**National Fish and Wildlife Foundation**
**Final Programmatic Report**

**Project Name and Number:** Broadkill River Oyster Gardening and Stock Enhancement Demonstration Project (DE) #2006-0101

**Recipient Organization/Agency:** University of Delaware Sea Grant Program

**Recipient Organization Web Address**: http://www.ocean.udel.edu/seagrant/

**Date Submitted:** March 30, 2009

## 1) Summary of Accomplishments

The project had three components: hydrographic and bottom survey of the Oyster Rocks area in the lower Broadkill River; oyster gardening to involve watershed residents and supplement nursery culture of hatchery produced oysters ; and pilot scale oyster restoration. 1) In order to determine whether this region is suitable for oysters and oyster gardening and delimit boundaries, we undertook both hydrographic and bottom mapping surveys in the Oyster Rocks region. 2) Five oyster gardening sites were established on Deep Creek a narrow tributary connecting to the Broadkill at the east side of the river behind the residential community of Broadkill Beach. 3) After obtaining the necessary state and federal permits, we established two sampling sites in the Oyster Rocks area and compared three oyster stock enhancement field methods at each site. Oyster plantings in both locations were disturbed in high energy environment created by wind, weather and tidal flow with the oysters from the individual plots dispersed. Among our recommendations, we note a significant natural recruitment observed at the entrance of the Broadkill River, and we conclude that a stock enhancement strategy to increase the amount of shell available for new recruitment in sub-tidal and intertidal areas is preferable to oyster gardening and field planting.

## 2) Project Activities & Results

The eastern oyster, *Crassostrea virginica*, has supported a historically, culturally, and economically important fishery in the Delaware Bay and throughout the Mid Atlantic region (Tweed and Epifanio 1988). Over the last century, this fishery has been in decline from a number of factors, including extensive harvesting, habitat loss, eutrophication, predators, and diseases. Research and restoration efforts have been undertaken as part of a management strategy to maintain and enhance this fishery in the region.

Live, productive oyster beds with recent “set” have been found in the tributaries of the lower Delaware Bay. As part of the June, 2005 “Day in the Life of the Broadkill River” survey effort, University of Delaware scientists J. Ewart and D. Miller collected oysters showing good growth and recent settlement at the bar known locally as Oyster Rocks, located (38° 48’ N, 75° 12’ W) about 4 km upstream from the river mouth at Roosevelt Inlet near Lewes, Delaware.

While these results are encouraging, the lower sections of the Broadkill River have not been surveyed to the extent needed to make a reliable estimate of the total available oyster habitat or to identify feasible gardening sites. In addition to an assessment of potential oyster habitat, we outlined additional project objectives (see table below) in order to identify field gardening sites and to demonstrate to potential of oyster gardening in the Broadkill River.

**Table 1. Logic Model submitted with project proposal**

| Evaluation Matrix | Activities → | Project Outputs → | Post-Project Outcomes → | Indicator → | Baseline → | Predicted Project Output → | Predicted Post-Project Outcome |
|---|---|---|---|---|---|---|---|
| Hydrographic and bottom survey | Identify reaches of suitable salinity and hard bottoms | Delimit regions of estuary suitable for oyster gardening and field planting<br><br>GIS map of hard bottom regions | Delimited regions for bottom classification and mapping<br><br>Hard bottom sites identified will be candidate sites for enhancement / restoration | Standard estuarine water column measurements, GPS locations<br><br>Acoustic bottom classification using RoxAnn, utility well-established in literature and local waters | Historic salinity data available, but too widely spaced for our purposes<br><br>Only 7 hard bottom sites near Oyster Rocks known, no information on extent or their presence in other stretches | Longitudinal transect plots of temperature, salinity and stratification<br><br>GIS maps of bottom type, and database framework for hydrographic and water column data | Water-column conditions and bottom sites suitable for oystering identified<br><br>Baseline characterization of lower river and estuarine reaches of Broadkill |
| Oyster Gardening (OG) | Train OG volunteers<br><br>Deploy Taylor Floats with seed oysters at volunteer oyster gardening sites | Nursery culture of hatchery oysters and micro-habitat for fish and invertebrates | Oyster growth to juvenile stage and colonization of shell by other species | # of volunteers recruited & trained<br><br># of OG sites developed<br><br># of oysters produced | 0% volunteers<br><br>0% OG sites<br><br>0% oysters | 10-15 volunteers<br><br>10 OG sites<br><br>5-6K juvenile oysters | OG capability established<br><br>additional OG sites pending<br><br>additional oysters for planting |
| Oyster Stock Enhancement & Restoration | Transfer juvenile oysters to field sites | Develop 5-6 locations with 1 K oysters & additional shell (cultch) | Monitor oyster growth mortality & recruitment | Quantity of oysters & volume of shell | 0 oysters planted<br><br>no field survey data | 5-6K oysters planted | 5-6 restoration sites stocked for field monitoring |

**Hydrographic and Bottom Survey**

Historical accounts by oystermen, our previous surveys (2005, described above), and past hydrographic studies (De Witt 1968, 1971) all suggest that the Oyster Rocks region of the Broadkill River should be suitable for oyster populations and favorable for stock enhancement projects. Two important habitat criteria are water column salinity during the summer spawning period and the presence of hard substrata for larval settlement and oyster growth. To determine whether this region is suitable for oysters and oyster gardening, we undertook both hydrographic and bottom mapping surveys in the Oyster Rocks region.

Temperature and salinity profiles throughout the lower Broadkill River were obtained using small boat transects along the river channel and hand-held conductivity meter and global position system units in the same way we had previously characterized salinity in 2006. Salinity profiles in the top 4-5 m were taken at 14-15 stations along the mid-channel of the river between the USCG Station near the river mouth and Hazzard Landing (approximately 6 km upstream, 1.5 km upstream of Oyster Rocks). Surveys were scheduled for summer (and spawning) season conditions in July 2008 for both high and low water at both spring and neap tide circumstances, a total of four separate surveys. This scheduling was intended to encompass the greatest range of salinity variations at potential oyster gardening sites during the likely oyster spawning interval.

Salinity profiles are plotted against distance upstream from the river mouth in Roosevelt Inlet in Figure 1. Upstream is to the left in these plots, and landmark locations are indicated in the bottom panel. Contour lines represent salinity, the top two plots are spring tides, the lower two neap tides and the middle two are high tides. As expected, salinity decreases upstream, and higher salinities are found in the Oyster Rocks regions on high tides (middle two plots). Salinities range from 28-30 at high tide to 15-20 at low tide in our survey. Since we expect these values to represent the widest range in salinities at Oyster Rocks, we conclude that salinity conditions in this region are suitable for oyster beds (Kennedy 1996).

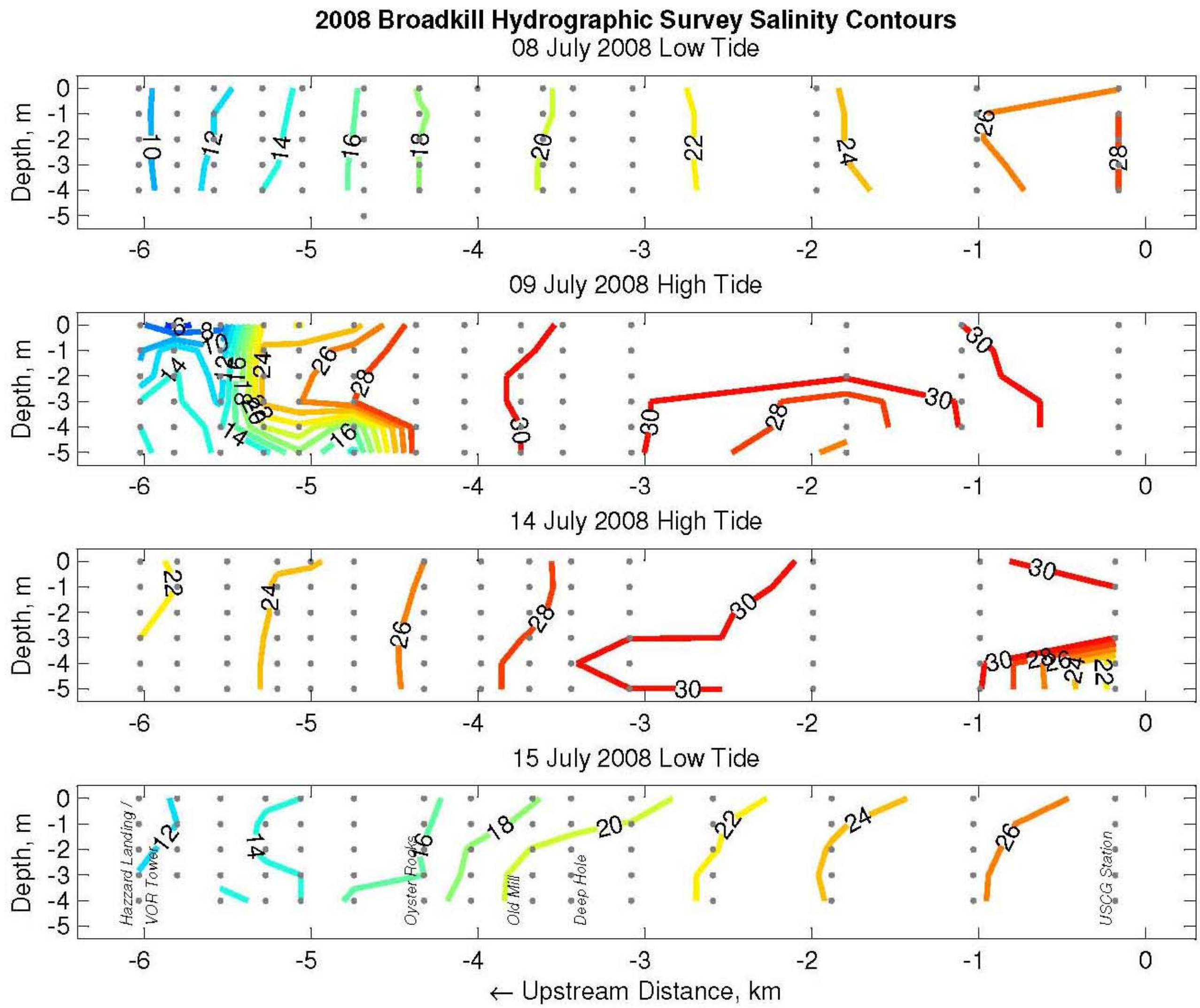


**Figure 1. Broadkill Salinity Contours**

Acoustic bottom classification was used to map presence of hard bottom in the Oyster Rocks region. A survey using a small boat and the commercial system RoxAnn (Chivers et al. 1990, Service 1998, Smith and Greenhawk 1998, Hamilton et al. 1999) provided by the Delaware Bay Benthic Mapping Project was conducted on 12/1/07. Acoustic signals are sent from a gunnel-mounted (Figure 2) transducer, and the return signal was analyzed for hardness and roughness in real time and mapped on a laptop display. The cruise track deliberately crisscrossed and remapped section of the river bottom to give as complete a picture as possible of the bottom in the channel as well as near the channel sides. When a change in bottom type was seen, a grab sample (Figure 3) was taken to ground truth the acoustic map. In total, thirteen grab samples were taken and immediately characterized in the same scheme used by the Delaware Bay Benthic Mapping Project http://www.swc.dnrec.delaware.gov/coastal/Pages/BenthicMapping.asp

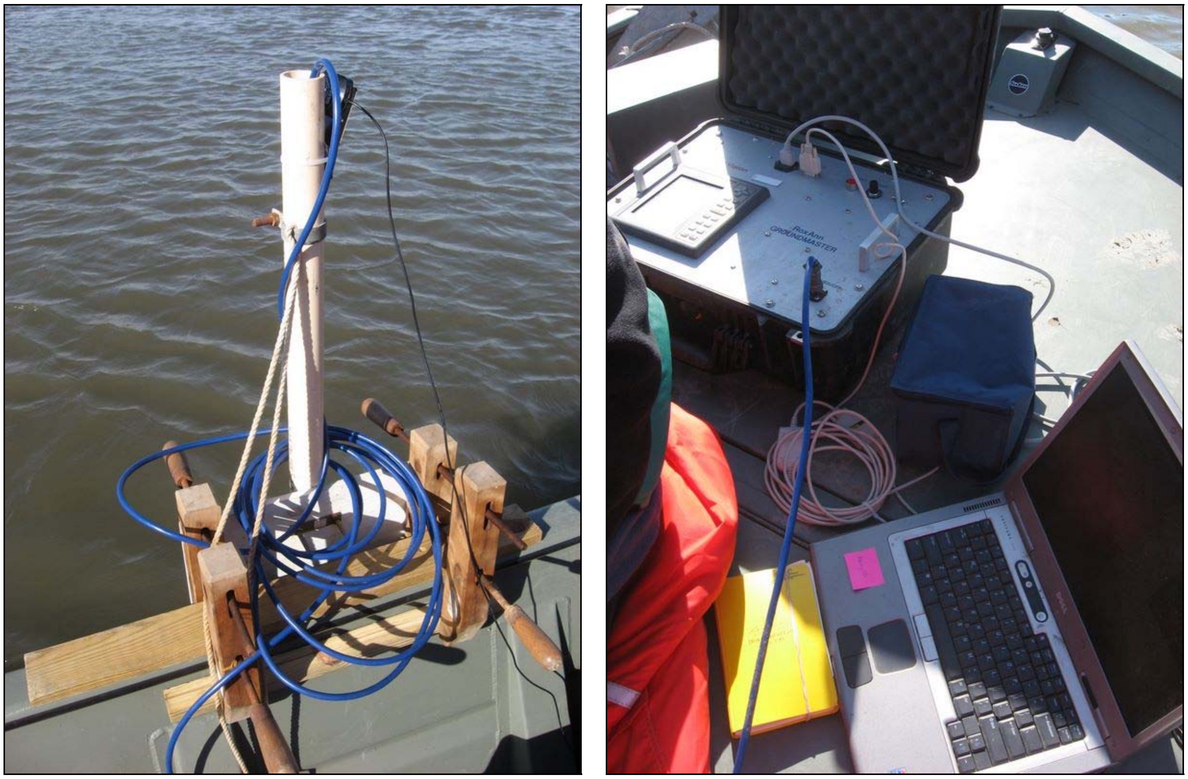

**Figure 2. Transponder apparatus and tracking system**

**Figure 3. Transponder and benthic grab used to verify sediment characteristics**

RoxAnn acoustic data were subsequently analyzed using the same classification used for mapping Delaware Bay areas including its oyster beds (e.g., off Port Mahon). The results of our survey were imported into a GIS system and color-coded by bottom type (Figures 4 and 5). The survey extended from downstream of Deep Creek (at right) upstream to Hazzard Landing (at left, the VOR tower landmark is also visible). The hatched areas are classified as hard bottom as shell or oyster beds, and this figure show that extensive areas on the main channel of the river are of this bottom type both upstream and downstream, of Oyster Rocks, indicated by the access road and boat ramp at the center-bottom of the figure.

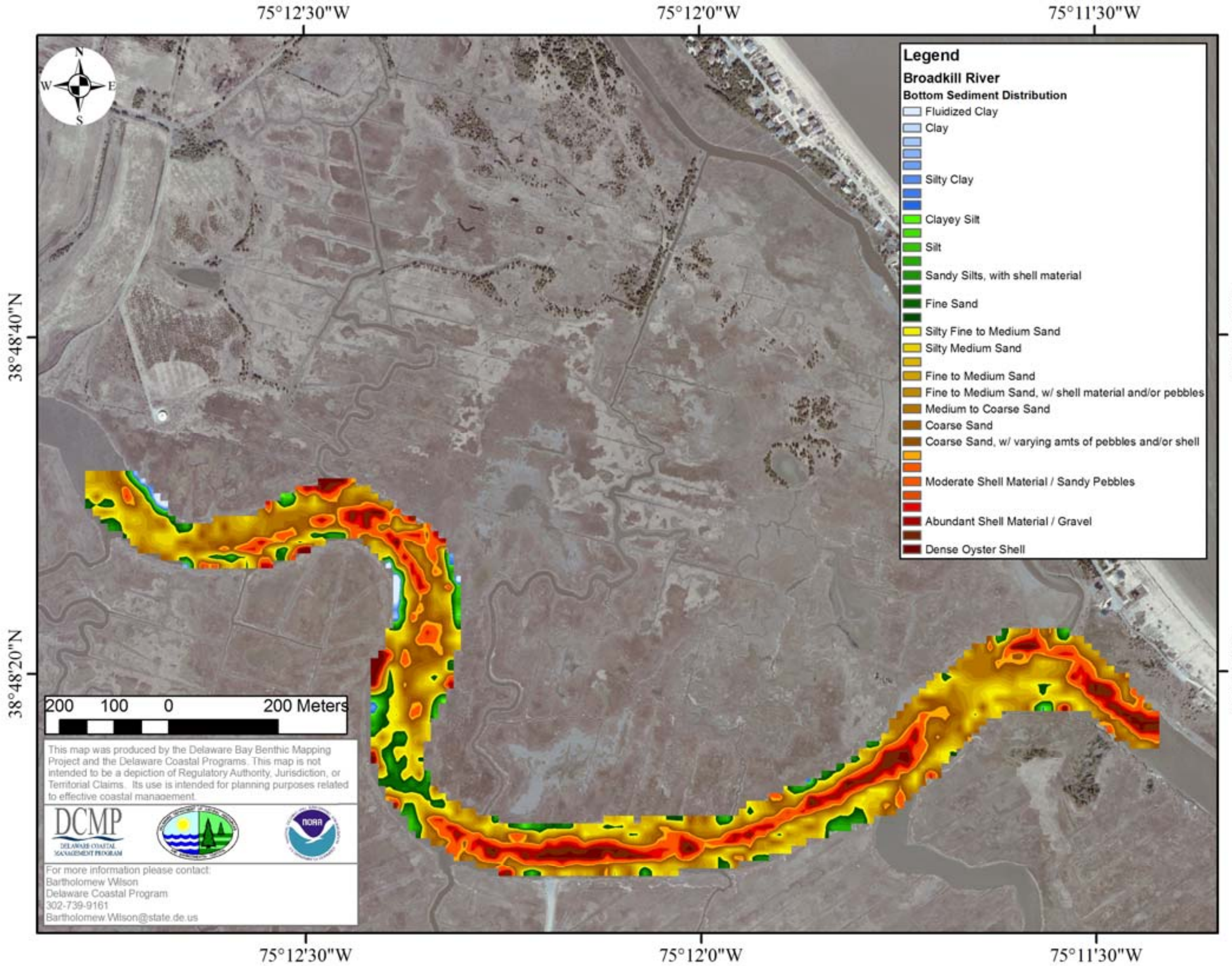


**Figure 4. Bottom sediment distribution**

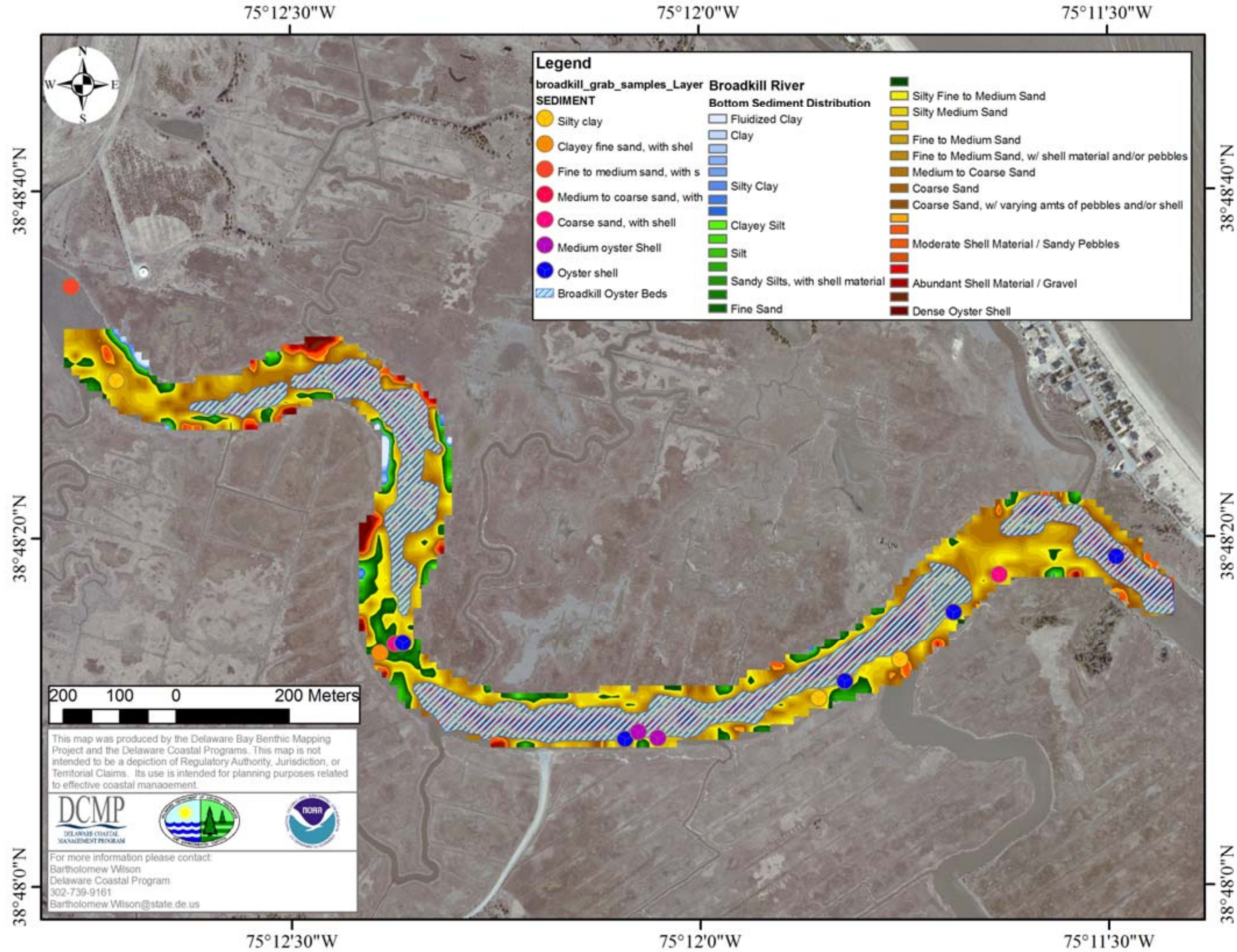


**Figure 5. Broadkill Grab Sample**

**Figure 6. Verifying survey bottom conditions, shell and market sized oyster at Oyster Rocks, 12/1/2007**

The survey identified a large area of sub-tidal hard bottom extending above and below the turns in the river adjacent to the area of the river known as Oyster Rocks (at the end of Oyster Rocks Road). The Oyster Rocks section and adjacent areas to the east and west represent a long tract of the river approximately 2,600 meters (8,530 feet) in length with bottom conditions suitable for oyster recruitment and growth (Figure 6). Because the area of potential oyster habitat was much larger than anticipated, a detailed assessment of this zone is recommended as a future project to determine available substrate (shell) and oyster standing stocks.

Rapid current/tidal flow in the Oyster Rocks section of the Broadkill and further down river is responsible for scouring sediments and creating the hard bottom conditions for oysters and also for erosion of the river banks. Wind, weather and boat wakes are other significant contributing factors to shoreline erosion. Most of the intertidal shoreline along the area surveyed drops off rapidly from the marsh edge and is steeply sloped - with some areas as much as 90 degrees along large sections of the lower river. Shoreline bordering the surveyed zone of hard bottom and other relatively lower energy areas accumulating silts and clays creating soft-mud bottom conditions were also noted (shown as yellow-orange-red areas in Figure 4 and 5). Both types of shoreline are unsuitable for oyster stock enhancement plantings because of their physical characteristics (too steep, too soft or both) and absence of shell or other hard substrate. Flatter intertidal locations with relatively firmer sand/mud and shell bottom conditions more acceptable for oyster plantings were located at two areas bordering the eastern and western ends of Oyster Rocks (Figure 7) which were chosen as test sites.

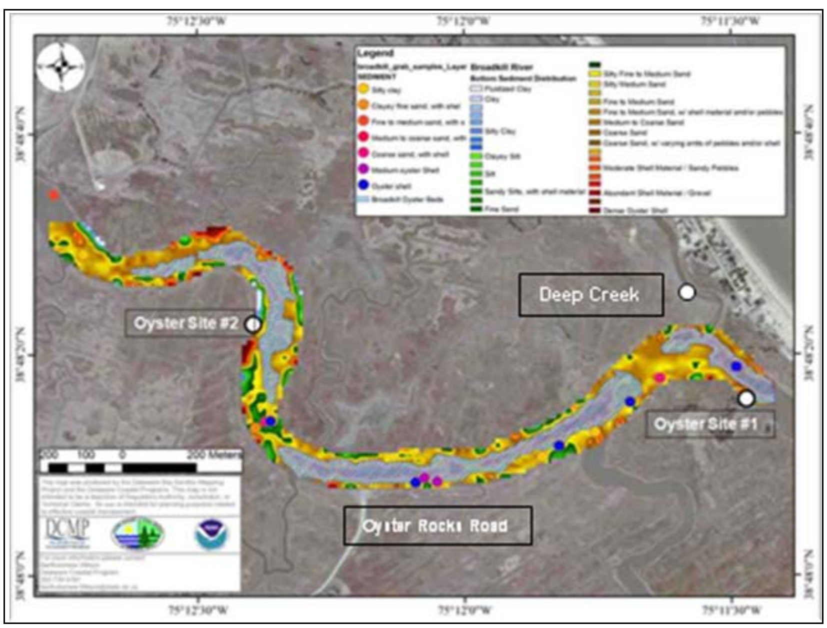


**Figure 7. Bottom survey area, oyster gardening (Deep Creek) and field planting sites**

## Oyster Gardening

Oyster gardening is an increasingly popular method for the nursery culture of hatchery produced oysters for restoration or stock enhancement fieldwork. Small (5-15 mm; 0.2 – 0.6 inches) seed oysters are raised to a larger size (35-50 mm, 1.38 – 1.97 inches or greater) by coastal resident volunteers. These volunteers are typically recruited and trained to maintain the oysters by deploying floating baskets (Taylor floats - a 2 foot (0.6 M) x 4 foot (1.2 M) x 1.5 foot (0.46 M) PVC coated wire basket attached to a float ring made of 4 inch (101 mm) diameter PVC pipe (Figure 8) at their private docks in residential lagoons or other protected waters. Field planting of larger juvenile sized oysters (Figure 9) produced by this nursery process often helps to minimize losses from predation and can improve field performance. Holding oysters in the water column (floats) vs on the bottom generally promotes faster growth and also improves survival. While in the floats, the oysters and shell also serve as habitat and refuge for numerous species of juvenile fish and macro-invertebrates.

**Figure 8. Taylor Floats**

**Figure 9. Seed and Juvenile Oysters**

Five oyster gardening sites were established on Deep Creek a narrow tributary connecting to the Broadkill at the east side of the river behind Broadkill Beach (Figure 7). Mr. Thomas Wooding, a Cape Henlopen High School (Lewes, Delaware) senior and Eagle Scout candidate from Broadkill Beach, Delaware helped to coordinate the oyster gardening activity in his neighborhood. As part of qualifying as an Eagle Scout, Mr. Wooding constructed the Taylor Floats and baskets to be used in the project, collected water quality data at the different gardening sites and worked with neighbors who volunteered to participate and use their docks for raising oysters. Training on the proper care and maintenance of the seed oysters and floats, on the objectives and goals of the program and on the ecological role and benefits of oyster populations in the estuary was also provided.

The general approach and methodology to utilize volunteers for the nursery culture of oysters for this project are based on the successful Delaware Inland Bays oyster gardening program. This ongoing oyster restoration/stock enhancement program was first established in 2003 (with a NFWF small grant). Over the last six years, the Delaware Center for the Inland Bays along with the Delaware Sea Grant Marine Advisory Program and Delaware State University have developed a community-based effort that has grown to more than 100 oyster gardening sites and 150 volunteers utilizing the network of residential lagoons common to Rehoboth, Indian River and in particular Little Assawoman Bays. Oyster spat on shell and juvenile oysters produced at the University of Delaware College of Marine and Earth Studies shellfish facilities (Figure 11) located adjacent to the Broadkill River in support of the Inland Bays program were also used in support of the Broadkill River project.

Approximately 500-750 hatchery-produced cultchless (individual) seed oysters (25-40 mm shell height) were deployed at each gardening/nursery site in spring 2007. The seed oysters were produced using Rutgers University (Haskin High Performance Line) brood stock selected for resistance to MSX and Dermo diseases. Both diseases are caused by microscopic marine parasites common to the eastern seaboard. Dermo (*Perkinsis marinus*) and MSX (*Haplosporidian nelsoni*) resistant brood stock lines are preferred to produce seed oysters used for commercial oyster aquaculture and field restoration/stock enhancement. The oysters deployed to the Broadkill gardening sites were somewhat larger than those typically used in other programs. They were selected because of their availability (from the previous season) during spring 2007, as it takes one growing season for the hatchery/spat/nursery process to produce oysters for field planting; and because the oysters were produced at the Rutgers University (Delaware Bay based) hatchery in Bivalve, New Jersey, a consideration supported by DNREC Fish and Wildlife officials for importation of oysters into Delaware waters.

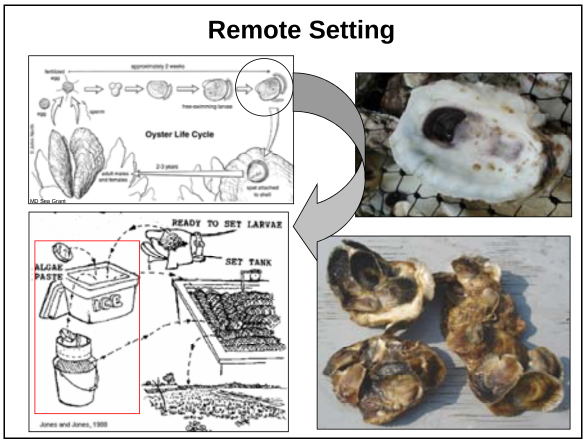


**Figure 10. Remote setting process**


**Figure 11. U. Delaware Broadkill River setting tank**

Also during spring/summer 2007 a remote setting tank was established at the University of Delaware College of Marine and Earth Studies (CMES) shellfish laboratory at the entrance of the Broadkill River to produce oyster spat for the Inland Bays gardening program. Remote setting is a process by which mature oyster larvae (produced in this case at the Rutgers hatchery in New Jersey) were concentrated and then transported to a remote or secondary location (Lewes, Delaware) for release into an aerated tank with clean oyster shell to facilitate oyster spat production (Figures 10 and 11). Oyster spat (on shell) produced during the 2007 set were used in support of the Broadkill project.

## Oyster Stock Enhancement Field Evaluation/Demonstration

Acquisition of all the required permits for the field demonstration portion of the project - U.S Army Corps of Engineers - nationwide permit for aquaculture (NWP 48), Coastal Zone Federal Consistency Review from Delaware Coastal Program (FC 07.117) and Subaqueous Lands Permit granted by State of Delaware - was completed in September 2007.

The first individual bottom plantings were established at Oyster sites (OS) 1 and 2 (Figures 12 and 13) during October 2007. These plots covered a 14 square foot (1.30 square meters) area of low intertidal bottom (-0.3 to -0.5 MLW) consisting of sand, mud and shell hash (old weathered oyster shell fragments). Both planting areas were bordered by bagged oyster shell to prevent erosion of the plot contents and to serve as potential substrate for natural larval settlement. A layered base of clean oyster shell was deposited on the sediment inside the plot boundary and the shell base was stocked with approximately 2,000 15 – 20 mm oyster spat on shell. Natural oyster set on scattered loose shell representing two or possibly three year classes was also found along the intertidal zone at both sites (Figure 14).

**Figure 12. October 2007 oyster planting at OS #2 Broadkill River**

**Figure 13. OS #2 October 2007**

**Figure 14. 2007 spat on shell and natural oyster set (OS#2)**

Both stations were visited during spring 2008. The plots weathered the winter relatively intact but one obvious disadvantage was noted. The oyster shell bag perimeter, while successful at retaining the spat on shell planted in the plot, also sufficiently reduced current flow resulting in accumulation of sediment. Also, the bags themselves became heavily fouled with sea lettuce (*Ulva lactuca*). Although new (spring) oyster shell growth was observed, over-winter mortality from sedimentation and secondarily from predation was estimated at 30-50% (Figures 15 and 16). The plantings at both sites were re-adjusted for the 2008 season by raking up and replanting the surviving spat on shell and by increasing the size and configuration of shell bag perimeter to allow increased current flow and to minimize sedimentation (Figure 17).

**Figure 15. OS #1 with sediment accumulation and fouling**

**Figure 16. Spat on shell, OS #1, Spring 2008**


**Figure 17. Three plots at OS #1, Spring 2008**

To compensate for the lack of suitable intertidal demonstration planting sites within the benthic survey area, additional plots were established at Oyster sites 1 and 2 during spring 2008 (Figures 17 – 21). A comparison among three oyster stock enhancement field methods was undertaken by establishing two additional individual plots on either end of the initial Fall 2007 planting (Plot 1 Figure 17). Each new 14 square foot (1.30 square meters) bottom plot consisted of an oyster shell base without a shell bag perimeter. One shell base (Plots 1-1 and 2-1) was covered with approximately 500 hundred 2- 3 inch (50-75 mm) cultchless (single) oysters produced at the Broadkill oyster gardening sites on Deep Creek. The second shell base (Plots 1-3 and 2-3) was covered with approximately 750 1 and 5/8 – 2 inch (40-50 mm) juvenile oysters on shell clusters produced at the University of Delaware shellfish laboratory remote setting tank. Clean shell bags were also added on each end of the three plot array to monitor any natural spat fall during the 2008 season.

In both locations the intertidal bottom composition was mixed sand/mud and old fragmented oyster shell. The shell helped to stabilize the shoreline to the marsh edge and also served as substrate for natural oyster recruitment (Figure 18). The combination of shell, mud and sand

resulted in semi-firm bottom conditions which were easily compressed while developing the sites but provided sufficient support for the three different oyster plantings.  Bottom plots at both locations were established well below the Mean Low Water mark (-0.3 to -0.5 MLW) at the intertidal/sub-tidal interface. The purpose for the low intertidal placement was to minimize winter exposure and freezing since the first plantings were established during fall 2007; and to minimize the potential for vandalism by passing boaters. Opportunities to access the sites were limited as they were only periodically exposed during larger (spring) low

**Figure 18. Natural oyster set on shell fragments 2008**

**Figure 19. Plot 1-1 OS #2 Spring 2008**

**Figure 20. Plot 1-3 OS #2 Spring 2008**


**Figure 21. Three field plantings at Oyster site #2 Broadkill River, Spring 2008**

tides. Wind and weather events affecting tidal amplitude and time occurrence of spring tides also limited field access during the summer months.

In Fall (October-November ) 2008 we unexpectedly found that the oyster plantings in both locations were completely washed out with the oysters from the individual plots dispersed and mixed among the shell fragments, natural set and other debris on the intertidal shoreline (Figures 22 and 23). The only remaining references to the plantings were the shell bags used as a perimeter for Plot 2 and for assessing natural spatfall. Both sites were exposed and thus vulnerable to northeast winds. Most likely a combination of tidal, wind and wave energy during a late summer/fall coastal storm or series of weather events was responsible for breaking down the plots and returning the sites back to their natural state. Boat wakes (spring through fall) and their contribution to shoreline erosion could also have been a factor. Oysters washed out from all plantings (plots 1-3) at both sites were found to be in good condition with evidence of summer growth (Figures 24 to 31). The overall condition of hatchery produced cultchless (single) and oysters set on shell suggests that deploying them directly on the intertidal flats vs developing individual plots could have been a more effective and less time consuming stock enhancement strategy.

Shoreline erosion, especially in the lower reaches of the Broadkill River, is significant. Different approaches or methods to stabilize river banks would be required depending on the area in question. However, in the two sites used for field plantings and in similar locations with relatively flat intertidal zones, addition of more shell to prevent erosion would also serve as additional substrate for natural oyster recruitment. Shell bags deployed during Fall 2007 and Spring 2008 did not appear attract any natural set during the 2008 season, but examples of different year classes of natural recruitment on intertidal shell fragments were easily found at both locations.

**Figure 22. OS #1 showing remnants of Plots 1-3**

**Figure 23. Planted oysters scattered on the bottom**

**Figure 24. OS #1 Natural set, October 2008**

**Figure 25. OS #1 Plot 1, October 2008**

**Figure 26. OS #1 Plot 2, October 2008**

**Figure 27. OS #1 Plot 3, October 2008**

**Figure 28. OS #2 Natural set, October 2008**

**Figure 29. OS #2 Plot 1, October 2008**

**Figure 30. OS #2 Plot 2, October 2008**

**Figure 31. OS #2 Plot 3, October 2008**

Additional natural recruitment was observed in other intertidal areas where rip rap and other hard surfaces are present. Natural oyster set in the intertidal zone at the College of Marine and Earth Studies (CMES) harbor and in Canary Creek located adjacent to entrance of the Broadkill River is extensive (Figure 32). The larval source for this recruitment, while not confirmed, is believed to be the Oyster Rocks area of the Broadkill - as it is the closest source of adult spawning oyster stock. To a much lesser degree, natural recruitment is also found further upriver on relatively sparse loose shell hash in the areas identified for bottom plantings suggesting that availability of intertidal (and sub-tidal) hard substrate and structure (shell, rock etc) is a limiting factor for natural recruitment along the lower Broadkill and vicinity around Oyster Rocks.

**Figure 32. Natural oyster set on rip-rap at the CMES Harbor, Lewes, Delaware**

The shell bags placed in the intertidal zone at both planting sites were resilient enough to withstand the high energy environment created by wind, weather and tidal flow and are the only remaining remnants of the planting sites developed during Fall 2007 and Spring 2008. Surplus shell bags from the 2007 remote setting operation with hatchery produced oysters deployed further down river at the University of Delaware Shellfish laboratory (Figure 33) also exhibited good growth and survival during the 2008 season. This approach could also prove to be effective for both shoreline stabilization and oyster stock enhancement.

**Figure 33. Remote setting tank shell bags with hatchery produced spat Fall 2007 (left) and fall 2008 (right)**

## 3) Lessons Learned and Future Recommendations

The objectives of the project were to conduct hydrographic and bottom surveys of area of the lower Broadkill River in the vicinity of Oyster Rocks; and to develop an oyster gardening capability using resident volunteers to produce oysters for stock enhancement field trials in areas identified by the survey. The oyster gardening and to some extent the field planting phases of the project were based on the successful application of field methods developed for the Inland Bays oyster gardening program. Similarities and significant differences exist between to Broadkill River and the Delaware Inland Bays. Both estuaries support very good to excellent oyster growth and show evidence of shoreline erosion but are quite different in their other physical and biological characteristics.

The Inland Bays (Rehoboth, Indian River and Little Assawoman are relatively shallow barrier island/coastal lagoons. Numerous residential lagoon developments in the estuary offer protected waters for oyster gardening and there is widespread use of rip-rap around the bays for shoreline stabilization. The off-bottom profile, structure and protection provided by the rip-rap are ideal for field trans-planting oysters from the gardening sites. Minimal evidence of oyster standing stocks and natural oyster recruitment is found in Rehoboth and Indian River Bays. No wild populations of oysters are found in the Little Assawoman Bay.

By contrast, the Broadkill is a highly turbid estuary with strong tidal currents. Only one residential area (Broadkill Beach) and the facilities of University of Delaware are located in the study area and the majority of the lower portion of the river flows through an extensive acreage of wetlands including the Prime Hook National Wildlife Refuge. Shoreline erosion is significant and shoreline stabilization structure such as rip-rap and bulk heading is largely absent being confined to the entrance of the river and adjacent areas. The extent and area of hard bottom habitat suitable for oysters at Oyster Rocks and adjacent areas is much larger than anticipated. Multiple year classes of oysters are found in the river, although total abundance and distribution is not well understood. Evidence of natural oyster recruitment (indicating a significant occurrence of spawning and larval production originating in the river) is prevalent especially in areas with shell, rip-rap or other off-bottom structure.

The physical characteristics of the misnamed Deep Creek (which is actually narrow and shallow) turned out not to be ideal for oyster gardening using Taylor Floats because of frequent drainage of the Creek during low tides. However, oyster growth and survival in Deep Creek using hanging baskets was considered to be very good to excellent. Based on previous work in further down river at the CMES facilities at the mouth of the Broadkill River and Roosevelt Inlet, oyster growth and survival in Deep Creek was consistent with off-bottom tray and hanging basket (water column) culture methods.

The intertidal bottom plantings were un-stable in the high energy environment created by wind and wave action and tidal currents. Planted oysters from all three plots at both study locations were eventually scattered and mixed with wild set. The good condition of recovered hatchery produced oysters suggests that direct deployment on the intertidal flats could be a more effective and less time consuming stock enhancement strategy. Shell bags with hatchery set oysters also performed well and could also provide shoreline a stabilization option.

**Future Recommendations:**

1) A thorough assessment of oyster abundance and distribution and of available cultch (shell) at Oyster Rocks and adjacent areas identified in the survey.
2) Given the significant natural recruitment observed at the entrance of the Broadkill River, a stock enhancement strategy to increase the amount of shell available for new recruitment in sub-tidal and intertidal areas is preferable to oyster gardening and field planting
3) Future addition of larger volumes of shell should be first applied to improve the sub-tidal areas of hard bottom detected in the survey and to stabilize eroding shoreline where feasible.
4) Nursery culture of hatchery produced oysters via volunteer oyster gardening and use of the University of Delaware shellfish laboratory facilities can be effective as a secondary method to introduce disease resistant stocks, enhance oyster populations and/or stabilize eroding shoreline in select intertidal areas

**Dissemination**

Results for the Broadkill River Oyster Gardening and Stock Enhancement Project are posted on the Delaware Aquaculture Resource Center website at http://darc.cms.udel.edu/broadkill/index.htm.

The Broadkill River Tributary Action Team website http://broadkill.ocean.udel.edu/ has a link to the project.

An Oyster Gardening exhibit was included in the feature Coast Day 2008 exhibit on "Are you Up to the Challenge". Approx. 10,000 visitors attended the annual event. See http://www.ocean.udel.edu/coastday/

Broadkill River water quality data is posted at the UD Citizen Monitoring Program – Broadkill River Monitoring Program at http://citizen-monitoring.udel.edu/

Results are also being shared directly with state resource managers, Partnership for the Delaware Estuary educator/scientists and on request

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