuary, the target site was chosen adjacent to a 1998 and a 2006 planting. No side scan data was available for Duvall.

The bottom under all three transect lines at Duvall was determined to be bad for planting due to the absence of shell and relatively high penetration.

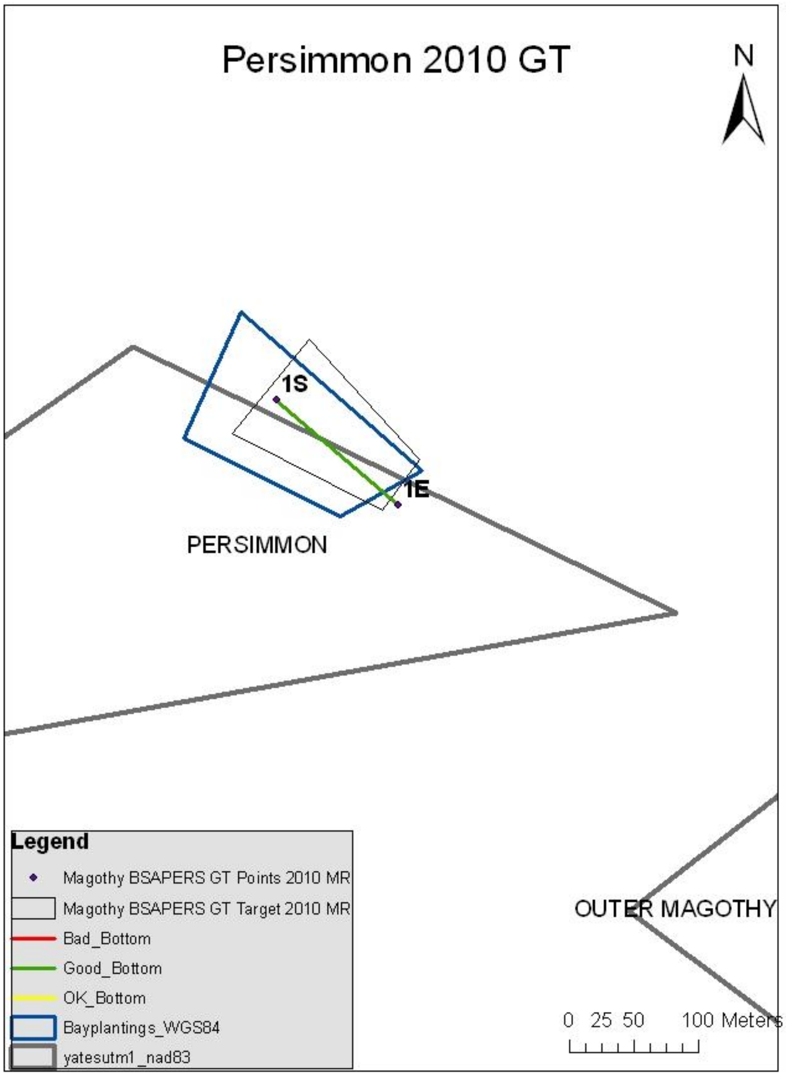
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
4/30/10	S	Expansion	1	100	Zero	Finger	Sand
4/30/10	S	Expansion	2	50	Zero	Finger	Sand
4/30/10	S	Expansion	3	50	Zero	Finger	Sand



Since no objective for the Thunder and Lightning 2010 planting, a large area in the center of the Yates bar was selected as the target area for GT. No side scan data were available for Thunder and Lightning.

The bottom under transect lines one, two and four was not suitable for planting, as the transect lines were over mud that was at least elbow deep or no shell was present. Since no objective was set for this site, the area around transect lines 3 and 4 was explored. The bottom under transect three was deemed good for planting because it contains exposed shell and was over hard bottom. Based on the GT survey, the most appropriate area for planting at Thunder and Lightning is around transect line three. This area also happens to be on top of a historical shell-only planting.

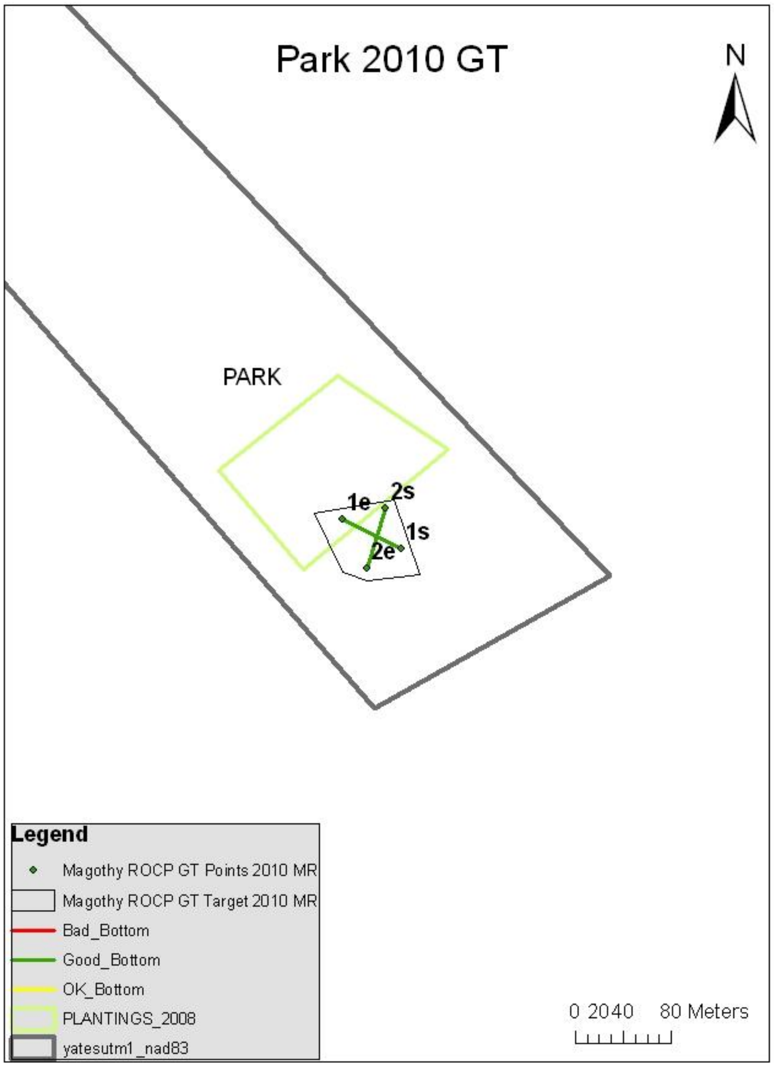
Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
5/4/10	MR	UNK	1	50	Zero	Shoulder	Mud
5/4/10	MR	UNK	2	50	Some	Elbow	Mud
5/4/10	MR	UNK	3	50	Exposed	Hard Bottom	Loose Shell
5/4/10	MR	UNK	4	50	Zero	Finger	Sand



Since the objective for the Persimmon 2010 planting was not known, the target area was chosen to be over a historical shell-only planting. No side scan data were available for Persimmon.

The bottom under the transect line at Persimmons was deemed good for planting due to the presence of exposed shell and hard bottom.

Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
7/15/10	H	UNK	1	50	Exposed	Hard Bottom	Loose Shell



Since the objective for the Park 2010 planting was not known, the target area was chosen to be over a historical shell-only planting. No side scan data were available for Persimmon.

The bottom under both transect lines at Park was deemed good for planting due to the presence of exposed shell and hard bottom.

Date	Bar Type	Objective	Transect #	# Points	Mode Exposed Shell	Mode Penetration	Mode Substrate
7/15/10	H	UNK	1	25	Exposed	Hard Bottom	Loose Shell
7/15/10	H	UNK	2	25	Exposed	Hard Bottom	Loose Shell

SECTION II

Paynter Lab Post Planting Monitoring 2010
Data Summary and Conclusions

In 2010, 16 sites throughout Chesapeake Bay were surveyed by a diver 4-8 weeks after a planting of spat on shell from the Horn Point Laboratory Oyster Hatchery in Cambridge, MD. The diver survey date, number of acres planted, and the amount of spat planted at each of the 16 locations is presented in **Table 1**. As suggested by the planting dates, the 2010 plantings involved multiple plantings over the same areas. Most sites were visited repeatedly and over-planted in an attempt to improve spat survival; this differs from previous years that included a greater number of sites without over-planting.

Table 1 – 2010 post planting monitoring hatchery summary.

Site	2010 Planting Dates	Sample Date	Acres Planted	Amount of Spat Planted (millions)
Blunt	6/21, 6/23, 6/28, 6/30	8/20/2010	6.46	34.41
Bolingbroke Sand	5/24	7/9/2010	10.52	6.94
Brewer	8/30, 9/1	10/21/2010	6.41	14.87
Cook Point	7/19, 7/26, 7/27, 8/2	9/21/2010	7.98	39.44
Hickory Thicket (East Neck Bay)	7/5, 7/7, 7/12, 7/15	8/20/2010	7.06	32.04
Peach Orchard	8/23	10/21/2010	4.29	5.66
Sandy Hill (North)	7/21, 7/28, 8/4	8/26/2010	5.74	12.69
Sandy Hill (North)*	9/21	11/3/10	3.30	3.9
Sandy Hill (South)*	9/15, 10/4	11/3/10	4.79	3.9
Shoal Creek	5/12, 5/17, 5/18	7/9/2010	7.56	33.93
States Bank	5/5, 5/4, 5/10	7/9/2010	8.22	47.21
Strong Bay	6/7, 6/9, 6/14, 6/16	7/15/2010	8.85	45.95
Thunder and Lightning	9/13	10/21/2010	5.09	14.2
Wade	8/23	10/21/2010	2.36	5.33
Wade*	9/27	10/21/10	5.04	11.38
Weems Upper	8/3, 8/9, 8/11	10/21/2010	5.90	38.16

Using the planting boat's track lines as a target, a diver 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 six quadrat samples of varying shell densities (based on track lines) 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 fifty live spat observed in each sample were measured for shell height. The means of those shell metrics are summarized in **Table 2** for all sample locations in 2010.

Table 2 – 2010 post planting monitoring survey summary.

Site	River	2010 Planting Dates	Survey Date	# Shells Sampled	Average Count per Shell				
					Live	Gapers	Scars	Boxes	Shell Height (mm)
Blunt	Chester	6/21, 6/23, 6/28, 6/30	8/20/2010	64	0.27	0.00	0.34	0.05	29.79
Bolingbroke Sand	Choptank	5/24	7/9/2010	82	0.04	0.00	0.22	0.04	8.00
Brewer	South	8/30, 9/1	10/21/2010	107	1.82	0.03	1.06	0.03	19.74
Cook Point	Choptank	7/19, 7/26, 7/27, 8/2	9/21/2010	252	1.50	0.02	1.05	0.06	30.21
Hickory Thicket (East Neck Bay)	Chester	7/5, 7/7, 7/12, 7/15	8/20/2010	57	3.77	0.05	1.58	0.03	19.85
Peach Orchard	Severn	8/23	10/21/2010	50	1.88	0.00	1.10	0.04	25.47
Sandy Hill (North)	Choptank	7/21, 7/28, 8/4	8/26/2010	73	2.33	0.00	1.13	0.03	13.94
Sandy Hill (North)	Choptank	9/21	11/3/2010	50	1.10	0.00	1.14	0.04	31.68
Sandy Hill (South)	Choptank	9/15, 10/4	11/3/2010	101	1.26	0.00	1.31	0.36	7.70
Shoal Creek	Choptank	5/12, 5/17, 5/18	7/9/2010	63	2.43	0.10	0.67	0.10	14.68
States Bank	Choptank	5/5, 5/4, 5/10	7/9/2010	66	5.06	0.00	0.14	0.09	31.85
Strong Bay	Chester	6/7, 6/9, 6/14, 6/16	7/15/2010	161	0.55	0.00	0.28	0.02	12.91
Thunder and Lightning	South	9/13	10/21/2010	50	5.72	0.02	5.32	0.10	14.58
Wade	Severn	8/23	10/21/2010	51	0.90	0.02	1.31	0.00	25.83
Wade	Severn	9/27	10/21/2010	50	2.58	0.34	0.34	0.06	5.49
Weems Upper	Severn	8/3, 8/9, 8/11	10/21/2010	50	1.26	0.02	0.46	0.00	30.31

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 two sites: Strong Bay in the Chester River (n=2) and the September Sandy Hill (North) planting in the Choptank River (n=50).

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 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 2010 plantings was 12.67% (±9.45). However, it is important to note the range of the data was 0.38% survival (Bolingbroke Sand) to 33.86% survival (Hickory Thicket). The percent survival of spat planted by bar is presented in **Table 3.** The 2008 and 2009 percent survival was available for a small number of the bars monitored in 2010. The 2008 and 2009 percent survival were calculated from different data than presented in Table 3 and are shown here to illustrate the large amount of annual variation in percent survival.

Table 3 – 2010 spat survival by bar.

Bar Name	2010 Planting Dates	Acres Planted	Mean # Live Spat/Shell	Amount of Shell Planted	Amount of Spat Planted (Millions)	Live Spat Calculated from Survey (Millions)	2010 % Survival	2009 % Survival	2008 % Survival
Blunt	6/21, 6/23, 6/28, 6/30	6.46	0.27	2,880,000	34.41	0.78	2.3	4.4	-
Bolingbroke Sand	5/24	10.52	0.04	720,000	6.94	0.03	0.4	27.9	11.6
Brewer	8/30, 9/1	6.41	1.82	1,440,000	14.87	2.62	17.6	-	-
Cook Point	7/19, 7/26, 7/27, 8/2	7.98	1.50	2,880,000	39.44	4.31	10.9	-	-
Hickory Thicket (Big Neck East)	7/5, 7/7, 7/12, 7/15	7.06	3.77	2,880,000	32.04	10.85	33.9	-	-
Peach Orchard	8/23	4.29	1.88	360,000	5.66	0.68	12.0	-	-
Sandy Hill (North)	7/21, 7/28, 8/4	6.29	2.33	960,000	12.69	2.24	17.6	-	-
Sandy Hill (North)	9/21	5.50	1.10	640,000	12.88	0.70	5.5	-	-
Sandy Hill (South)	9/15, 10/4	4.79	1.26	960,000	18.67	1.21	6.5	-	-
Shoal Creek	5/12, 5/17, 5/18	7.56	2.43	2,160,000	33.93	5.25	15.5	12.8	44.6
States Bank	5/5, 5/4, 5/10	8.22	5.06	1,760,000	47.21	8.90	18.9	6.5	27.8
Strong Bay	6/7, 6/9, 6/14, 6/16	8.85	0.55	2,720,000	45.95	1.49	3.2	23.1	15.7
Thunder and Lightning	9/13	5.09	5.72	720,000	14.2	4.12	29.0	19.5	-
Wade	8/23	2.36	0.90	360,000	5.33	0.32	6.1	-	-
Wade	9/27	5.04	2.58	720,000	11.38	1.86	16.3	-	-
Weems Upper	8/3, 8/9, 8/11	5.90	1.26	2,160,000	38.16	2.72	7.1	-	-
				TOTAL/MEAN	**373.76**	**48.07**	**12.7(±9.5)**	**15.7**	**24.9**

Identical metrics were collected in 2008 and 2009 from sites comparable to those sampled in 2010 (see **Table 4**). Fewer spat were planted in 2010 than 2009, and survival was fairly consistent. In 2008, however, comparable amounts of total spat were planted relative to 2010, and survival in 2008 was higher, although survival in all years was under 20%. In 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.

Table 4 – Comparison of 2008, 2009, and 2010 summary survey 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**	**SD**
2008	20	27	215.64	369.95	30.23	3.94	14.94	17.0	14.4
2009	19	56	408.82	647.41	17.9	3.4	11.45	12.0	13.9
2010	13	16	323.44	373.76	14.86	2.03	20.13	12.8	9.5

In order to examine the source of the variability seen in post planting spat per shell and percent survival, 2008, 2009, and 2010 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 2008 and 2010, no significant relationship was found between percent survival and any of the variables examined, whereas 2009 data showed a negative relationship between initial spat per shell and survival. It is possible that 2009 data was an anomaly, as 2008 and 2010 showed no such trend. The 2010 spat survival relative to initial spat per shell is shown below (**Figure 1**) and is also shown alongside data from 2008 and 2009 (**Figure 2**). No trend was observed in survival relative to spat growth rate (**Figure 3**), 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, 2010 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 1–2010 data showing the spat survival as detected in post-planting monitoring surveys relative to the initial hatchery spat planted. Data did not suggest a relationship between the two variables.

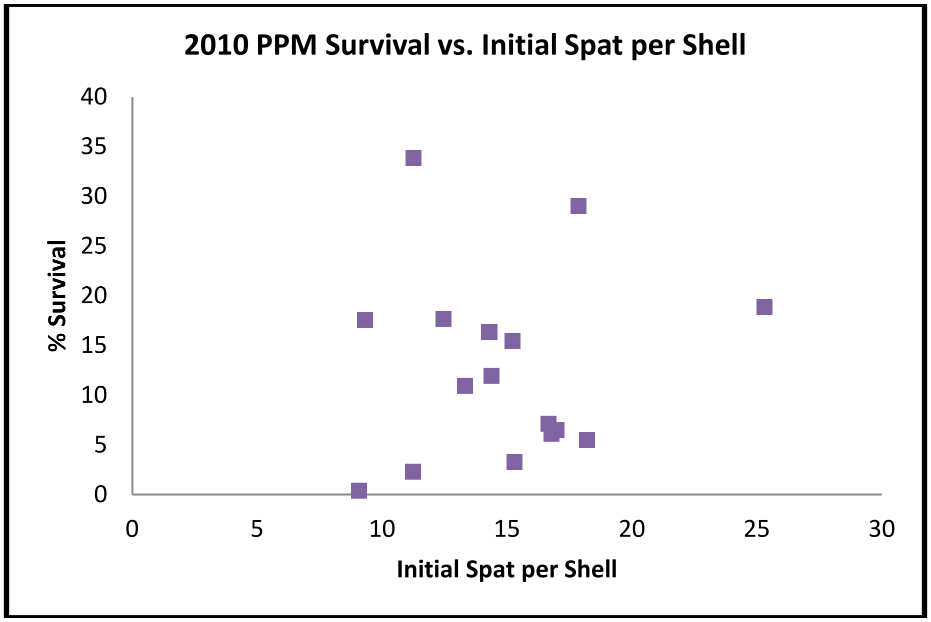


Figure 2–2008-2010 data showing the relationship between initial hatchery spat planted and spat survival, as detected in post-planting monitoring surveys. No trend was observed across all three years, although 2009 data showed a distinct negative correlation between initial spat/shell and % survival.

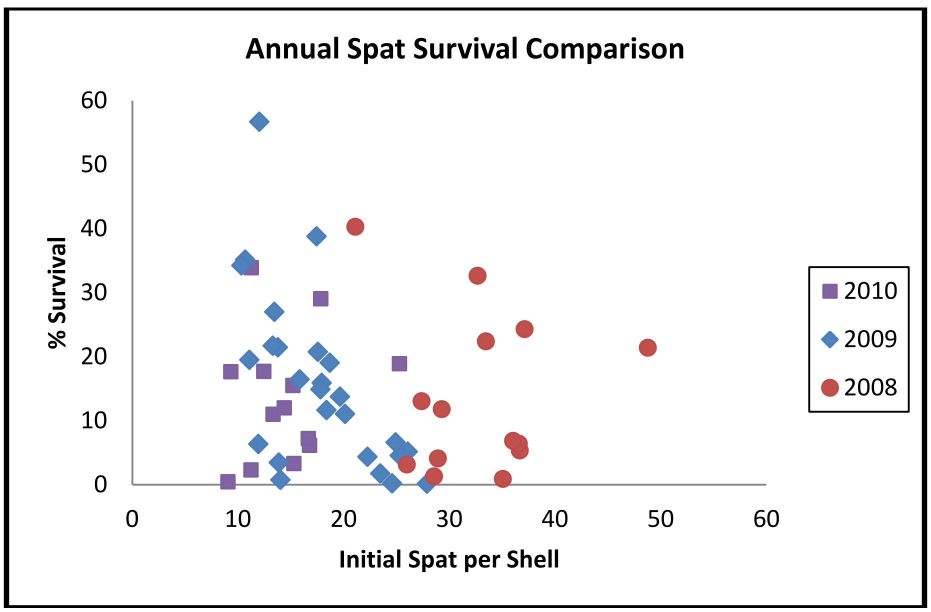
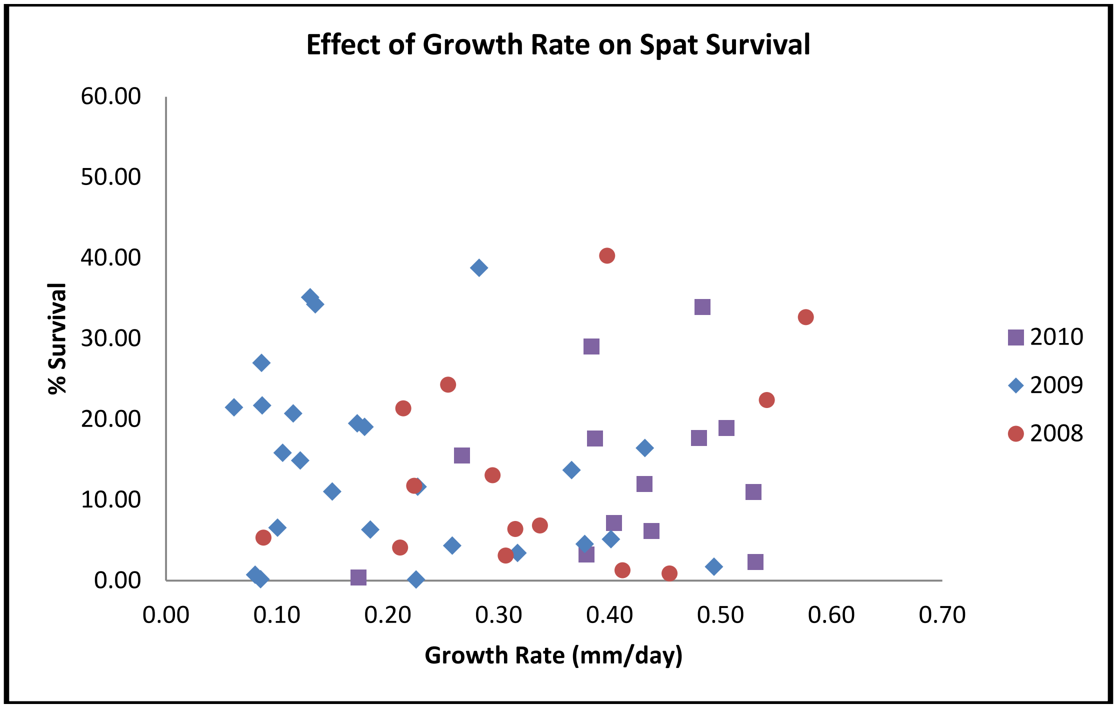


Figure 3–No trend was observed in spat survival by spat growth rate (mm/day), indicating that the environmental parameters known to impact spat growth (oxygen concentration, food availability) does not seem to correlate with survival of spat in the northern Chesapeake Bay.



As mentioned above, in 2010 the sampling approach differed from previous years. Quadrat-based sampling was used, per recommendations following the 2009 Paynter Lab report. The intent of quadrat sampling in 2010 was to investigate the effects of shell density on survival. By using a quadrat to collect shells within a standard area, density comparisons could be made. At each bar, divers attempted to collect six total quads—three at a "high density" area and three "low density". High and low density sites within a bar were selected based on the density of planting boat track lines at each bar.

At some sites, it was not possible to collect shells from a "low density" area, and thus the quadrat-method was not used. Below, **Table 5** shows the bars sampled using quadrats, as well the metrics per quad. (Data presented above in Table 2 for 2010 includes sums and averages of these quadrat data for comparison across all bars.)

Table 5–2010 post planting monitoring survey summary per quad.

Site	River	Planting Dates	Sample Date	# of Shells Sampled	Average per Shell: Live	Gapers	Scars	Boxes	Shell Height (mm)
Blunt	Chester	6/21, 6/23, 6/28, 6/30	20-Aug-10	5	0.20	0.00	0.00	0.00	34.00
Blunt	Chester	6/21, 6/23, 6/28, 6/30	20-Aug-10	7	0.57	0.00	0.57	0.00	23.17
Blunt	Chester	6/21, 6/23, 6/28, 6/30	20-Aug-10	8	0.13	0.00	0.13	0.00	34.00
Blunt	Chester	6/21, 6/23, 6/28, 6/30	20-Aug-10	11	0.00	0.00	0.36	0.27	-
Blunt	Chester	6/21, 6/23, 6/28, 6/30	20-Aug-10	15	0.73	0.00	1.00	0.00	28.00
Blunt	Chester	6/21, 6/23, 6/28, 6/30	20-Aug-10	18	0.00	0.00	0.00	0.00	-
Brewer	South	8/30, 9/1	21-Oct-10	8	1.63	0.00	0.63	0.00	20.23
Brewer	South	8/30, 9/1	21-Oct-10	10	1.00	0.10	0.50	0.00	18.21
Brewer	South	8/30, 9/1	21-Oct-10	13	2.92	0.08	0.69	0.00	18.23
Brewer	South	8/30, 9/1	21-Oct-10	13	2.08	0.00	2.62	0.00	21.82
Brewer	South	8/30, 9/1	21-Oct-10	17	1.29	0.00	0.82	0.12	20.04
Brewer	South	8/30, 9/1	21-Oct-10	46	1.98	0.00	1.09	0.07	19.90
Cook Point	Choptank	7/19, 7/26, 7/27, 8/2	21-Sep-10	2	1.00	0.00	0.00	0.00	30.00
Cook Point	Choptank	7/19, 7/26, 7/27, 8/2	21-Sep-10	5	0.20	0.00	0.00	0.20	51.00
Cook Point	Choptank	7/19, 7/26, 7/27, 8/2	21-Sep-10	10	0.60	0.00	0.30	0.00	27.60
Cook Point	Choptank	7/19, 7/26, 7/27, 8/2	21-Sep-10	59	1.88	0.03	3.51	0.07	26.01
Cook Point	Choptank	7/19, 7/26, 7/27, 8/2	21-Sep-10	83	2.77	0.04	0.70	0.02	25.74
Cook Point	Choptank	7/19, 7/26, 7/27, 8/2	21-Sep-10	93	2.53	0.05	1.82	0.05	20.89
Hickory Thicket	Chester	7/5, 7/7, 7/12, 7/15	20-Aug-10	7	4.57	0.00	0.57	0.00	23.37
Hickory Thicket	Chester	7/5, 7/7, 7/12, 7/15	20-Aug-10	9	1.89	0.00	2.33	0.11	21.70
Hickory Thicket	Chester	7/5, 7/7, 7/12, 7/15	20-Aug-10	9	1.56	0.00	2.78	0.00	18.95
Hickory Thicket	Chester	7/5, 7/7, 7/12, 7/15	20-Aug-10	9	13.00	0.22	2.67	0.00	20.23
Hickory Thicket	Chester	7/5, 7/7, 7/12, 7/15	20-Aug-10	10	0.20	0.00	0.60	0.00	15.50
Hickory Thicket	Chester	7/5, 7/7, 7/12, 7/15	20-Aug-10	13	1.38	0.08	0.54	0.08	19.35
Sandy Hill (North)	Choptank	7/21, 7/28, 8/4	26-Aug-10	6	3.33	0.00	1.67	0.00	13.95
Sandy Hill (North)	Choptank	7/21, 7/28, 8/4	26-Aug-10	7	1.86	0.00	0.86	0.00	8.50
Sandy Hill (North)	Choptank	7/21, 7/28, 8/4	26-Aug-10	8	1.00	0.00	0.50	0.00	10.53
Sandy Hill (North)	Choptank	7/21, 7/28, 8/4	26-Aug-10	14	4.00	0.00	0.93	0.07	18.32
Sandy Hill (North)	Choptank	7/21, 7/28, 8/4	26-Aug-10	15	1.93	0.00	1.67	0.13	15.70
Sandy Hill (North)	Choptank	7/21, 7/28, 8/4	26-Aug-10	23	1.87	0.00	1.17	0.00	16.64
Sandy Hill (South)	Choptank	9/15, 10/4	03-Nov-10	7	0.14	0.00	1.86	0.14	9.00
Sandy Hill (South)	Choptank	9/15, 10/4	03-Nov-10	8	0.63	0.00	0.75	0.38	6.13
Sandy Hill (South)	Choptank	9/15, 10/4	03-Nov-10	12	1.33	0.00	1.33	0.50	7.84
Sandy Hill (South)	Choptank	9/15, 10/4	03-Nov-10	17	3.12	0.00	2.18	0.88	4.97
Sandy Hill (South)	Choptank	9/15, 10/4	03-Nov-10	18	0.28	0.00	0.17	0.00	12.40
Sandy Hill (South)	Choptank	9/15, 10/4	03-Nov-10	39	2.05	0.00	1.59	0.23	5.87
States Bank	Choptank	5/5, 5/4, 5/10	09-Jul-10	1	6.00	0.00	0.00	0.00	33.33
States Bank	Choptank	5/5, 5/4, 5/10	09-Jul-10	6	2.00	0.00	0.00	0.00	21.88
States Bank	Choptank	5/5, 5/4, 5/10	09-Jul-10	10	3.80	0.00	0.00	0.10	39.79
States Bank	Choptank	5/5, 5/4, 5/10	09-Jul-10	12	3.33	0.00	0.08	0.17	38.11
States Bank	Choptank	5/5, 5/4, 5/10	09-Jul-10	15	4.27	0.00	0.40	0.00	38.21
States Bank	Choptank	5/5, 5/4, 5/10	09-Jul-10	22	10.95	0.00	0.36	0.27	19.80
Strong Bay	Chester	6/7, 6/9, 6/14, 6/16	15-Jul-10	2	2.00	0.00	0.00	0.00	19.25
Strong Bay	Chester	6/7, 6/9, 6/14, 6/16	15-Jul-10	19	0.00	0.00	0.21	0.00	13.50
Strong Bay	Chester	6/7, 6/9, 6/14, 6/16	15-Jul-10	22	0.05	0.00	0.23	0.00	9.70
Strong Bay	Chester	6/7, 6/9, 6/14, 6/16	15-Jul-10	23	0.04	0.00	0.22	0.00	12.13
Strong Bay	Chester	6/7, 6/9, 6/14, 6/16	15-Jul-10	39	0.92	0.00	0.67	0.08	12.49
Strong Bay	Chester	6/7, 6/9, 6/14, 6/16	15-Jul-10	56	0.27	0.00	0.34	0.02	10.38

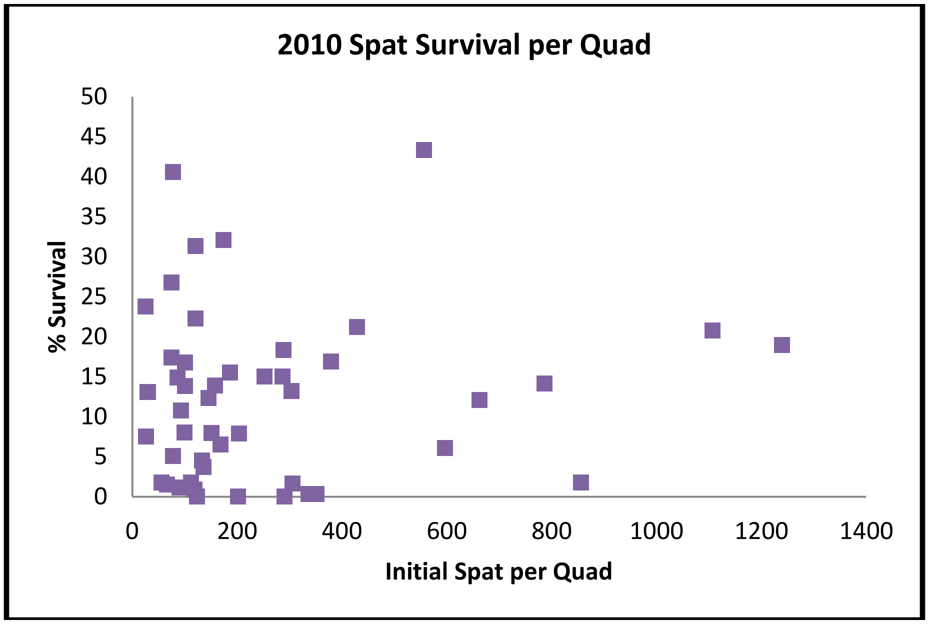
The amount of live spat per shell in each quad was multiplied by the total amount of shell found in each quad to calculate the amount of spat per quad detected by the post-planting monitoring survey. Spat survival was then calculated as the percentage of spat planted (per quad as the initial spat per shell multiplied by the total shells per quad) that was detected by the survey. The mean per quad spat survival for 2010 plantings was 12.37%. However, it is important to note the range of the data was 0.00% survival (Blunt and Strong Bay) to 43.29% survival (States Bank). As in the complete 2010 data, quad-based survival data shows high variability. The percent survival of spat planted by bar is presented in **Table 6.**

Table 6–2010 spat survival by bar, per quad.

Site	Shells in Quad	Initial Spat per Quad	Mean Live per Shell	Total Live Spat per Quad	Quad % Survival	Site % Survival	SD
Blunt	5	56.25	0.20	1	1.78		
Blunt	7	78.75	0.57	4	5.08		
Blunt	8	90.00	0.13	1	1.11		
Blunt	11	123.75	0.00	0	0.00		
Blunt	15	168.75	0.73	11	6.52		
Blunt	18	202.50	0.00	0	0.00	2.4	2.8
Brewer	8	74.72	1.63	13	17.40		
Brewer	10	93.40	1.00	10	10.71		
Brewer	13	121.42	2.92	38	31.30		
Brewer	13	121.42	2.08	27	22.24		
Brewer	17	158.78	1.29	22	13.86		
Brewer	46	429.64	1.98	91	21.18	19.5	7.3
Cook Point	2	26.67	1.00	2	7.50		
Cook Point	5	66.69	0.20	1	1.50		
Cook Point	10	133.37	0.60	6	4.50		
Cook Point	59	786.89	1.88	111	14.11		
Cook Point	83	1106.98	2.77	230	20.78		
Cook Point	93	1240.35	2.53	235	18.95	11.2	7.9
Hickory Thicket	7	78.92	4.57	32	40.55		
Hickory Thicket	9	101.47	1.89	17	16.75		
Hickory Thicket	9	101.47	1.56	14	13.80		
Hickory Thicket	10	112.74	0.20	2	1.77		
Hickory Thicket	13	146.56	1.38	18	12.28	17.1	14.3
Sandy Hill (North)	6	74.85	3.33	20	26.72		
Sandy Hill (North)	7	87.33	1.86	13	14.89		
Sandy Hill (North)	8	99.80	1.00	8	8.02		
Sandy Hill (North)	14	174.65	4.00	56	32.06		
Sandy Hill (North)	15	187.13	1.93	29	15.50		
Sandy Hill (North)	23	286.93	1.87	43	14.99	18.7	8.9
Sandy Hill (South)	7	119.00	0.14	1	0.84		
Sandy Hill (South)	8	136.00	0.63	5	3.68		
Sandy Hill (South)	12	204.00	1.33	16	7.84		
Sandy Hill (South)	17	289.00	3.12	53	18.34		
Sandy Hill (South)	18	306.00	0.28	5	1.63		
Sandy Hill (South)	39	663.00	2.05	80	12.07	7.4	6.8
States Bank	1	25.30	6.00	6	23.71		
States Bank	6	151.83	2.00	12	7.90		
States Bank	10	253.05	3.80	38	15.02		
States Bank	12	303.65	3.33	40	13.17		
States Bank	15	379.57	4.27	64	16.86		
States Bank	22	556.70	10.95	241	43.29	20.0	12.5
Strong Bay	2	30.61	2.00	4	13.07		
Strong Bay	19	290.81	0.00	0	0.00		
Strong Bay	22	336.73	0.05	1	0.30		
Strong Bay	23	352.04	0.04	1	0.28		
Strong Bay	39	596.93	0.92	36	6.03		
Strong Bay	56	857.13	0.27	15	1.75	3.6	5.2
	TOTAL/MEAN	12383.52	1.84	1673	12.37	12.4	10.6

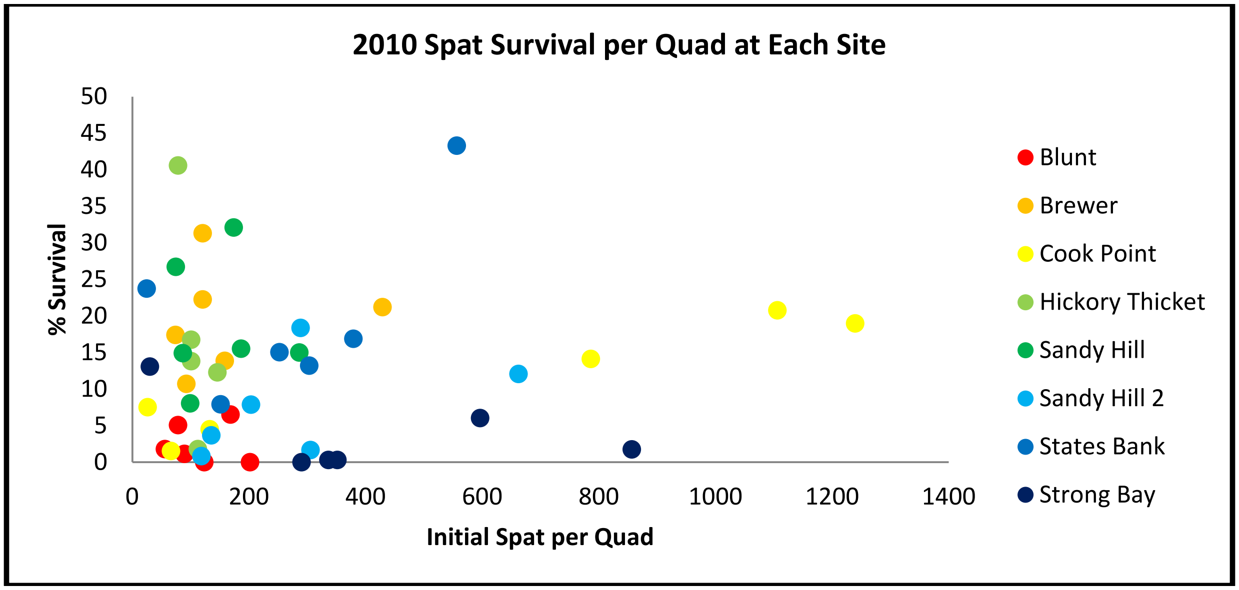
In order to examine the source of the variability seen in post planting spat per shell and percent survival at the quadrat level, 2010 quadrat data were examined for a relationship between spat survival and initial spat density. As in the comparisons without quadrat-sampling, no clear trend was observed. **Figure 4** shows that there was no direct relationship between the initial spat per quad and spat survival in 2010.

Figure 4– 2010 data showing the spat survival relative to initial hatchery spat per quad. This includes six quads at each site where quadrat sampling was possible. No clear trend exists between initial spat density and survival.



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. As **Figure 5** shows, although six sets of shell samples were collected at each site at areas with many planting track lines as well as few track lines, a wide range of shell densities was not achieved at most sites. The majority of initial spat per quad values fall under 500, however for the few sites that have higher values (Cook Point and Strong Bay) no significant trend was observed.

Figure 5– 2010 data showing the spat survival relative to initial hatchery spat per quad at each bar sampled. This data illustrates the difficulty in collecting variable shell densities within a bar.



Conclusions:

The 2010 planting season involved several changes attempting to achieve greater survival success and more relevant data. First, the planting approach differed from previous years, as fewer bars were planted overall, but were over-planted over multiple trips to each bar. Additionally, while not a highly controllable factor, the number of initial spat per shell was lower in 2010 than previous years. Neither of these differences appears to have had a drastic impact on spat survival, as the overall 2010 spat survival was consistent with that of 2009.

Using the data collected in post-planting monitoring surveys, the relationship between initial spat per shell and spat survival were compared, yielding no significant trend for 2010. This is similar to data from 2008, however 2009 data showed a negative correlation between initial spat per shell and survival. Continued post-planting monitoring surveys in 2011 could help identify the relationship seen in 2009 as an anomaly or possible trend.

In an effort to more closely examine the relationship between initial spat planted and post-planting survival, surveys were conducted using a standard sample area (a 0.3m x 0.3m quadrat). This allowed for a stronger comparison of initial spat density over a specific area. Using this approach, 2010 data again showed no relationship among initial spat density and post-planting spat survival. As mentioned above, although a range of shell density sample sets were targeted, this was not achieved at most sites. It is recommended that quadrat-based sampling is continued in 2011 surveys, possibly with greater focus on high-density areas within bars to create the desired density range. This can also be enhanced through continued over-planting as was done in 2010.

SECTION III

Paynter Lab Patent Tong Survey 2010
Data Summary and Conclusions

Patent tong surveys were conducted throughout 2010 on oyster bars in the Chester, Choptank, and Magothy Rivers. Below is the list of all sites sampled.

Table 1. Oyster bars tonged during the 2010 field season.

River	Bar Name	Planting Date	Surveyed
Chester	Coppers Hill/Piney Point	9/25/2007	8/17/2010
Chester	Drum Point	6/26/2007	9/14/2010
Chester	Emory Hollow	5/22/2008	10/20-10/22
Chester	Emory Wharf	2005, 2006, 2008	11/23/10, 2/17/11
Chester	Hickory Thicket	9/19/2006	9/20/2010
Chester	Possum Point	2008	11/23/10, 2/17/11
Chester	Spaniards Point	10/9/2006	8/30-9/10
Chester	Willow Bottom	5/30/2007	9/14/2010
Choptank	Bolingbroke Sands	2008	12/3-12/17
Choptank	The Black Buoy	2005, 2009	12/3-12/17
Magothy	Black	2008	10/8/2010
Magothy	Park/Rock Point	2008	10/8/2010
Magothy	Ulmstead Point/Umphasis	8/8/2006	10/8/2010

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 1 shows an example of the grid with sampling points from the Bolingbroke Sands oyster bar 2010 patent tong survey. 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 2-14).

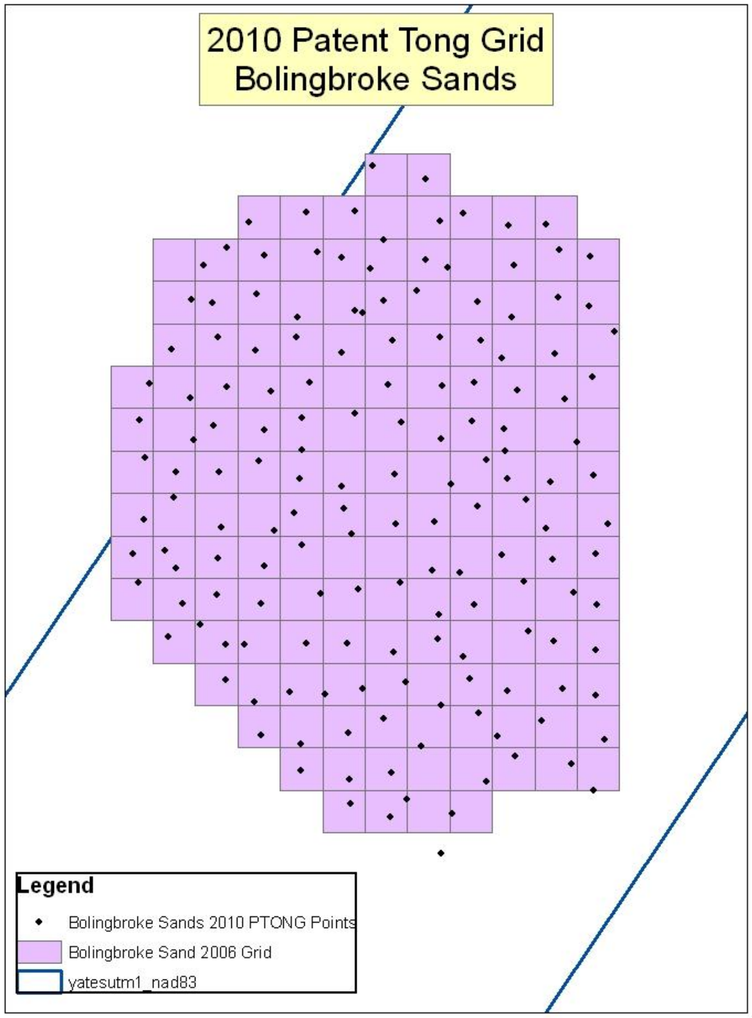
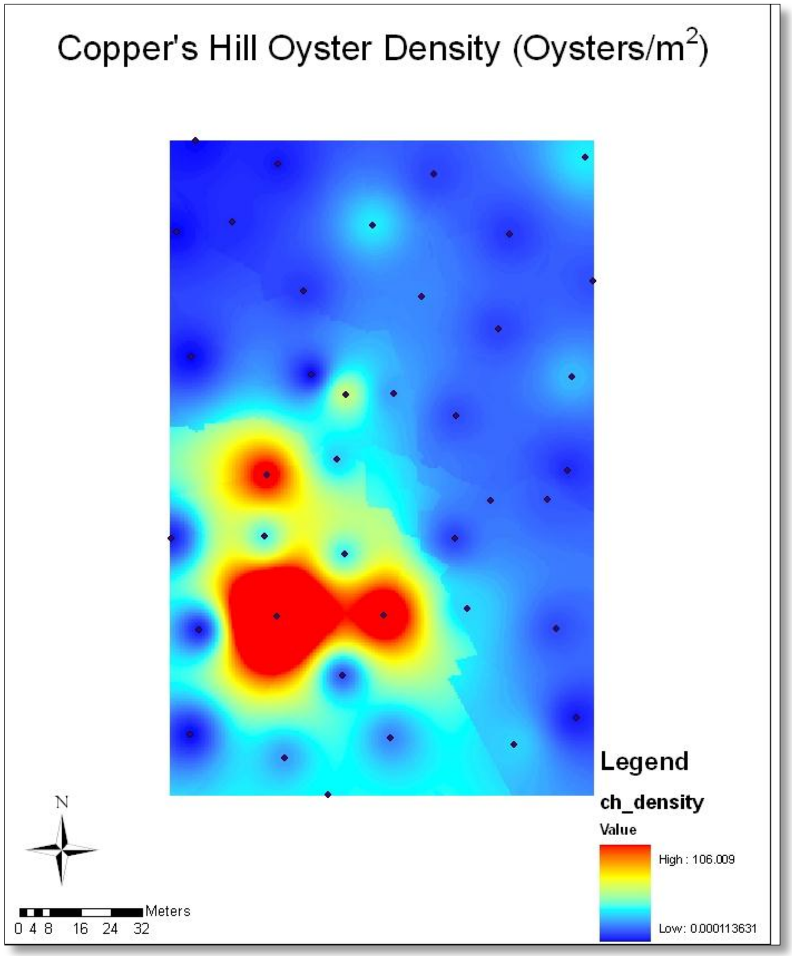


Figure 1. Example of a patent tong grid used in the 2010 patent tong season. Each grid cell is 25x25m in size and each black point represents one patent tong grab.

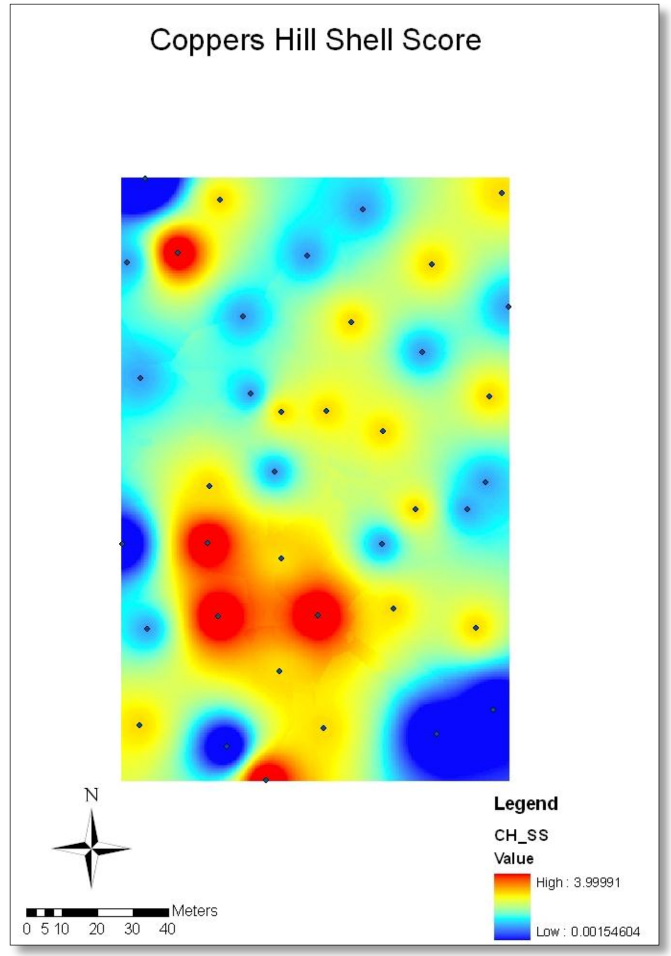
Table 2 summarizes the metrics collected for each site sampled in 2010 (amount of live and dead oysters, percentage of oysters found that were dead, live oyster size and density, percent of area sampled with greater than 5oy/m^2, percent of area sampled with shell coverage, population estimate, total biomass and *Perkinsus marinus* (Dermo) prevalence and weighted prevalence). At The Black Buoy and Emory Wharf, multiple year classes were sampled and disease was determined separately for each age class. For both sites, older animals had higher disease prevalence and weighted prevalence than their younger counterparts.

Table 2. Data collected on 2010 patent tong surveys.

Bar Name	Year Planted	# Live Oysters Collected	# Dead Oysters Collected	Dead Oysters (% of Total)	Average Live Oyster Length	SD	Average Live Oyster Density (#/m2)	SD	% Total Area >5oy/m2	% Total Area with Shell Coverage	Population Estimate (Oysters)	Biomass (kg)	Dermo Prevalence (%)	Dermo Weighted Prevalence
Coppers Hill/Piney Point	2007	626	19	3	95	19	9	18	57	99	216,160	290	20.0	0.17
Drum Point	2007	73	2	3	107	24	1	2	4	35	25,207	46	10.0	0.01
Emory Hollow	2008	2244	36	2	87	17	14	20	73	89	631,561	862	3.3	0.03
Hickory Thicket	2006	346	29	8	84	19	2	4	8	87	119,475	124	12.0	0.04
Spaniards Point	2006	1036	42	4	109	16	2	3	4	70	357,735	665	80.0	1.05
Willow Bottom	2007	28	0	0	110	17	0	1	1	36	9,669	18	58.6	0.26
Bolingbroke Sands	2006	400	32	7	92	21	2	4	7	52	155,280	232	100.0	1.73
The Black Buoy	2005	667	37	5	65	40	3	10	20	60	258,929	162	33.3	0.14
The Black Buoy	2009	-	-	-	-	-	-	-	-	-	-	-	7.4	0.003
Black	2008	114	4	3	74	14	1	9	4	1	39,365	30	6.7	0.10
Park/Rock Point	2008	67	5	7	75	16	2	5	4	13	23,135	18	10.7	0.04
Ulmstead Point/Umphasis	2006	518	10	2	98	15	15	25	69	80	178,867	261	20.0	0.21
Emory Wharf	2008	201	17	8	113	26	7	5	11	49	69,406	138	83.3	0.65
Emory Wharf	2005, 2006	-	-	-	-	-	-	-	-	-	-	-	26.7	0.27
Possum Point	2005, 2006	171	8	5	119	17	26	4	62	70	59,047	142	30.0	0.14
2010 Mean	-	499	19	4	95	-	6	-	25	57	-	-	33.5	0.32
2010 Total	-	-	-	-	-	-	-	-	-	-	2,143,835	2,988	-	-

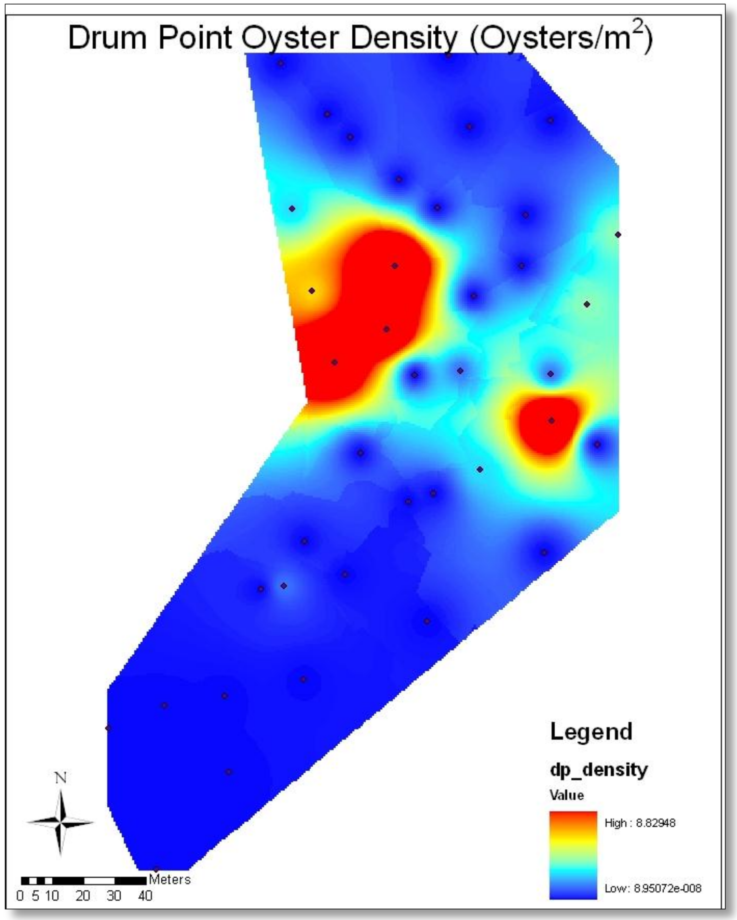


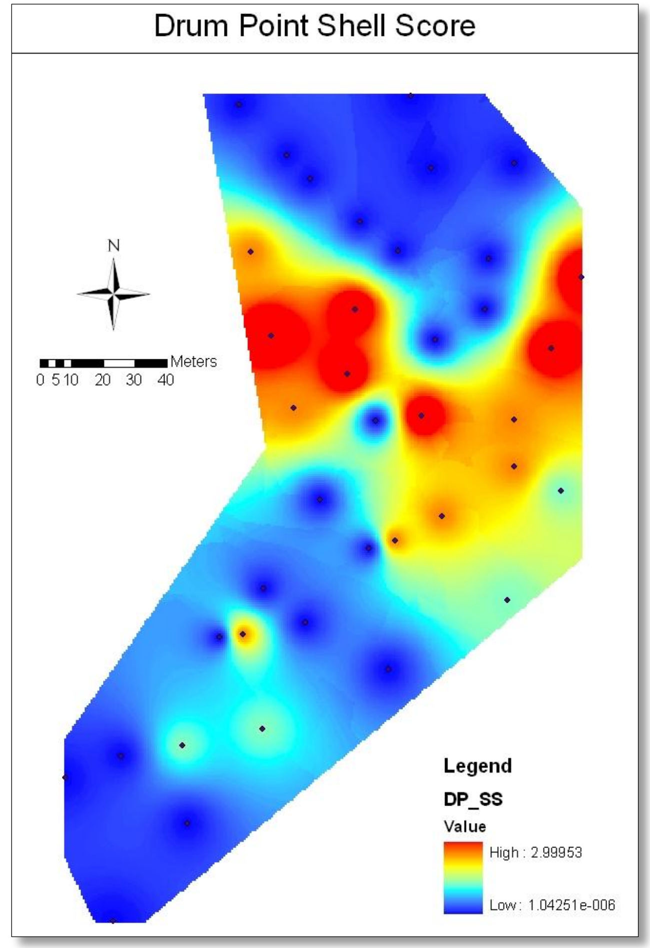
2a



2b

Figure 2. Oyster density (2a) and shell score (2b) plots at Coppers Hill, an oyster bar in the Chester River. Where oyster density was highest, shell score, overall, was also high. Fifty-seven percent of the bar had oyster densities greater than 5oy/m^2, despite 99% shell coverage, indicating that not all areas with shell had oysters present.





3a

3b

Figure 3. Oyster density (3a) and shell score (3b) plots at Drum Point, an oyster bar in the Chester River. Where oyster density was highest, shell score, overall, was also high. However, oyster densities and shell coverage were low at this bar; only 4% of the bar contained oysters at densities higher than 5oy/m^2 and only 35% of the bar had any shell coverage.

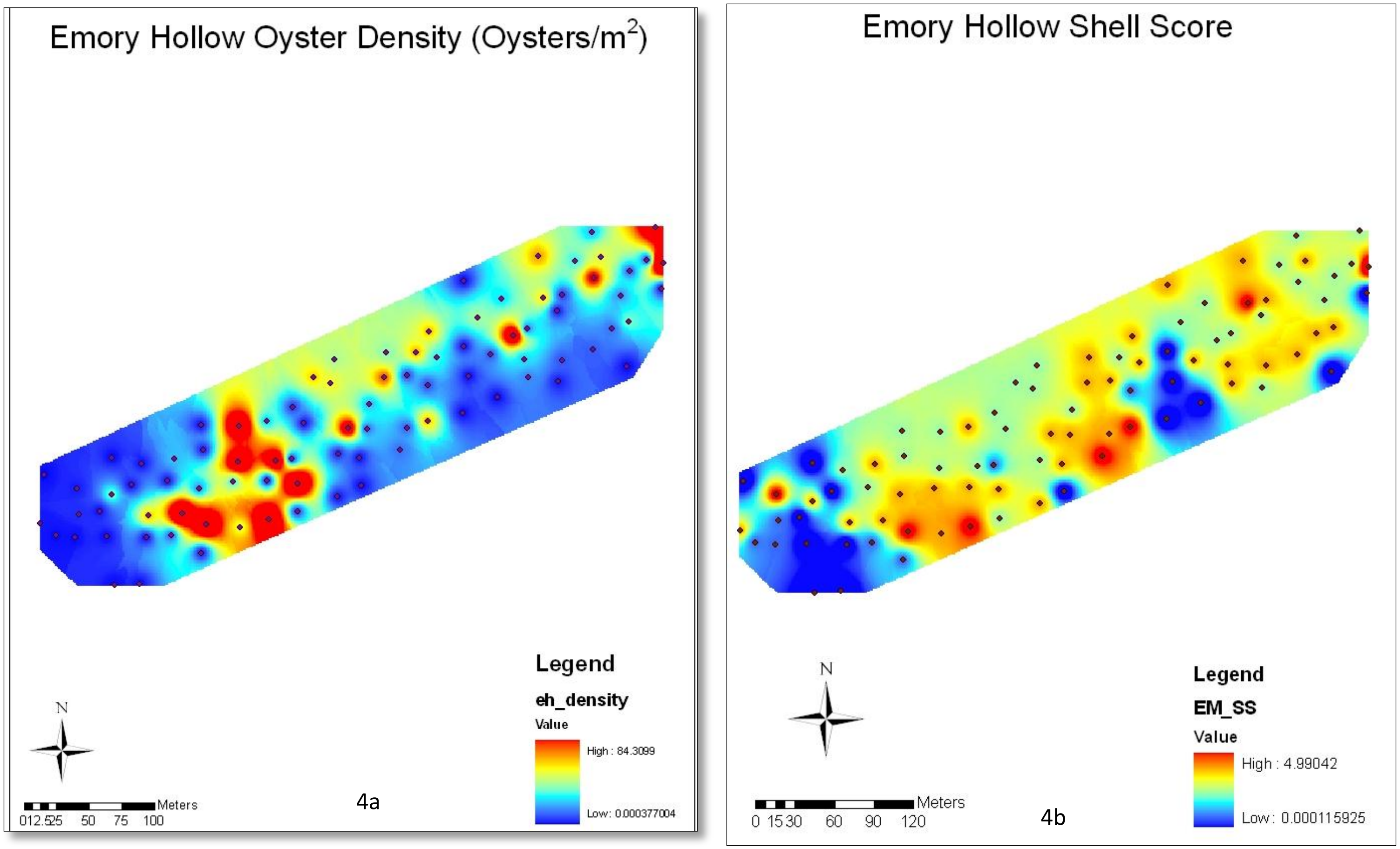
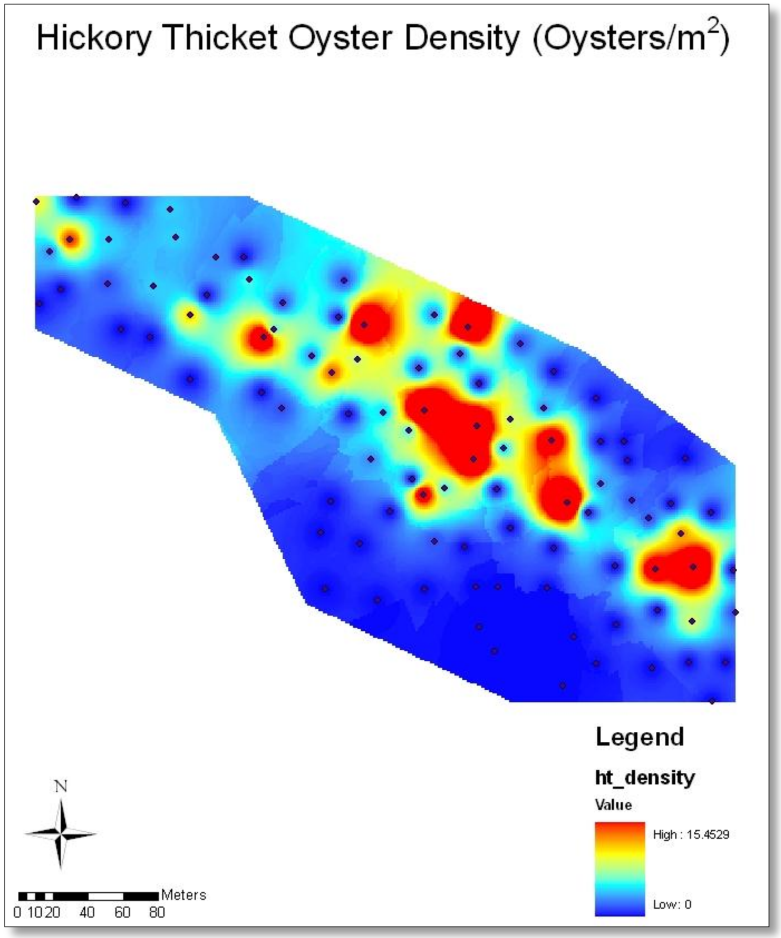


Figure 4. Oyster density (4a) and shell score (4b) plots at Emory Hollow, an oyster bar in the Chester River. Generally, shell score was higher in areas of high oyster density and 73% of the bar had oyster densities greater than 5oy/m^2. However, oysters were not found in all areas with shell, as 89% of the bar had shell coverage.



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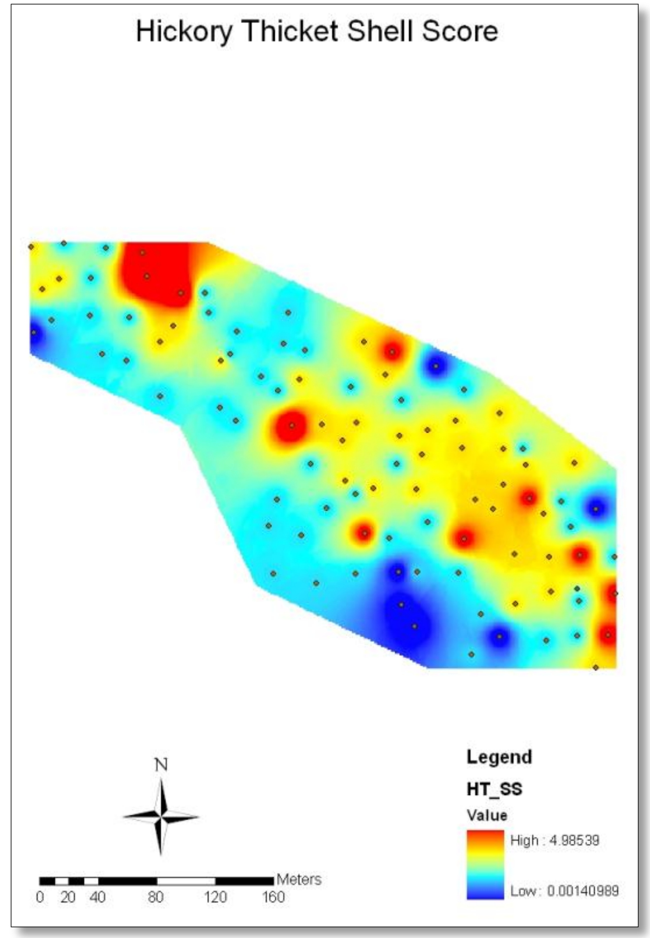
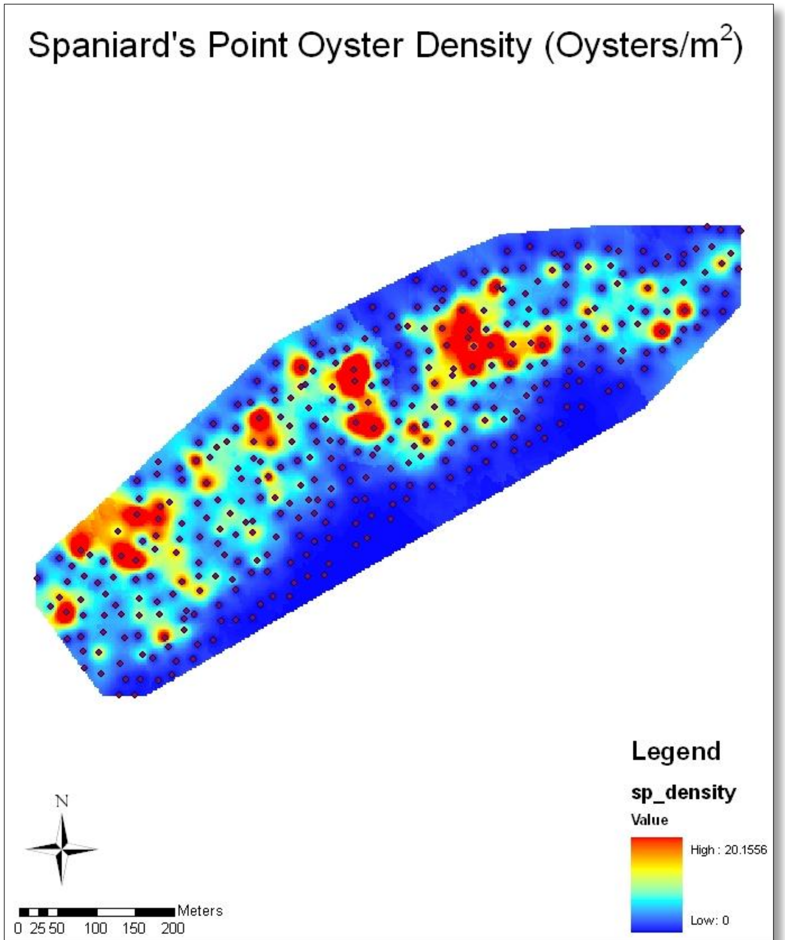


5b

Figure 5. Oyster density (5a) and shell score (5b) plots at Hickory Thicket, an oyster bar in the Chester River. Shell scores were higher in the center of the bar where most oysters were found, but only 8% of the bar had oyster densities greater than 5oy/m^2, while 87% of the bar had shell coverage.



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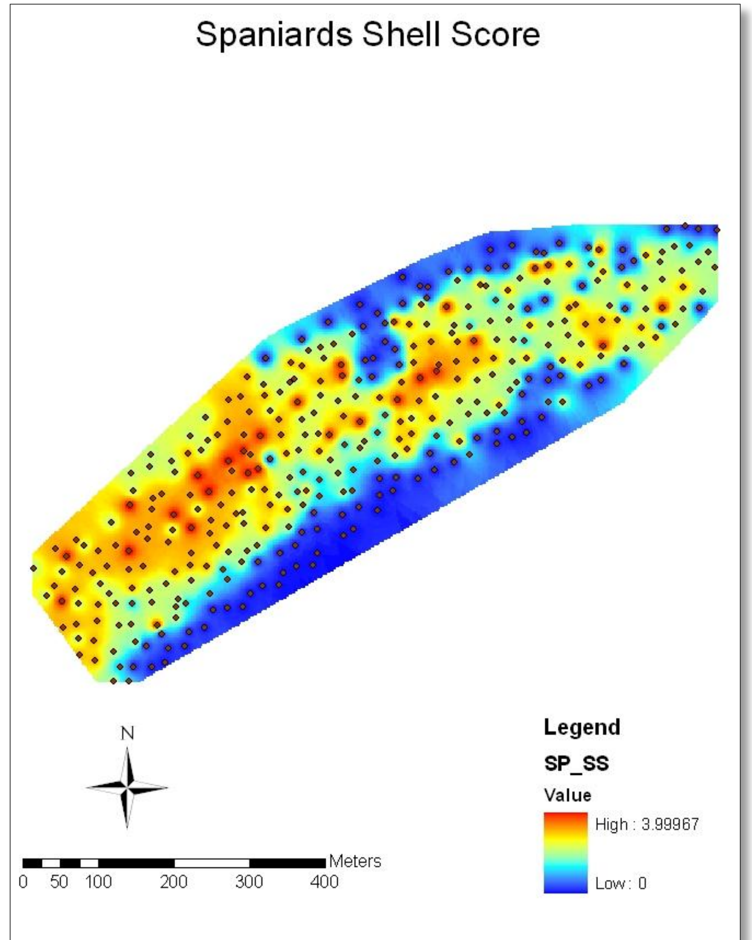
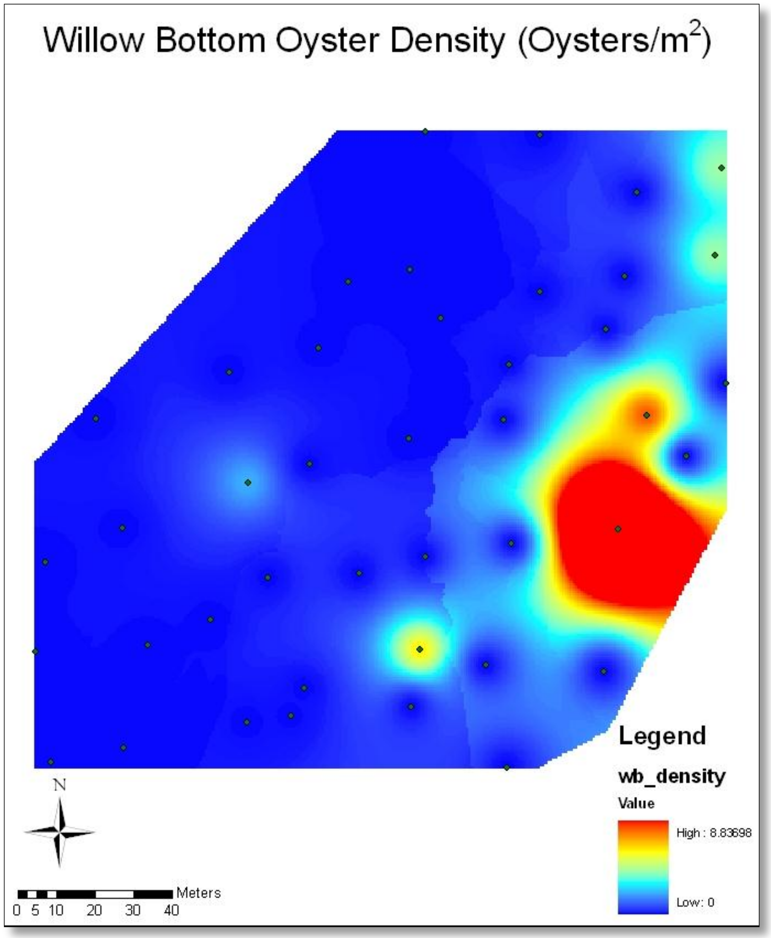
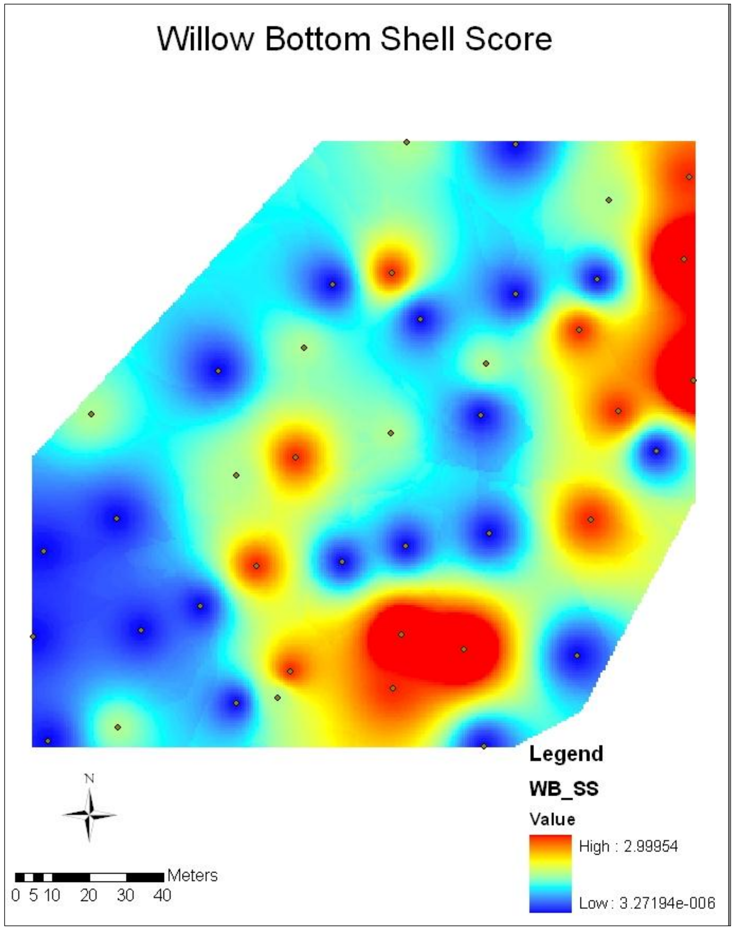


6b

Figure 6. Oyster density (6a) and shell score (6b) plots at Spaniard's Point, an oyster bar in the Chester River. Overall, in areas of high oyster density, shell score was also high. However, only 4% of the bar had oyster densities greater than 5oy/m^2 while 70% of the bar had shell coverage, indicating that not all areas with shell had oysters present.

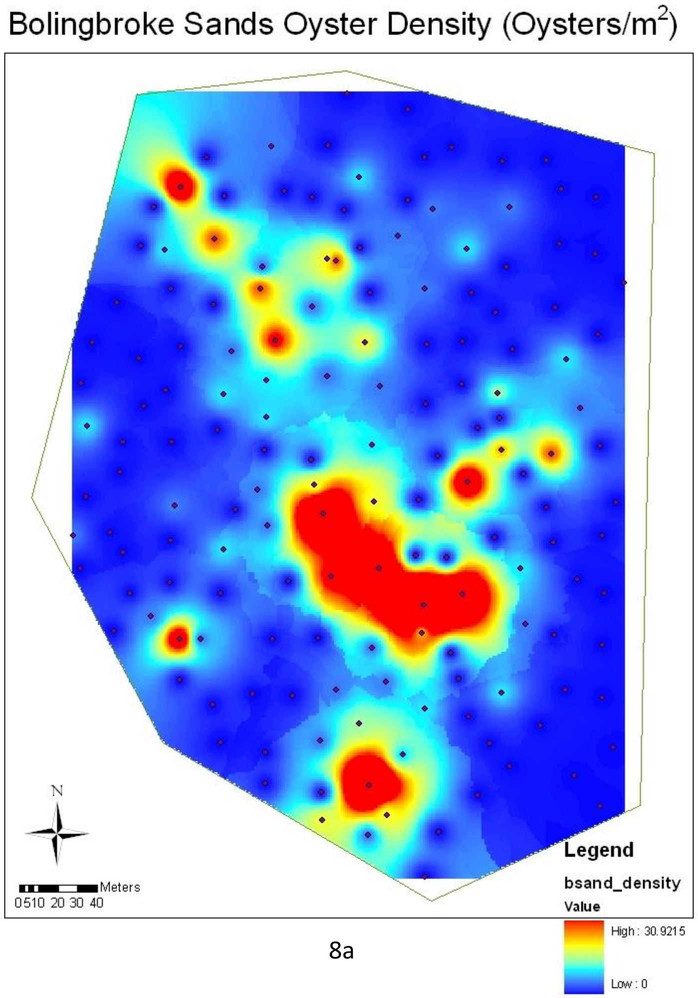


7a

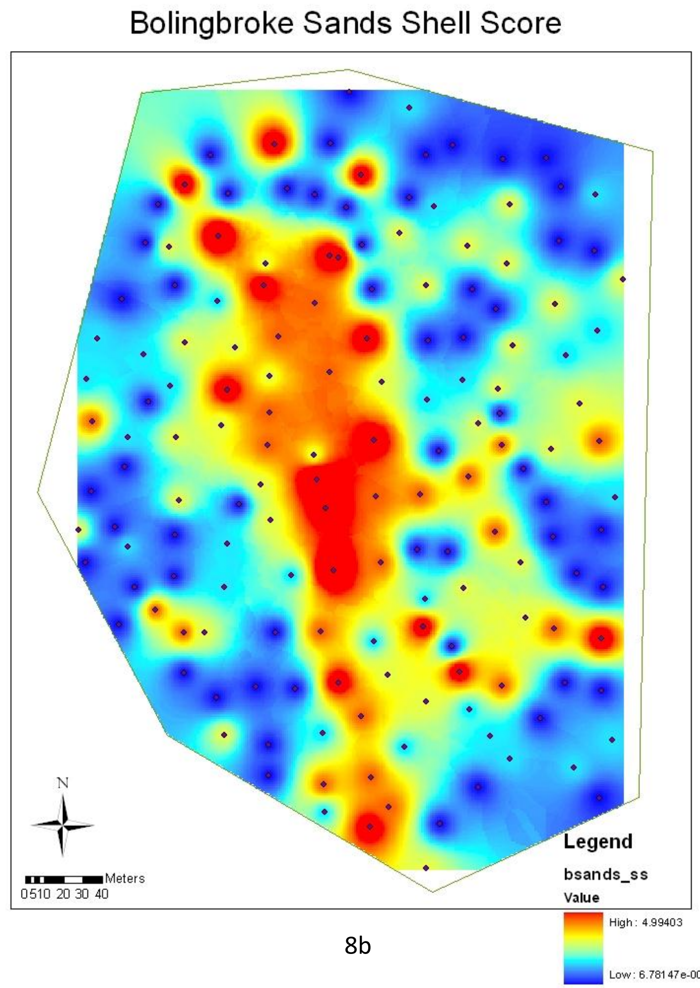


7b

Figure 7. Oyster density (7a) and shell score (7b) plots at Willow Bottom, an oyster bar in the Chester River. Although the one area of high oyster density did occur on an area with high shell score, this bar's oyster and shell coverage are both poor overall. Only 1% of the bar has oyster density greater than 5oy/m^2 and only 36% of the bar had any shell coverage.



8a



8b

Figure 8. Oyster density (8a) and shell score (8b) plots at Bolingbroke Sands an oyster bar in the Choptank River. Areas of high oyster density also had high shell scores, however not all areas of high shell score yielded high oyster density. However, only 7% of the bar had oyster densities greater than 5oy/m^2, while 52% of the bar had shell coverage, indicating that not all areas with shell had oysters present.

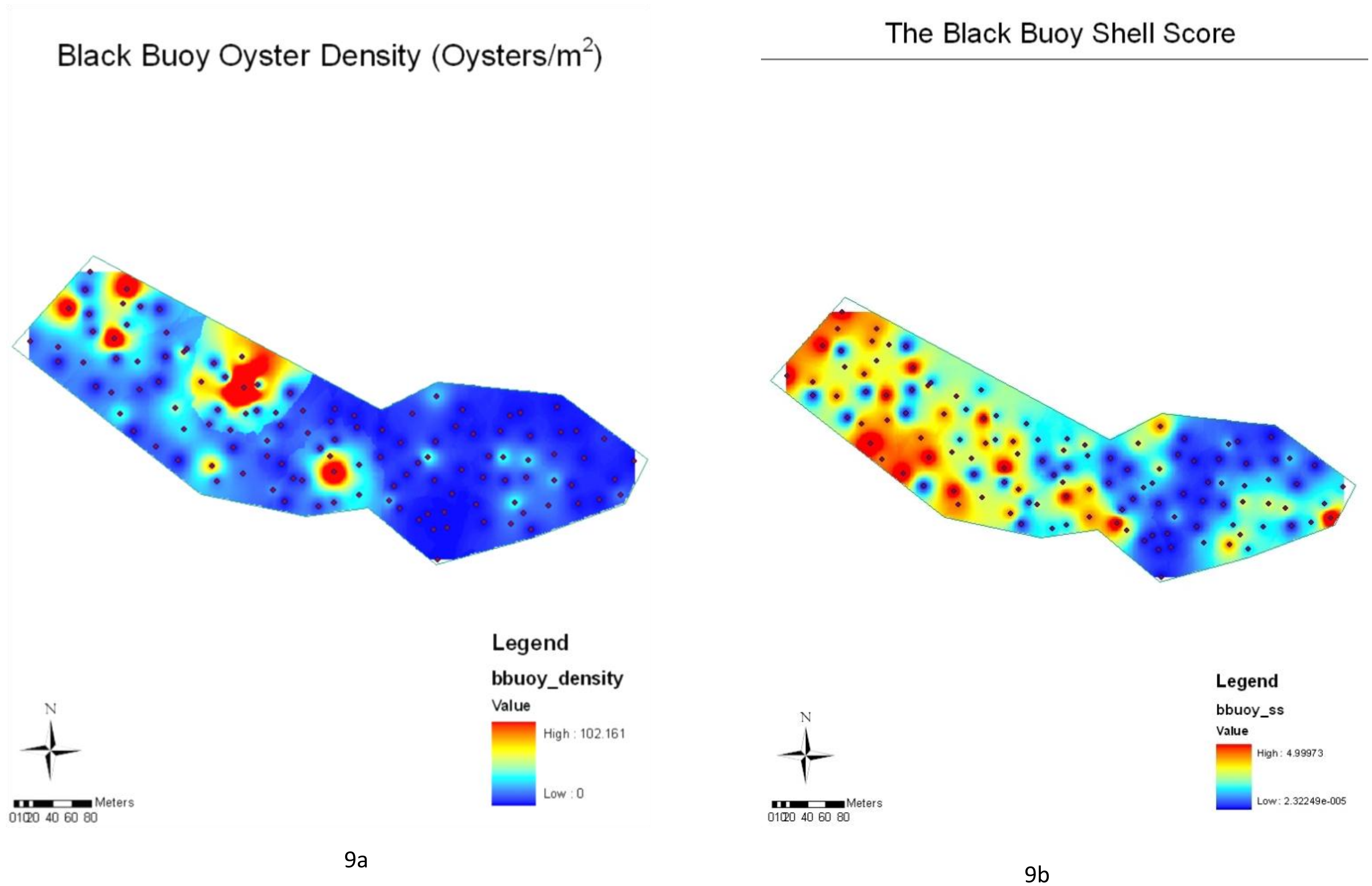
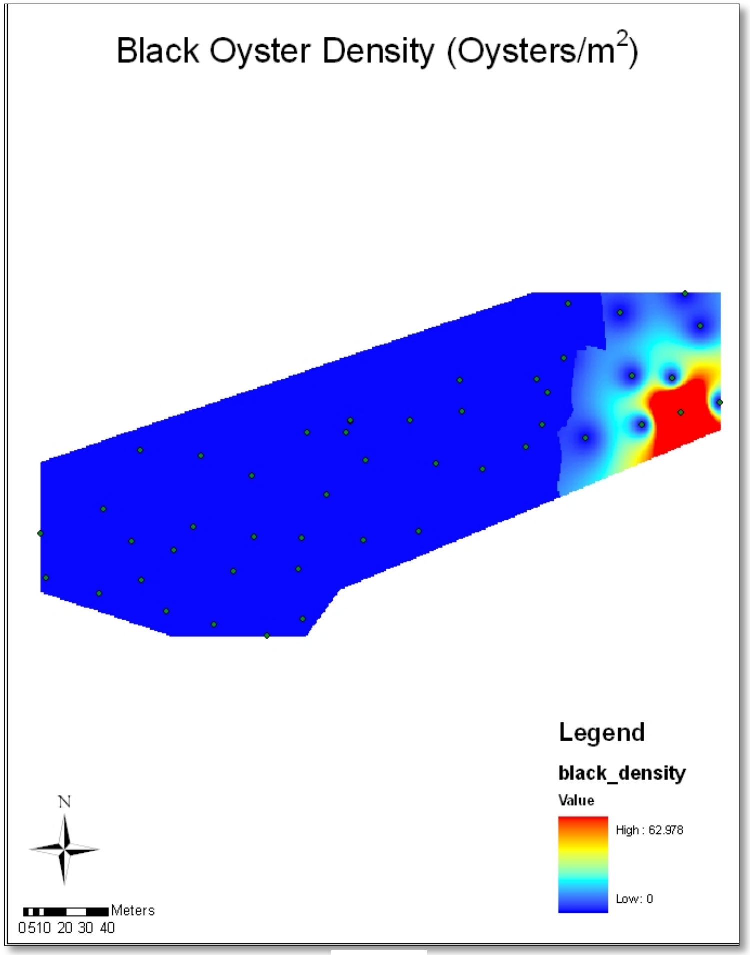
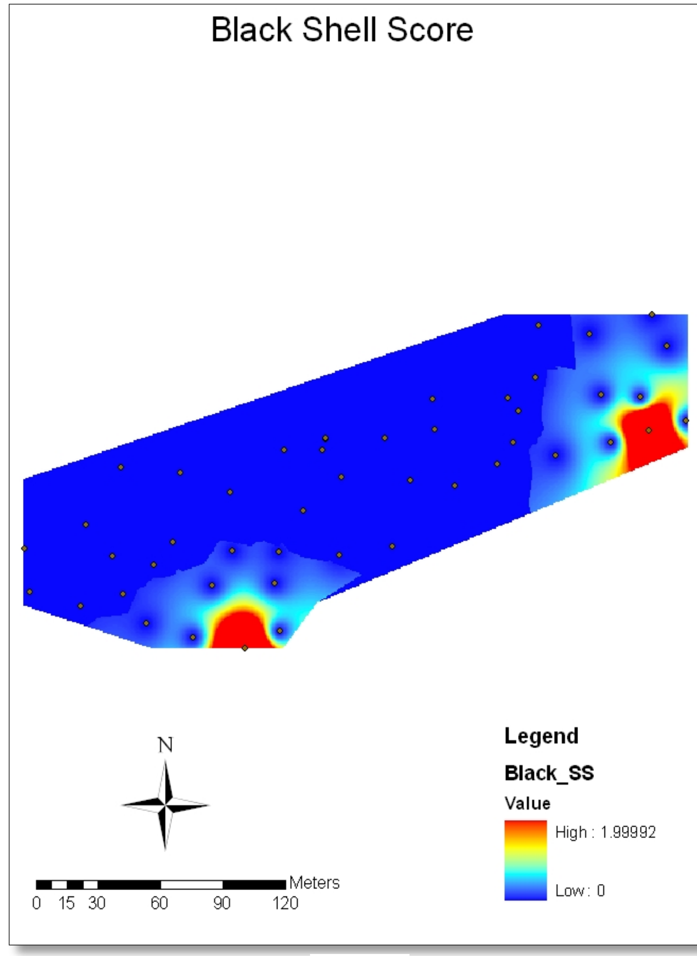


Figure 9. Oyster density (9a) and shell score (9b) plots at The Black Buoy, an oyster bar in the Choptank River. Areas of highest oyster density did not occur in areas of highest shell score, however some shell coverage was present where all oysters were found. Twenty percent of the bar had oyster densities greater than 5oy/m^2 and 60% of the bar had shell coverage, indicating that not all areas with shell had oysters present.

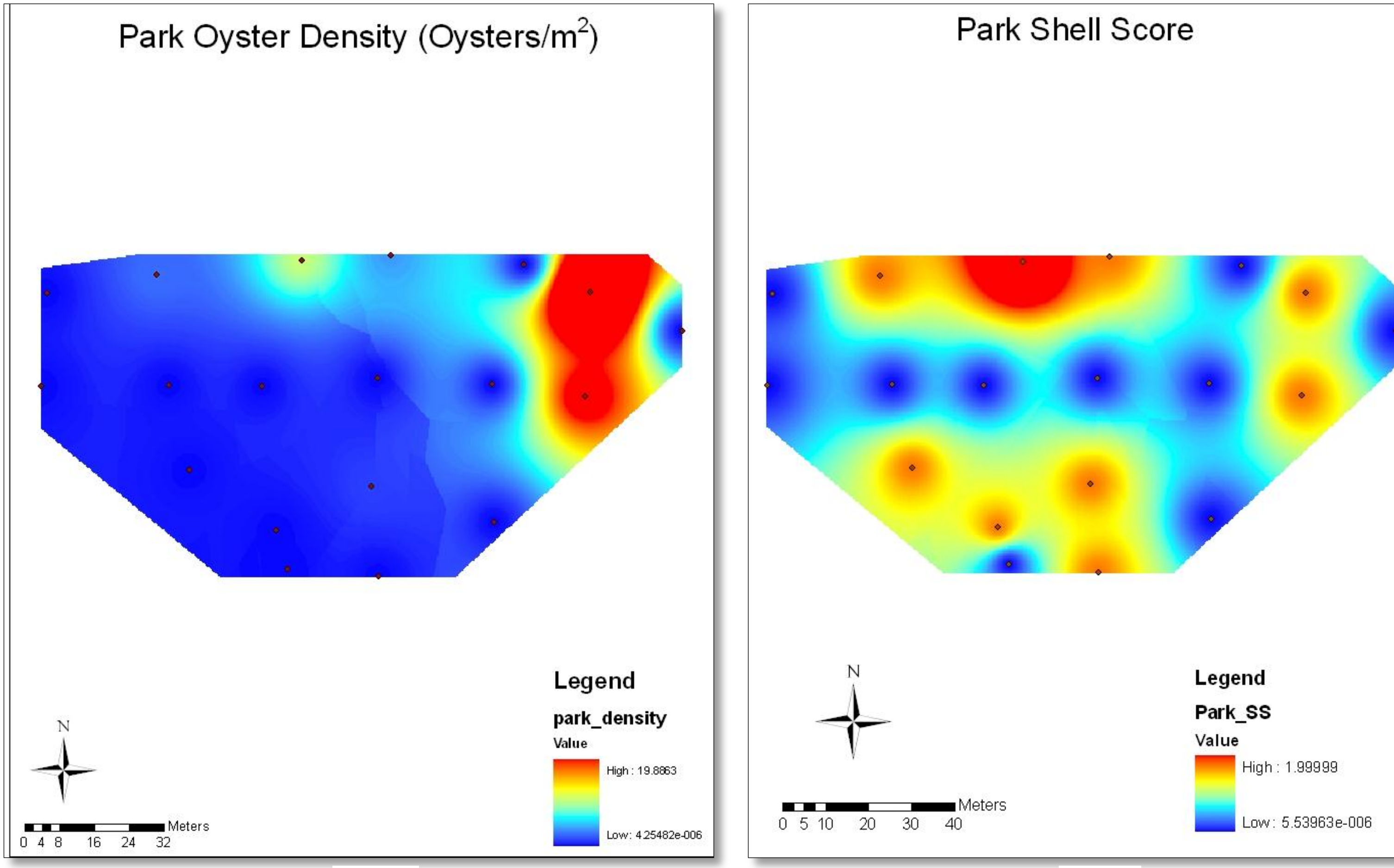


10a



10b

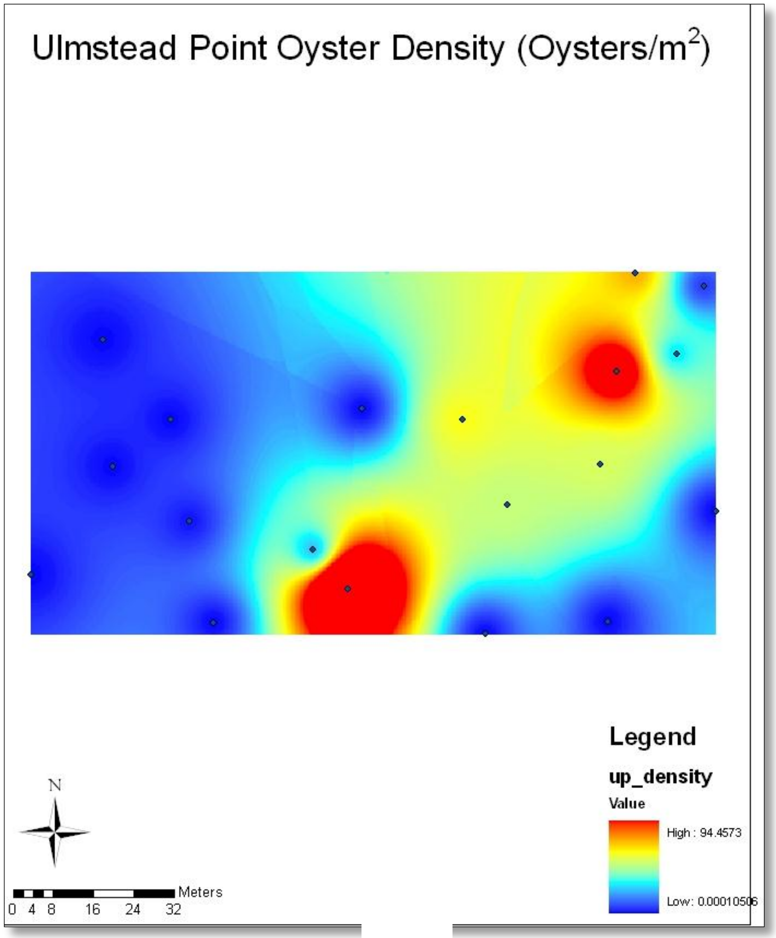
Figure 10. Oyster density (10a) and shell score (10b) plots at Black, an oyster bar in the Magothy River. The oyster density and shell score at Black generally coincide. In the southeast corner of the bar, a section of high shell score did not yield high numbers of oysters. However, both oyster density and shell coverage were extremely low at this bar; only 4% of the bar had oyster densities greater than 5oy/m^2 and only 1% of the bar had shell coverage.



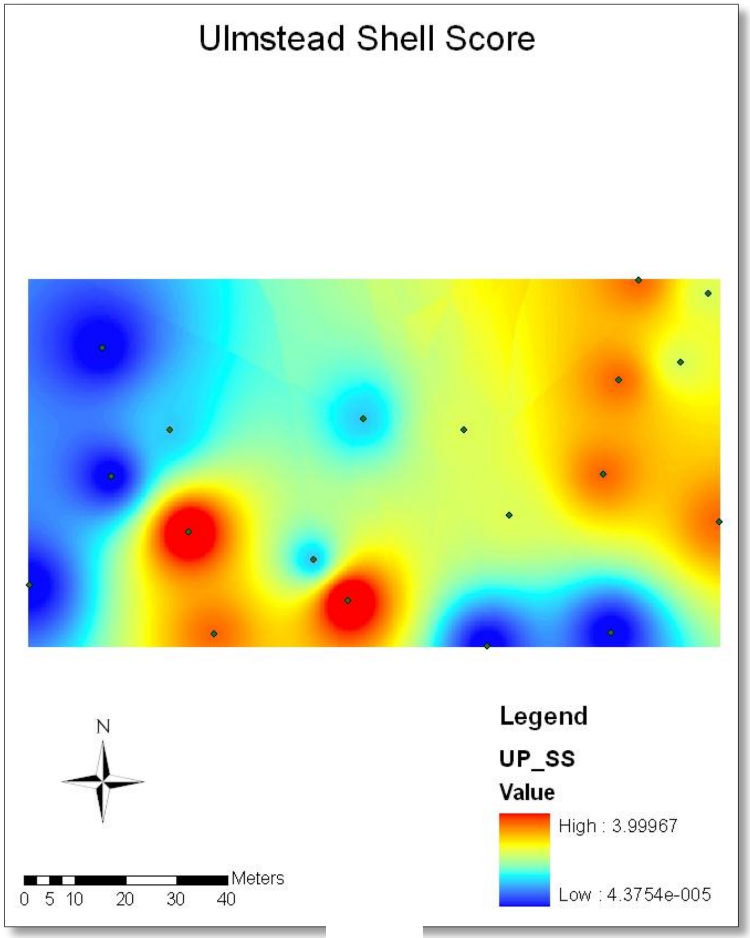
11a

11b

Figure 11. Oyster density (11a) and shell score (11b) plots at Park, an oyster bar in the Magothy River. In general, the two areas of high oyster density (on the east edge of the bar and the center of the northern edge) were also areas of high shell score. However, multiple areas of high shell score did not yield high oyster density. Both oyster density and shell coverage were extremely low at this bar; only 4% of the bar had oyster densities greater than 5oy/m^2 and only 13% of the bar had shell coverage.

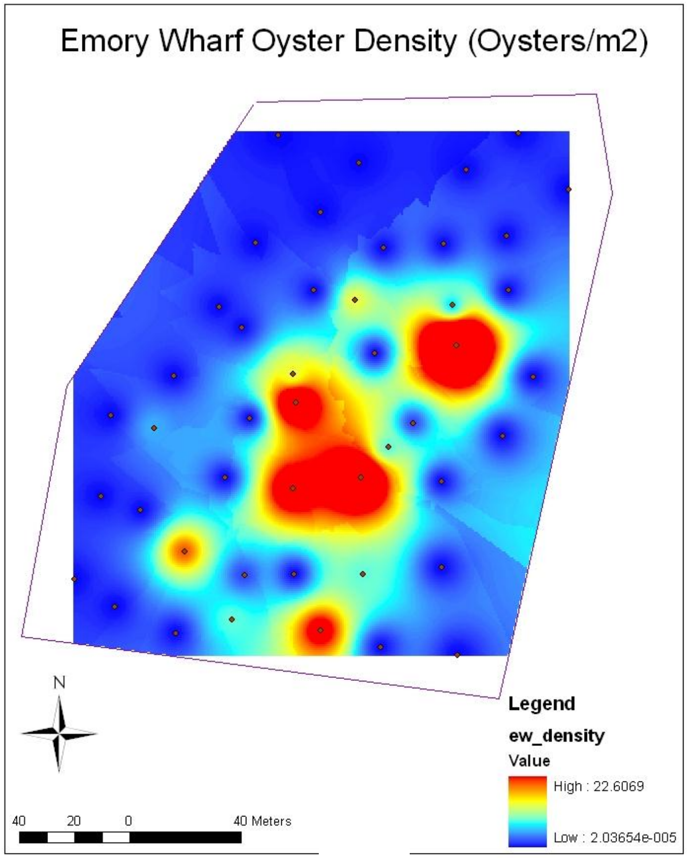


12a

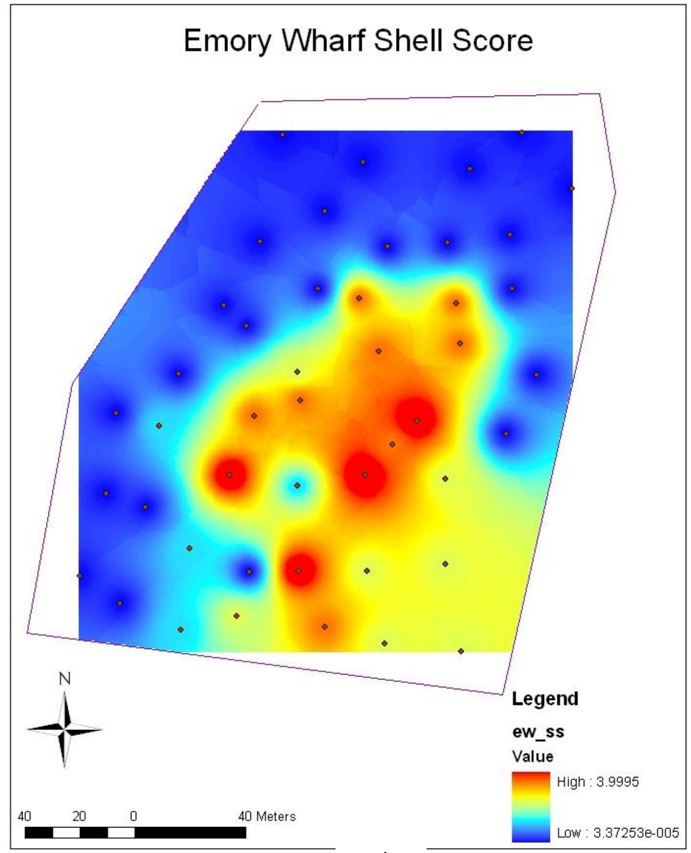


12b

Figure 12. Oyster density (12a) and shell score (12b) plots at Ulmstead Point, an oyster bar in the Magothy River. Areas of high oyster density also had high shell scores, however not all high shell scores yielded high oyster densities. Sixty-nine percent of the bar had oyster densities greater than 5oy/m^2 and 80% of the bar had shell coverage, indicating that not all areas with shell had oysters present.

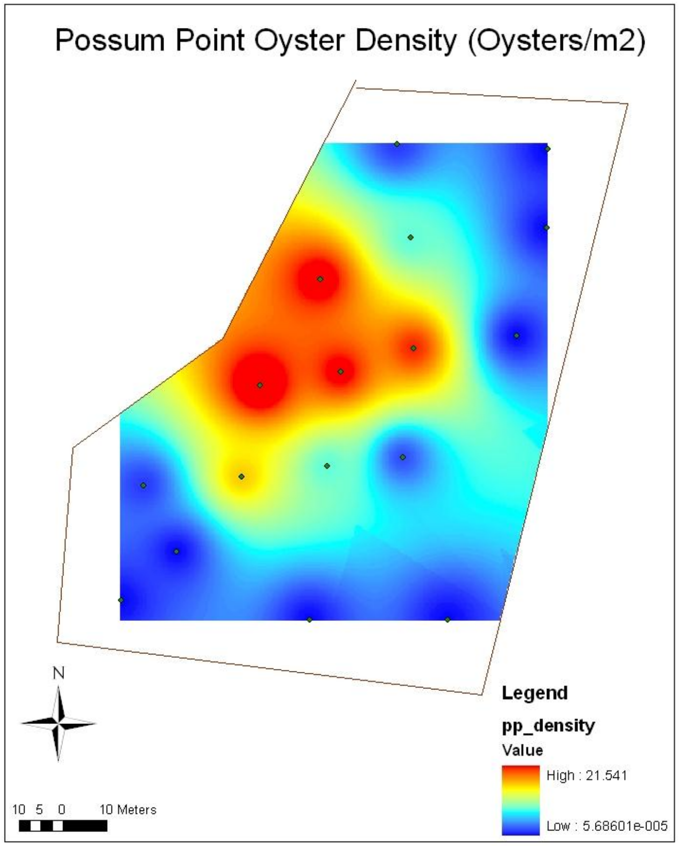


13a

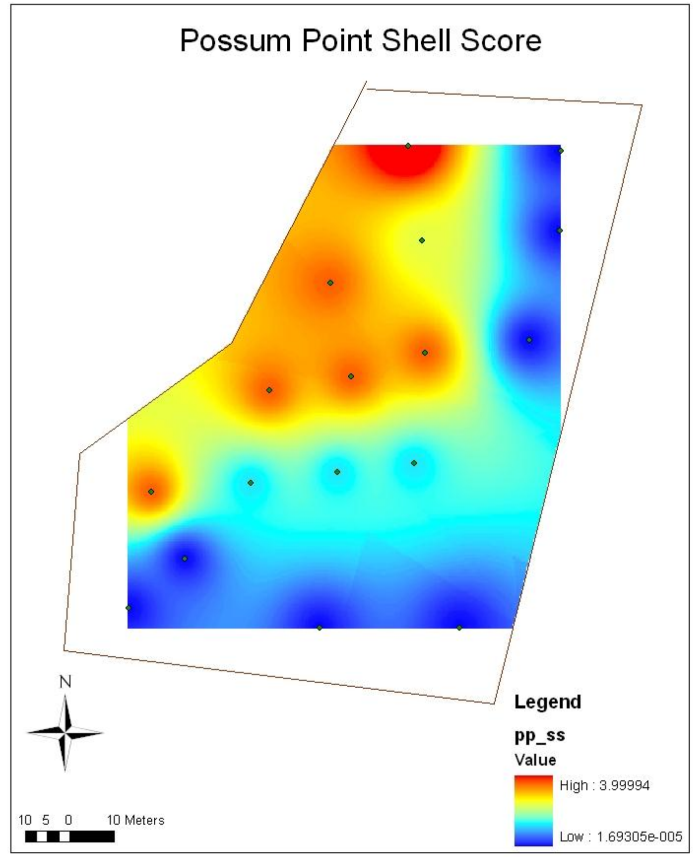


13b

Figure 13. Oyster density (13a) and shell score (13b) plots at Emory Wharf, an oyster bar in the Chester River. Areas of high oyster density also had high shell scores, however not all high shell scores yielded high oyster densities. Eleven percent of the bar had oyster densities greater than 5oy/m^2 while 49% of the bar had shell coverage, indicating that not all areas with shell had oysters present.



14a



14b

Figure 14. Oyster density (14a) and shell score (14b) plots at Possum Point, an oyster bar in the Chester River. Areas of high oyster density also had high shell scores, however not all high shell scores yielded high oyster densities. Shell score and oyster densities greater than 5 oysters/m^2 were similar in amount and location at this bar, with 62% of the bar having oyster densities greater than 5 oysters/m^2 and 70% of the bar having shell coverage. However, the small size of this bar (2.1 acres) may influence the high continuity of these measurements.

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 2010 was 5oy/m^2, but only 23% of the area surveyed achieved greater than that density. Fifty-seven percent of the area surveyed had any shell coverage, again indicating that shell coverage is greater than oyster coverage on the bars sampled. Considering that just over 50% of the area surveyed had any shell, we suggest that future patent tong sampling be limited to areas where shell has been found in the past. This will reduced the area necessary to sample by about half, allowing for a greater number of bars to be sampled in the future. A more quantitative method of determining the amount of shell on each bar will be developed in 2011 to more accurately estimate shell coverage. 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.

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 IV.

SECTION IV

Paynter Lab Intensive Oyster Bar Long-Term Patent Tong Monitoring
2007-2010

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 four consecutive years (2007-2010). These bars, their location, harvest status and planting dates are outlined in Table 1 below.

Table 1. Oyster bars targeted for long-term monitoring.

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

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 2008-2010. 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 2008-2010. Results for individual sites are presented below.

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. 1). The biomass of oysters at Coppers Hill was also reflective of the planting and growth activities at the bar from 2007-2010 (Fig. 2). 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 1 and 2 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. 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.

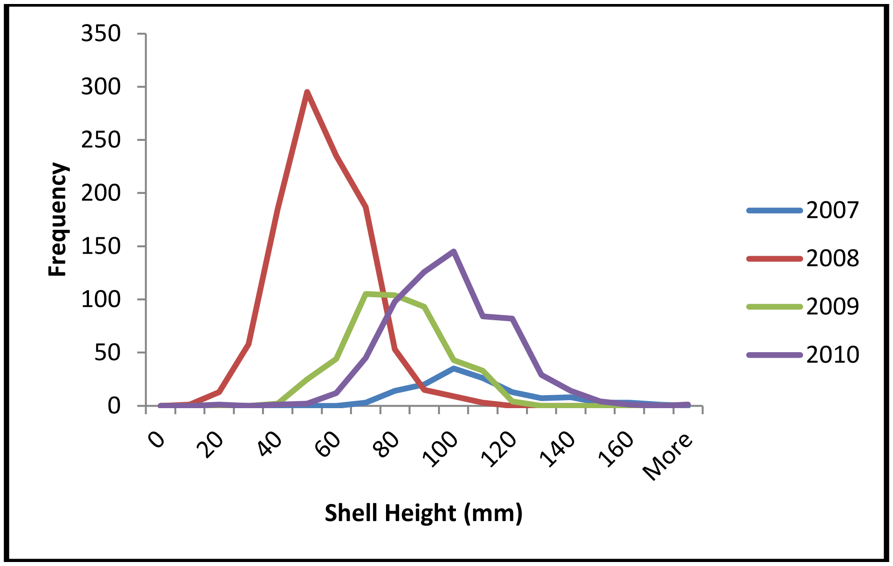


Figure 1. Size frequency of oysters sampled at Coppers Hill during 2007-2010 patent tong surveys. Coppers Hill was planted in 2007 (after patent tong survey) and 2008. The size frequencies indicate the patent tong survey detected the size distribution and relative amounts of oysters on Coppers Hill before and after planting.

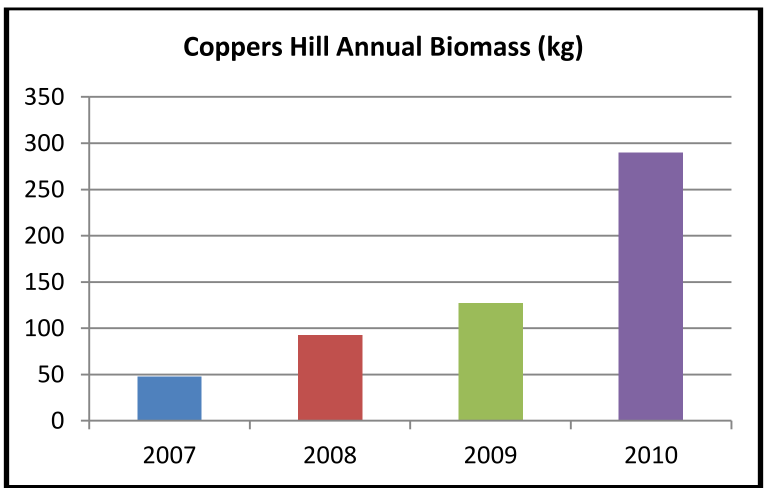


Figure 2. Biomass of oysters at Coppers Hill during 2007-2010 patent tong surveys. The biomass of oysters at Coppers Hill was consistent with the size distribution of oysters in each year.

The survey statistics for Coppers Hill are presented in Table 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.

Table 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)
2007	102	86	28	25	1	29,696	48
2008	51	803	57	7	13	277,279	93
2009	77	462	8	2	7	159,530	128
2010	94	626	19	3	9	216,160	290

The density plots for Coppers Hill are presented in Figure 2 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. 2a). In contrast, in 2009 oyster density reached a maximum of 62 oysters/m^2, mostly concentrated in the southern half of the planting (Fig. 2b). 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).

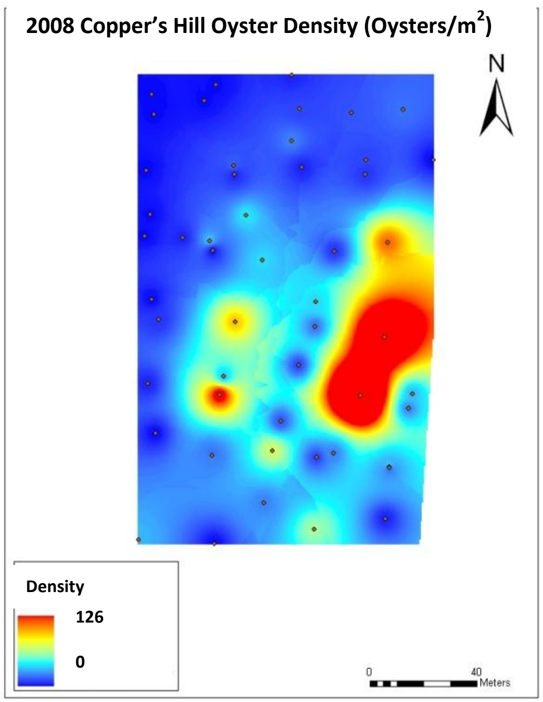


Figure 3a.

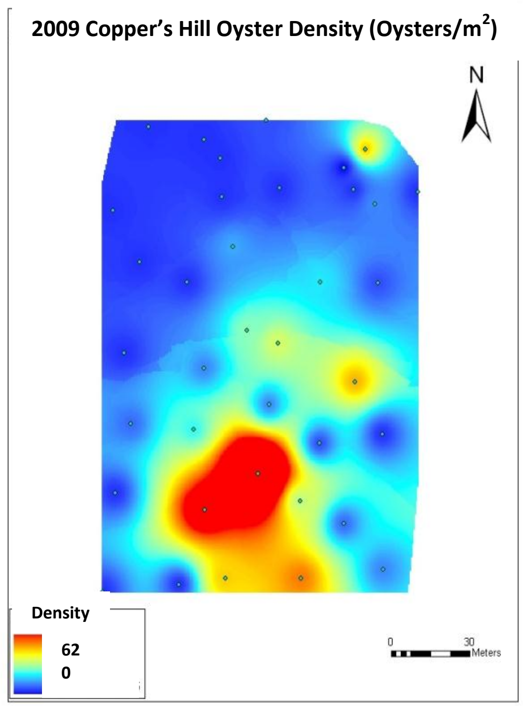


Figure 3b.

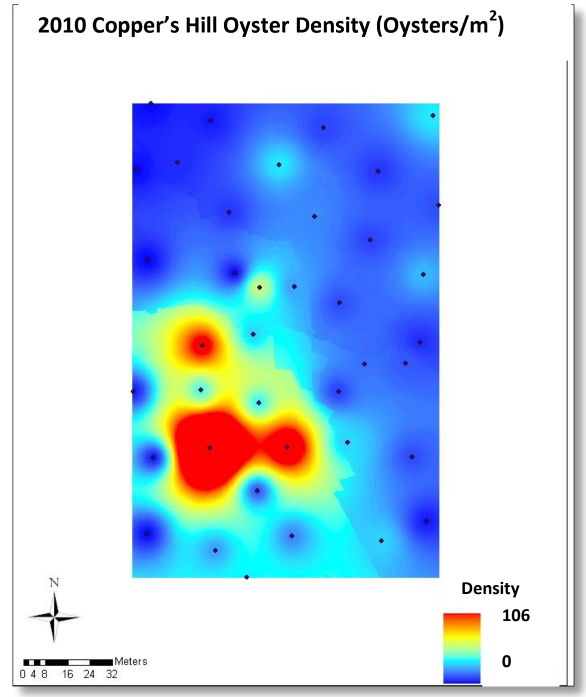


Figure 3c.

Figure 3. Coppers Hill oyster density plots from 2008 (3a), 2009 (3b) and 2010 (3c) patent tong surveys. 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 density of oysters from 2009 to 2010 (106 oysters/m^2) indicates the bar was relatively undisturbed between the 2009 and 2010 surveys.

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. 4). 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. 5). 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, biomass increased slightly, as surviving oysters continued to grow.

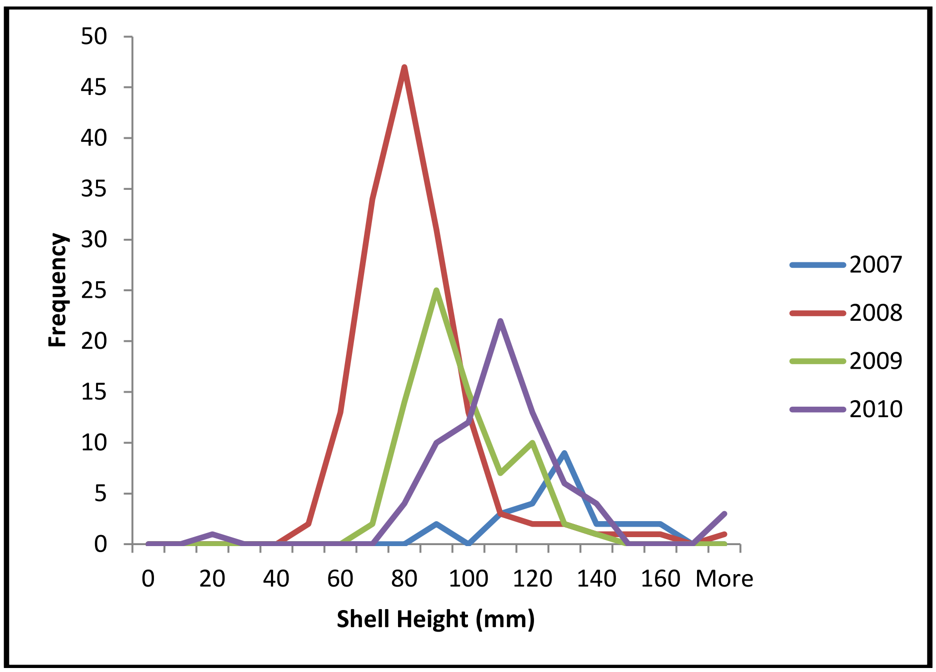


Figure 4. Size frequency of oysters sampled at Drum Point during 2007-2010 patent tong surveys. Drum Point was planted in 2007 (after patent tong survey). The size frequencies indicate the patent tong survey detected the size distribution and relative amounts of oysters on Drum Point before and after planting.

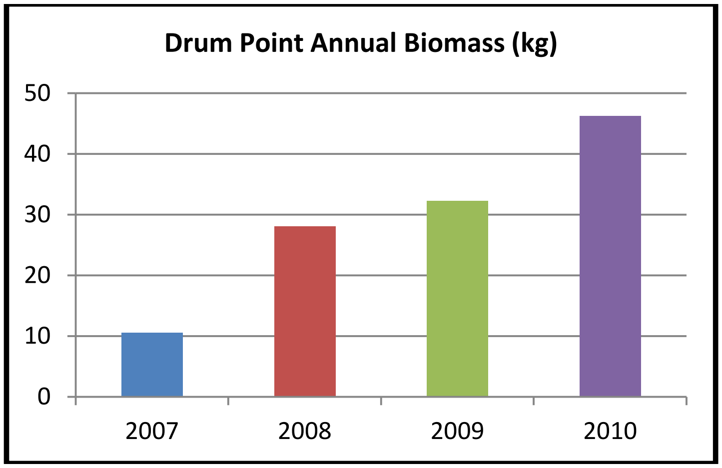


Figure 5. Biomass of oysters at Drum Point during 2007-2010 patent tong surveys. The biomass of oysters at Drum Point was consistent with the size distribution of oysters in each year.

The survey statistics for Drum Point are presented in Table 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. 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. We believe these increases are reflective of the natural variability present in the system as it reaches a sustainable post-planting population.

Table 3. Patent tong survey statistics for Drum Point.

Sampling Year	Mean Shell Height (mm)	Live Count	Box Count	Box Count (% of Live)	Mean Density (oysters/m^2)	Population Abundance	Biomass Sum (kg)
2007	123	13	8	38	<1	4,316	11
2008	80	97	7	7	1	33,494	28
2009	92	26	2	7	<1	8,978	32
2010	107	73	2	3	1	25,207	46

The density plots for Drum Point are presented in Figure 6 below. Oyster density in 2008 reached 12 oysters/m^2, mostly concentrated in the north and eastern portion of the planting (Fig. 6a). In contrast, in 2009 oyster density reached a maximum of 6 oysters/m^2, spread throughout the planting (Fig. 6b). 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.

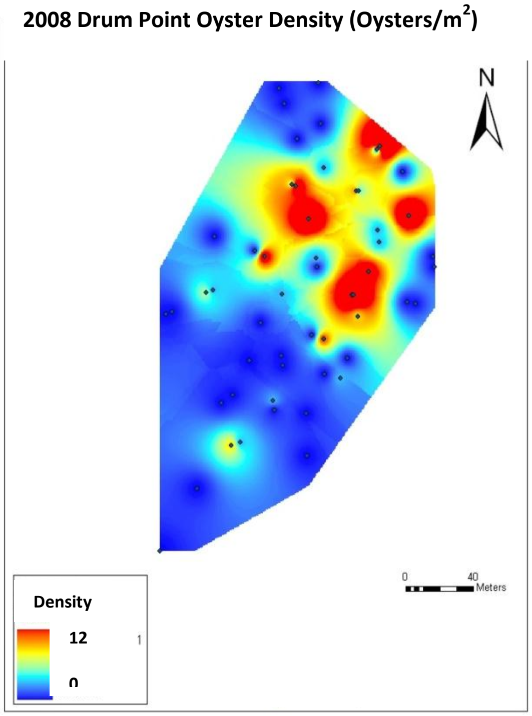


Figure 6a.

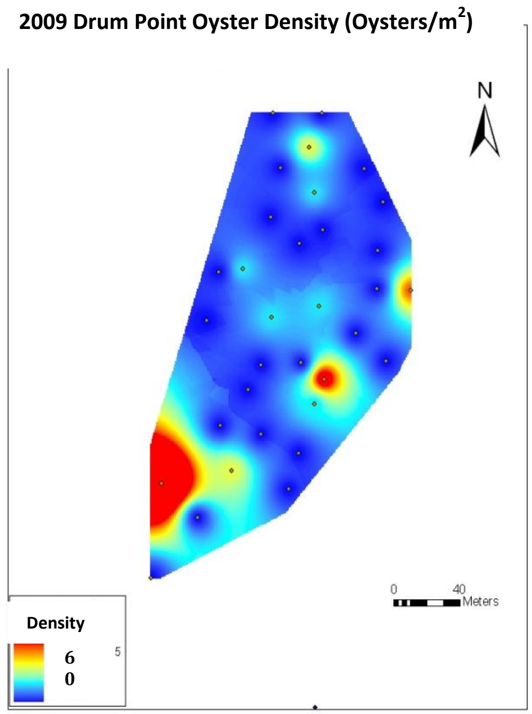


Figure 6b.

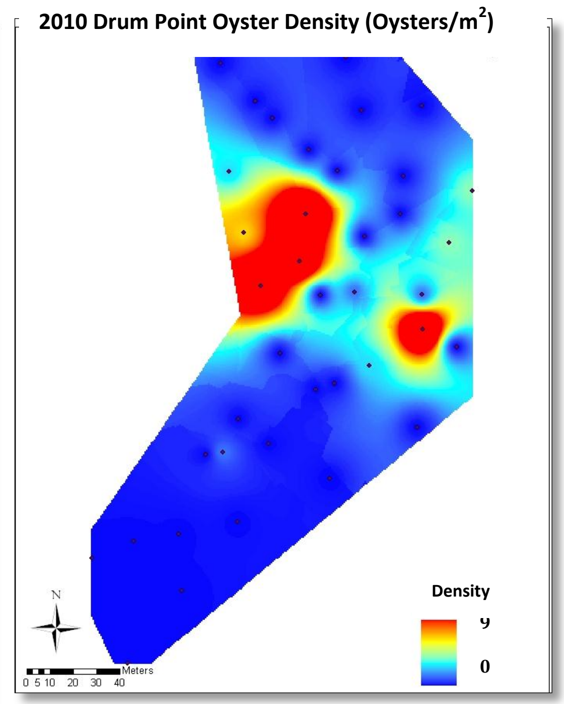


Figure 6c.

Figure 6. Drum Point oyster density plots from 2008 (6a), 2009 (6b) and 2010 (6c) patent tong surveys. 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 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.

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. 7). This pattern of size distributions indicates significant mortality post planting combined with growth of the surviving oysters. 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. 8). 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.

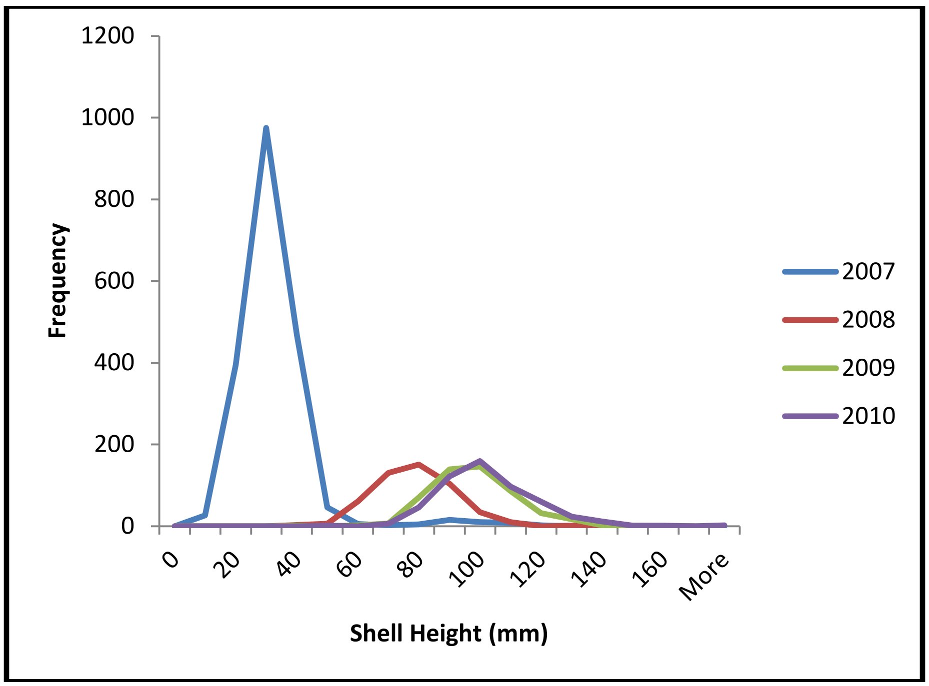


Figure 7. Size frequency of oysters sampled at Ulmstead Point during 2007-2010 patent tong surveys. Ulmstead Point was planted in 2006. The size frequencies indicate the patent tong survey detected significant mortality paired with growth of the surviving oysters and also adequately represented the size distribution and relative amounts of oysters on Ulmstead Point after planting.

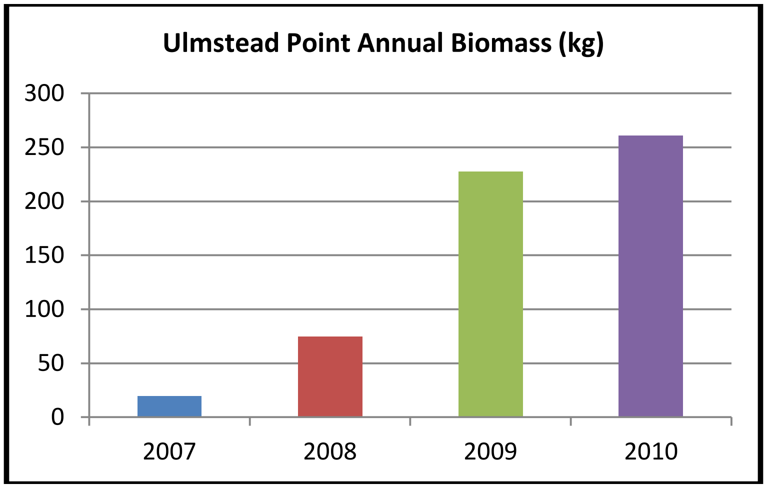


Figure 8. Biomass of oysters at Ulmstead Point during 2007-2010 patent tong surveys. The biomass of oysters at Ulmstead Point is consistent with the size distribution of oysters in each year.

The survey statistics for Ulmstead Point are presented in Table 4 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 2008-2010. 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.

Table 4. Patent tong survey statistics for Ulmstead Point.

Sampling Year	Mean Shell Height (mm)	Live Count	Box Count	Box Count (% of Live)	Mean Density (oysters/m^2)	Population Abundance	Biomass Sum (kg)
2007	27	625	161	20	20	225,138	19
2008	75	281	19	6	10	96,858	75
2009	94	512	1	0.2	19	176,796	228
2010	98	518	10	2	15	178, 867	261

The density plots for Ulmstead Point are presented in Figure 9 below. Oyster density in 2008 reached 50 oysters/m^2, spread throughout the planting (Fig. 9a). In 2009 oyster density reached a maximum of 80 oysters/m^2, also spread throughout the planting (Fig. 9b). Finally, 2010 oyster density reached a maximum of 94 oysters/m^2 consistently spread throughout the planting. The consistency in the density and spatial distribution of oysters on this sanctuary may be evidence of the undisturbed nature of this bar.

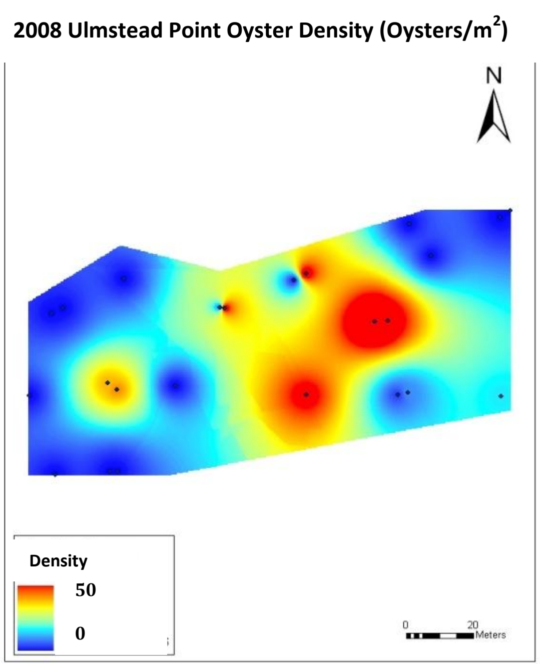


Figure 9a.

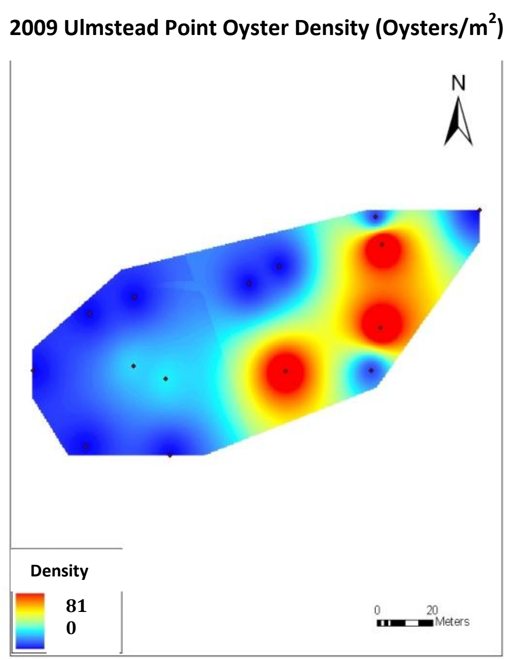


Figure 9b.

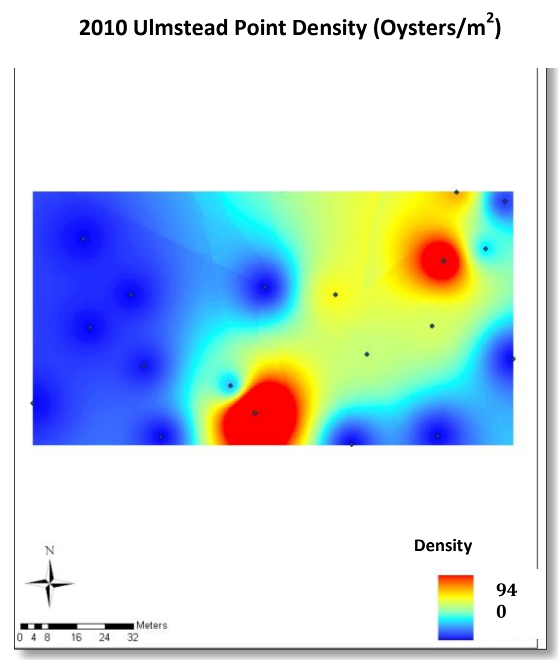


Figure 9c.

Figure 9. Ulmstead Point oyster density plots from 2008 (9a), 2009 (9b) and 2010 (9c) patent tong surveys. Oyster density and location remained consistent between 2008-2010, with density increasing slightly from year to year: 2008 (50 oysters/m^2), 2009 (oysters/m^2), and 2010 (94 oysters/m^2). The consistency in density and location of oyster from 2008 through 2010 may be indicative of the undisturbed nature of this 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. 7). This pattern of size distributions indicates high survival from year two to year three post-planting and also points to significant growth between years.

Biomass data at Willow Bottom complements the size frequency data. Figure 11 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 5).

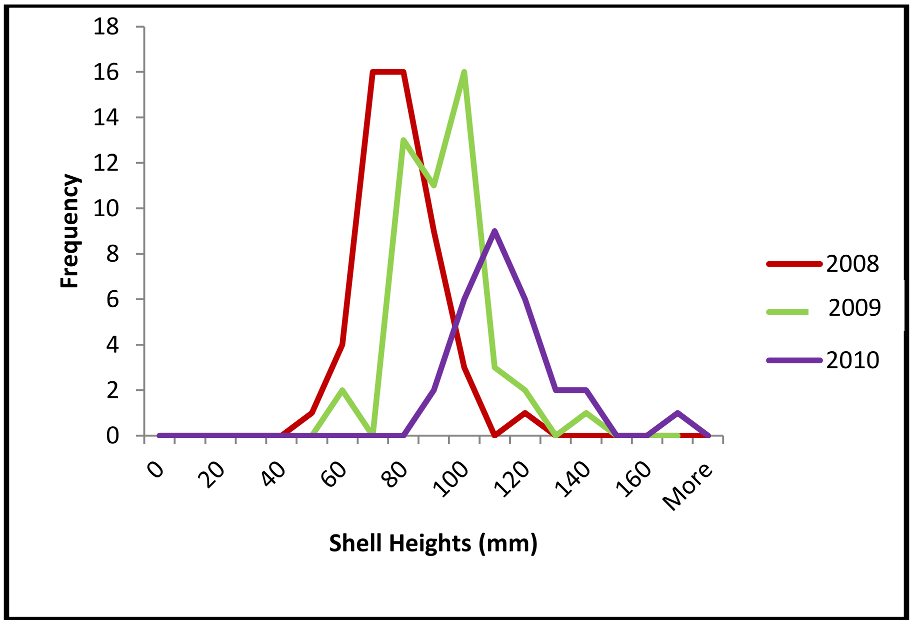


Figure 10. Size frequency of oysters sampled at Willow Bottom during 2007-2010 patent tong surveys. Willow Bottom was planted in 2007 after the patent tong survey and no oysters were found during the survey that year. The size frequencies indicate high survival from year two to year three post-planting and significant growth between all years at Willow Bottom.

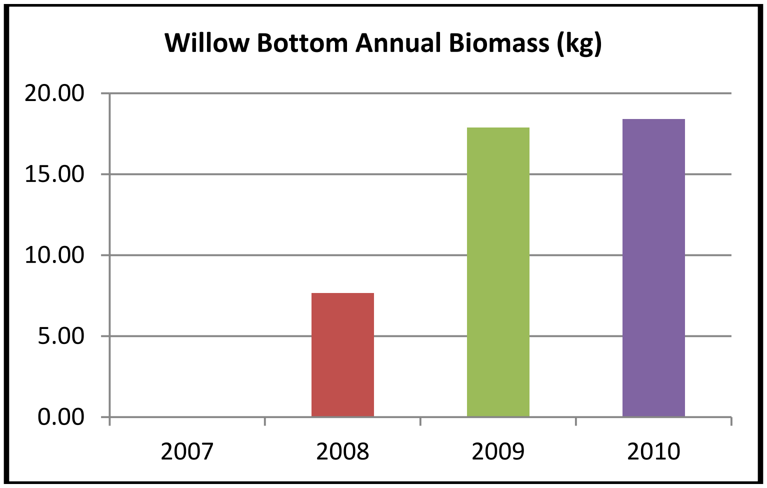


Figure 11. Biomass of oysters at Willow Bottom during 2007-2010 patent tong surveys. The biomass of oysters at Willow Bottom is consistent with the size distribution of oysters in each year.

The survey statistics for Willow Bottom are presented in Table 5 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. 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.

Table 5. Patent tong survey statistics for Willow Bottom.

Sampling Year	Mean Shell Height (mm)	Live Count	Box Count	Box Count (% of Live)	Mean Density (oysters/m^2)	Population Abundance	Biomass Sum (kg)
2007	N/A	0	0	N/A	0	0	0
2008	74	16	0	0	<1	5,352	8
2009	87	47	1	2	<1	16,229	18
2010	110	28	0	0	<1	9,668	18

The density plots for Willow Bottom are presented in Figure 12 below. Maximum oyster density was low in all years (4 oysters/m^2 in 2008, 8 oysters/m^2 in 2009, and 9 oysters/m^2 in 2010). Spatially, oysters were spread throughout the planting in 2008 and concentrated to the eastern half in 2009 and 2010. 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.

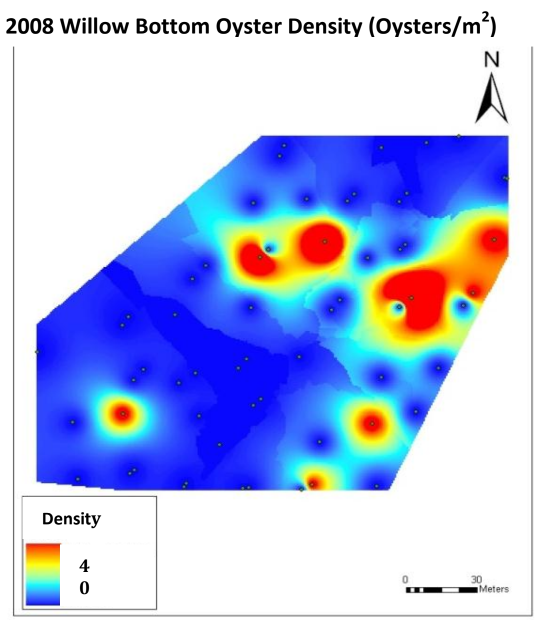


Figure 12a.

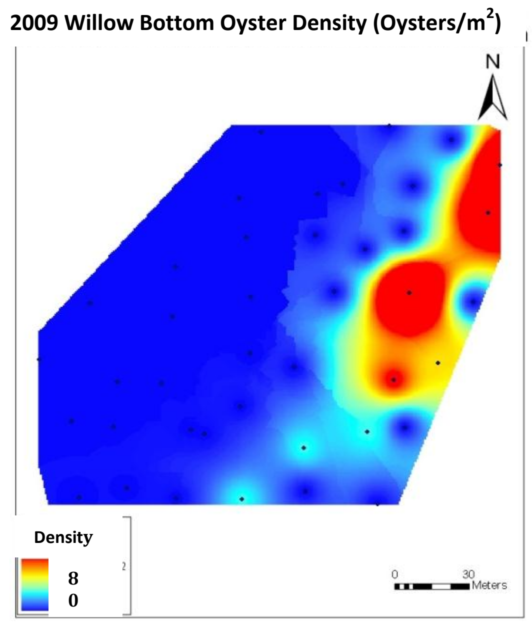


Figure 12b.

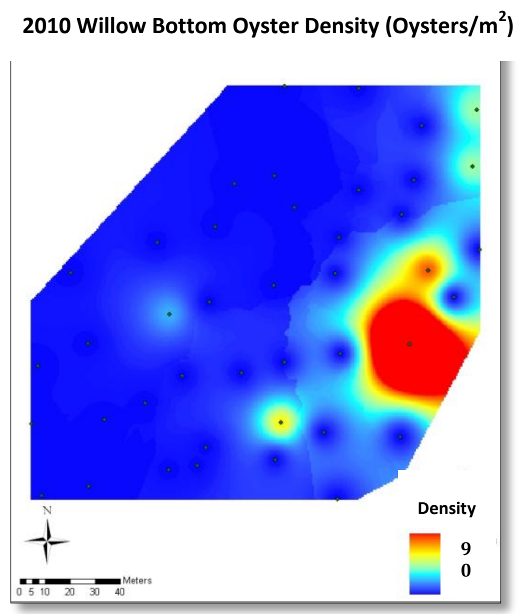


Figure 12c.

Figure 12. Willow Bottom oyster density plots from 2008 (12a), 2009 (12b), 2010 (12c) patent tong surveys. Oyster density was low throughout 2008 to 2010 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.

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 13 below).

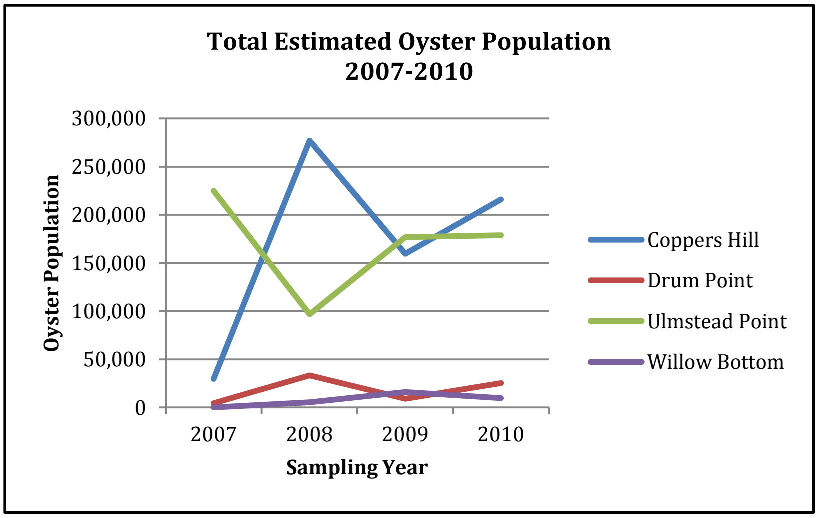


Figure 13. Oyster population at each bar sampled by sampling year. Although a large amount of variability exists in the population estimates, the bars sampled generally declined after the first year of sampling post-planting and then remained relatively consistent in the years following.

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 14 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 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.

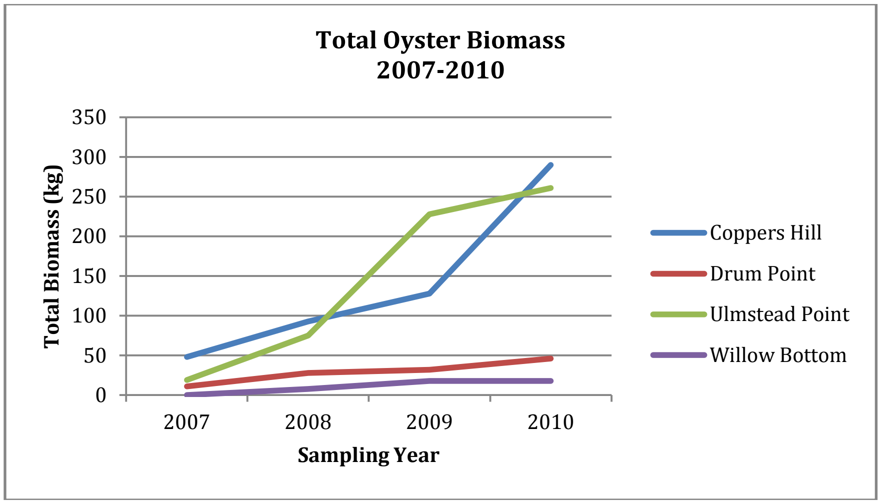


Figure 14. Total oyster biomass (in kg) at each bar sampled by sampling year. Biomass increased at each bar through time, despite a drop in average oyster size, emphasizing the influence that oyster size has on biomass at each bar sampled.

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. Although these data 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.

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 V

Paynter Lab Lessons Learned 2010

Ground Truthing

In general, areas of hard side scan return were confirmed to be hard bottom by divers. This result underscores the importance of having side scan data available prior to conducting GT surveys, as it makes the survey more efficient. 2010 was the first year in which side scan data were available for many GT sites and our results indicate that this process should continue into the future. The cooperation of MGS and NCBO was critical in this endeavor, and their participation was much appreciated. Our GT data provided confirmation of existing bottom conditions and these data are currently being analyzed with the help of MGS to understand the precision of the side scan sonar in determining bottom type. We hope to continue this analysis into the future. Our goal should be to confidently use side scan sonar to predict bottom quality without the need for diver confirmation.

Perkinsus marinus Infection

Mean *Perkinsus marinus* (Dermo) prevalence and intensity were low in 2010, and not significantly different from values reported for 2008 and 2009. These findings indicated that dermo was not a large factor in oyster mortality in the northern Chesapeake Bay, although sub-lethal infection rates may play a role in declines in the ecosystem services provided by those infected oysters, such as a decline in fecundity or filtration rates. A few exceptions existed at Spaniards Point (a weighted prevalence of 1.23), in the Chester River and Bolingbroke Sands (a weighted prevalence of 1.3), in the Choptank River. These populations should be exhaustively harvested.

Post Planting Monitoring

Conclusions:

The 2010 planting season involved several changes in an attempt to achieve greater survival success and more relevant data. First, the planting approach differed from previous years, as fewer bars were planted overall, but were over-planted by multiple trips to each bar. Additionally, while not a highly controllable factor, the number of initial spat per shell was lower in 2010 than previous years. Neither of these differences appeared to have had a drastic impact on spat survival, as the overall 2010 spat survival was consistent with 2008 and 2009.

Using the data collected in post-planting monitoring surveys, the relationship between initial spat per shell and spat survival were compared, yielding no significant trend for 2010. This was similar to data from 2008, however 2009 data showed a negative correlation between initial spat per shell and survival. Additional post-planting monitoring surveys in 2011 could help identify the relationship seen in 2009 as an anomaly or possible trend.

In an effort to more closely examine the relationship between initial spat planted and post-planting survival, surveys were conducted using a standard sample area (a $1m^2$ quadrat). This allowed for a stronger comparison of initial spat density over a specific area. Using this approach, 2010 data again showed no relationship among initial spat density and post-planting spat survival. As mentioned above, although a range of shell density sample sets were targeted, this was not achieved at most sites. It is recommended that quadrat-based sampling is continued in 2011 surveys, possibly with greater focus on high-density areas within bars to create the desired density range. This can also be enhanced through continued over-planting as was done in 2010.

Recommendations:

Identifying the factors influencing spat survival in the Chesapeake Bay is critical to the restoration of oysters in Maryland. Students and staff of the Paynter Lab have identified four main factors thought to influence spat survival: environmental variation, spat density, predation and spat size upon planting. Although environmental variation may have a large impact on spat survival, our lab would like to focus on factors whose impact could be reduced by manipulating current restoration techniques.

Spat Density

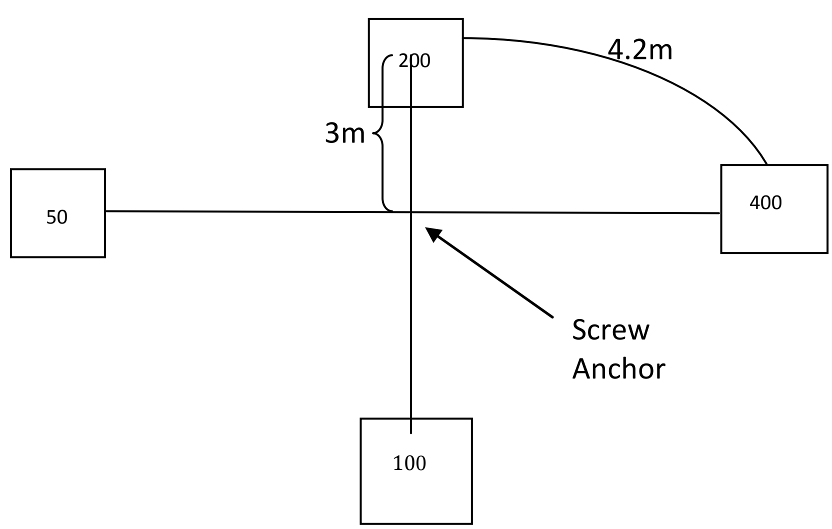
The density of spat on a given planting may affect spat survival. We propose to examine the effect of spat density on survival at both the experimental and bar-levels.

Bar-Level Density Experiment:

In 2010, the effect of spat density on survival was examined opportunistically on planted bars throughout the Chesapeake Bay (see 2010 PPM report for results). At each bar, divers attempted to collect six total quads—three at a "high density" area and three "low density". High and low density sites within a bar were selected based on the density of planting boat track lines at each bar. Although the data from this preliminary experiment indicate that spat density does not impact spat survival, we would like to repeat this experiment in 2011 to confirm these results. Quads will be used to collect spat at six locations on each planting in 2011 to continue to explore the relationship between spat density and survival at the bar level.

Experimental-Level Density Experiment:

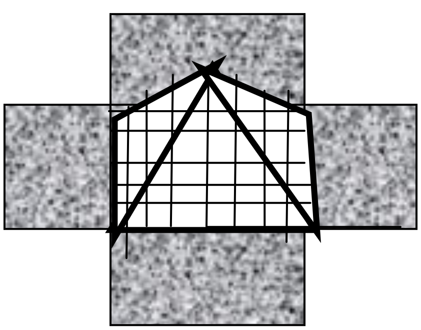
A main complication of the bar-level experiment was the lack of range of densities of spat that occurred post planting (0-100 spat/m^2). Considering this lack of density range, we would also like to conduct a density experiment in which spat densities are manipulated at a small scale. In August of 2011, spat on shell will be obtained from the Horn Point Laboratory oyster hatchery in Cambridge, Maryland. The initial number and size of spat on shell will be provided by the hatchery. Shells will be placed in 1m^2 quadrats deployed on the shell bed at densities of 50, 100, 200 and 400 shells per square meter on Glebe Bay oyster bar in the South River. Three replicates of each density will be deployed, totaling 12 quadrats on the bottom. One quadrat of each density will be kept in a flow-through tank at the Horn Point Laboratory oyster hatchery to serve as controls. Quadrats will be left on the bottom for 4-8 weeks, at which time the shells will be collected and spat on shell number and size will be measured and compared between densities. Below is a schematic of one replicate (of three) of the experimental design.

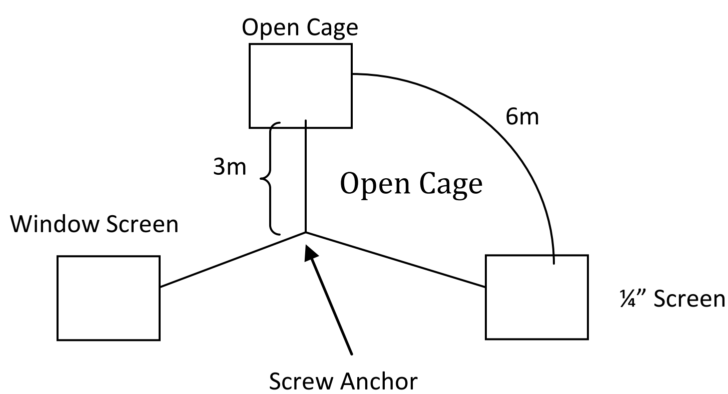


Predation

Many predators of spat exist in the Chesapeake Bay, but the direct affects of predation on spat survival in Maryland are not well understood. In 2010, an experiment was conducted in an attempt to quantify the affects of predation on spat survival. $1m^3$ cages were lined with either ¼ inch screening, 1/8 inch screening, window screening or were left open to exclude large predators, small predators, worms and no predators, respectively. About 20 shells with varying numbers of spat on shell were placed inside each cage and cages were deployed in Glebe Bay for 2 weeks in June of 2010. 20 shells were placed in the live well of the Paynter Lab boat as a control. Data from this first deployment was not analyzed due to many confounding factors in the experimental deployment and design. Primarily, the deployment and retrieval of the cages caused significant tearing the ¼ inch mesh, eliminating the smallest mesh size from the design. Also, no predators were captured upon retrieval of the cages, limiting the ability to determine the type and number of predators in each treatment. Finally, mud crabs were found in the live well when shells were removed, eliminating the control from the experiment. We propose to conduct a more streamlined experiment in 2011 (see below).

Spat on shell will be obtained from the Horn Point Laboratory oyster hatchery after a one to two week nursery period. This will allow for the identification of spat on shell with the naked eye and consistency in the number of spat in each cage upon deployment. In order to confirm the absence of a cage effect, three cages and three open cages will be deployed on the target bar (Green Marsh oyster bar in the Choptank River) for one full field day. In addition, a control will be maintained at the Horn Point Laboratory oyster hatchery using flow-through water from the Choptank River. Three treatments will be created out of $1m^2$ cages: open cage (total predation exposure), ¼ inch screening compartment (small predator exposure) and 1 mm aluminum mesh window screening compartment (worm predation exposure). Each treatment will be replicated four times, for a total of 12 cages. Cages will be loaded with a consistent number and density of shells and spat (15-25 shells with 70-100 spat per cage). Cages will be designed to allow for the predators inside each cage to be captured when cages are retrieved. To account for the need to secure spat to the cage frame in the "open" treatment, all shells will be attached to each cage by monofilament wire and glue. A sub-sample of shells will be kept at the hatchery to serve as a control. Cages will be deployed during July 2011 for two weeks. Spat size and number as well as predator abundance and diversity will be determined in each cage and compared to initial and control data. Below is a schematic of the cage design and experimental deployment (one of four replicates).





Spat Size

In 2009, a spat survival experiment was performed at Sandy Hill oyster Bar in the Choptank River, which showed that spat survival (as measured by number of spat per shell and spat shell height) was independent of planting size and substrate type. However, this experiment had several confounding factors and we would like to perform a similar study in a more complete fashion. Three separate plantings of both hatchery and nursery spat on shell should be conducted within two weeks of each other, again at Sandy Hill or a bar in close proximity, in June of 2011. In order to understand the effects of spat size on survival over time, we would like to measure spat number and size according to the following schedule:

Day #	Spat Type	Time	Amount of Shell Collected
1	Hatchery	Before shell is loaded onto planting boat	50 from hatchery tank
	Nursery		50 from nursery tank
1	Hatchery	Before planting	50 from planting boat
	Nursery		
1	Hatchery	1 hr post-planting	50 from planted area
	Nursery		
2-7	Hatchery	Any	50 from planted area
	Nursery		
14	Hatchery	Any	50 from planted area
	Nursery		
45	Hatchery	Any	50 from planted area
	Nursery		

We believe that the data provided by the previous three experiments will allow for a greater understanding of the factors affecting spat survival in the Chesapeake Bay and will provide guidelines for more efficient restoration in the future.

Patent Tonging

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, 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. Unsurprisingly, bars with high populations also had high oyster biomass. Mean oyster density in 2010 was 5oy/m^2, but only 23% of the area surveyed achieved greater than that density. Fifty-seven percent of the area surveyed had any shell coverage, again indicating that shell coverage is greater than oyster coverage on the bars sampled. Considering that just over 50% of the area surveyed had any shell, we suggest that future patent tong sampling be limited to areas where shell has been found in the past. This will reduced the area necessary to sample by about half, allowing for a greater number of bars to be sampled in the future. A more quantitative method of determining the amount of shell on each bar will be developed in 2011 to more accurately estimate shell coverage. 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.

The long term patent tong data for these four sites indicated that patent tongs were 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. Biomass data complemented the size frequency data, emphasizing at all four bars the influence that oyster size had on biomass relative to population size. At each bar, drops in population abundance were offset by an increase in 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 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 indicated a leveling-off of oyster density and distribution three to four years post planting.

On oyster bars with low oyster densities (and therefore 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. Although these data were generally capturing the nature of undisturbed oyster bars to equalize their oyster densities, populations, and spatial distributions over time post-planting, it was important to survey small bars such as these at the fine scale currently being sampled by the Paynter Lab in order to accurately portray oyster population dynamics on these bars.

Overall Summary

Due to the complexities of the Chesapeake Bay ecosystem, successful restoration requires the hard work and collaboration of many people and agencies. The oyster restoration program in Maryland relies on accurate data on the location, density and health of Maryland oysters to make informed management decisions. The successful collaboration of the Paynter Lab, the Maryland Geological Survey and NOAA's Chesapeake Bay Office to synthesize existing side scan sonar images with data on the true topography of the bay (as collected by diver observation) is the first step in the restoration process. This synthesis will not only make the determination of future restoration sites more efficient, it will also allow for quantification of the available bottom for future restoration efforts in Maryland.

Understanding the population dynamics of the existing oyster populations in Maryland is the next step in making informed restoration decisions in the future. Systematic patent tong surveys of managed reserve and sanctuary bars in 2010 have revealed low oyster densities across most bars, with only 23% of bar acreage having densities over 5oy/m^2. Shell coverage was better than oyster coverage across bars, with 57% of the area surveyed by patent tongs having shell coverage. However, this percentage only seems high compared to the low amount of oyster coverage on restored bars in Maryland. In order to achieve self-sustaining oyster populations through restoration efforts, the amount of shell coverage and oyster densities must be increased.

Another obstacle to the success of restoration is post-planting spat mortality. Post-planting monitoring data revealed low spat survival (13% survival in 2010), which was consistent with data from 2008 and 2009 (17% and 12% survival, respectively). Spat survival in 2010 was also highly variable (0.4 – 34% survival) and no pattern could be discerned from the data to help conclude the source of the variation observed in survival. Although we are still in the process of understanding the dynamics of post-planting oyster populations, we believe that an increase in the amount and density of spat planted combined with the increase in shell coverage mentioned above may help to increase survival. We would like to examine the effects of predation, spat density and spat size on post-planting spat survival in detail during the 2011 planting season.