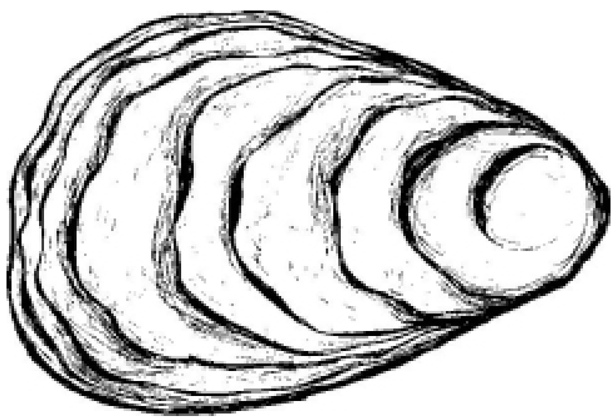
US Army Corps of Engineers
Philadelphia District

DELAWARE BAY OYSTER RESTORATION PROJECT
DELAWARE AND NEW JERSEY

DRAFT Environmental Assessment



April 2007

FINDING OF NO SIGNIFICANT IMPACT

DELAWARE BAY OYSTER RESTORATION PROJECT DELAWARE AND NEW JERSEY

The proposed project seeks to continue oyster restoration and includes a shell-planting and oyster transplanting program that will substantially promote improvements in the oyster populations in Delaware Bay, which in turn, will promote the economies not only of the Delaware Bay oyster fishery, but that of the Delaware Bay regional/recreational economy as a whole by improving water quality and habitat complexity within the estuary.

The Delaware Estuary is an ecologically valuable area. The Philadelphia District Army Corps of Engineers seeks to address the habitat degradation and the ensuing significant losses to an indigenous natural resource. From 1990 to 1995, the oyster industry provided little in jobs or revenue in Delaware Bay. Oystering reopened in 1996 in New Jersey but did not reopen until 2001 in Delaware. Since 2001, the condition of the oyster resource has deteriorated on both sides of the bay despite careful management and a limited controlled fishery, increasing the urgency for establishing a recruitment and enhancement program based on shell planting. Recognizing the problem, the New Jersey Legislature passed a joint resolution (SJR-19, 1996) establishing the "Oyster Industry Revitalization Task Force" (OIRTF) to develop recommendations that could lead to revitalization of the oyster industry and its associated environmental and economic benefits in the Delaware Bay. In 2001, representatives from both Delaware and New Jersey, including state regulatory agencies, the Delaware River and Bay Authority, the Delaware River Basin Commission, and interested citizens developed an oyster revitalization initiative based on the OIRTF. The primary goal was to enhance recruitment by enhancing natural seed supply through the planting of shell (cultch) to provide habitat for recruitment of juvenile oysters (spat). The planting of clean shell will increase oyster habitat, expand oyster abundance, and revitalize the natural resource with concomitant improvements in bay habitat quality from increased habitat complexity as well as increased water clarity brought about by the increased filtration by an abundant shellfish resource.

The proposed work is a continuation of the shell-planting project initiated in 2005. For the third consecutive year, shell planting and transplanting will take place in portions of the natural oyster beds of Delaware Bay in the states of Delaware and New Jersey, as well as the leased beds off the New Jersey Cape Shore of Delaware Bay, as selected by the New Jersey Department of Environmental Protection (NJDEP) and Delaware's Department of Natural Resources and Environmental Control (DNREC) based on bottom surveys that occur annually. Approximately 290,000 bushels of shell were planted on several existing oyster bed locations within Delaware Bay in July 2005. In 2006, 478,650 bushels of shell were planted. In addition to direct shell planting, previously planted shell with spat were transplanted upbay. For the proposed project, approximately 700,000 bushels of shell will be directly planted or placed downbay to relocate spatted shell for later upbay transplant. Spatted shell on privately leased grounds may be purchased, if available, and transplanted upbay; and broodstock oysters from marginal areas will be transplanted to waters where a better growth potential occurs. As in 2005 and 2006, roughly 25-acre plots will be planted in Bay waters of both states in June/July 2007. Local clam companies generate large quantities of ocean quahog and surf clam shells and these shells provide an adequate substitute for oyster shell. Hence, the project will recycle a waste product into a useful commodity, thereby alleviating present storage and disposal issues.

The shell planting program was designed to specifically address the issue of low recruitment and the inability of recruitment rates on natural oyster beds to sustain population abundance over time. A concomitant monitoring program will acquire the data necessary to evaluate the success of the shell-planting program. The increment in abundance achieved by the program over the abundance that would have been present in the absence of the program at present will be used to establish degree of success. The Monitoring and Assessment Program will consist of seven components: (1) monitoring of downbay shell plants pursuant to the decision to transplant the spatted shell upbay; (2) measurement of spat settlement potential carried out from late June through late September; (3) monthly tracking of trends in growth and disease exposure for the shell plants; (4) a quantitative evaluation in October to determine the overall success of each year's program at season's end; (5) dredge calibration to determine the applicability of remote sampling by oyster dredge of shell plants; (6) survey of targeted oyster beds to improve bed areal estimates, where required, and (7) the development of a shell budget to evaluate the efficacy of the shell-planting program in maintaining habitat integrity.

The proposed action was reviewed in accordance with ER-200-2-2 Environmental Quality Procedures for Implementing the National Environmental Policy Act (NEPA). The Environmental Assessment for this project is being coordinated with the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the New Jersey Department of Environmental Protection, Delaware's Department of Natural Resources and Environmental Control and all other known interested parties.

The Environmental Assessment has determined that the proposed activity is not likely to jeopardize the continued existence of any species or the critical habitat of any fish, wildlife, or plant that is designated as endangered or threatened, pursuant to the Endangered Species Act of 1973 as amended by P.L. 96-159.

A Section 401 Water Quality Certificate and a Coastal Zone Consistency Determination will be obtained from the New Jersey Department of Environmental Protection (NJDEP) for the proposed project. Under a current agreement with the State of Delaware, the proposed action meets the requirements for Nationwide Permit #4 and therefore, the Environmental Assessment, Section 404(b)(1) Compliance Review and Statement of Findings for Nationwide Permit #4 apply to this action. Delaware's Section 401 Water Quality Certification is waived. A Delaware Coastal Zone Management Federal consistency determination has been requested. Additional shell will be similarly placed and/or transplanted in subsequent years. Coordination with the NJDEP and DNREC would occur prior to subsequent events to ensure that the necessary state approvals are in place.

The proposed project is being coordinated with both New Jersey's and Delaware's State Historic Preservation Offices. There are no known properties listed on, or eligible for listing on, the National Register of Historic Places that would be adversely affected by the proposed project. The proposed project will avoid areas suspected of containing archaeologically sensitive sites and is therefore not expected to impact any cultural resources.

Because the Environmental Assessment concludes that the proposed project is not a major Federal action significantly affecting the human environment, I have determined that an Environmental Impact Statement is not required.

________________________________ ________________________________

Gwen Baker
Lieutenant Colonel, Corps of Engineers
District Commander

Date

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1.0. INTRODUCTION

The U.S. Army Corps of Engineers implemented a multi-year program to revitalize the population of the Eastern oyster *Crassostrea virginica* in Delaware Bay-a unique and ecologically valuable area. This Environmental Assessment evaluates environmental concerns relative to the problem of habitat degradation and the ensuing significant losses to an indigenous natural resource. The proposed project seeks to continue an established successful shell-planting program annually for a minimal period of 5 years and will substantially promote improvements in the oyster populations in Delaware Bay, which in turn, will improve water quality, enhance benthic habitat diversity, and promote the economies not only of the Delaware Bay oyster fishery itself, but that of the Delaware Bay region as a whole.

1.1. Authority

The project is located in the 1st New Jersey Congressional District and the at-large Delaware Congressional District. The project bill was authorized in the FY 05 Energy and Water portion of the omnibus appropriations bill under Section 1135 of the Water Resources Development Act of 1986, as amended, Continuing Authorities Program. The non-Federal co-sponsors are the Delaware Department of Natural Resources and Environmental Control (DNREC) and the New Jersey Department of Environmental Protection (NJDEP). The proposed project is supported by the U.S. Fish & Wildlife Service (USFWS), the Partnership for the Delaware Estuary (PDE), Delaware Bay Section Shellfisheries Council (NJ), Governor's Council on Shellfisheries (DE), the Delaware River Basin Commission (DRBC), the Delaware River and Bay Authority (DRBA), the National Marine Fisheries Service (NMFS), the Delaware Bay Shell Fisheries Council of New Jersey, the Cumberland County, New Jersey Empowerment Zone, (CCEZ),and the U.S. Environmental Protection Agency, Delaware National Estuary Program (USEPA). Rutgers University Haskin Shellfish Research Laboratory provides management and monitoring support for this project.

A secondary objective of the project is to seek involvement of a wider constituency in the revitalization program and thus, wider recognition of the importance of improving the Delaware Bay ecosystem. This component will be implemented by the Partnership for the Delaware Estuary, a regional, nonprofit organization, based in Wilmington, Delaware. In an effort to increase the Estuary-wide awareness and support for the revitalization of the oyster industry in Delaware Bay, a multifaceted education and outreach program has been implemented to bring together stakeholders region-wide to build stewardship for this natural resource.

1.2. Environmental Compliance

Coordination with federal and state agencies is ongoing and will insure environmental compliance. All environmental requirements for this project, including permit acquisition, will be completed. Table 1-1 provides a summary of the proposed project's relationship with environmental statutes and regulations.

Table 1-1: Environmental Statutes and Regulations.

Federal Statutes	**Compliance w/Proposed Plan**
Archaeological Resources Protection Act of 1979, as amended	Full
Clean Air Act, as amended	Full
Clean Water Act of 1977	Full
Safe Drinking Water Act	Full
Coastal Zone Management Act of 1972, as Amended	Full
Endangered Species Act of 1973, as amended	Full
Estuary Protection Act	Full
Federal Water Project Recreation Act, as Amended	N/A
Fish and Wildlife Coordination Act	Full
Land and Water Conservation Fund Act, as Amended	N/A
Magnuson-Stevenson Act – Essential Fish Habitat	Full
Marine Mammal Protection Act	Full
Marine Protection, Research and Sanctuaries Act	Full
National Historic Preservation Act of 1966	Full
National Environmental Policy Act, as amended	Full
Rivers and Harbors Act	Full
Watershed Protection and Flood Prevention Act	N/A

Wild and Scenic Rivers Act	N/A
Coastal Barrier Resources Act	N/A

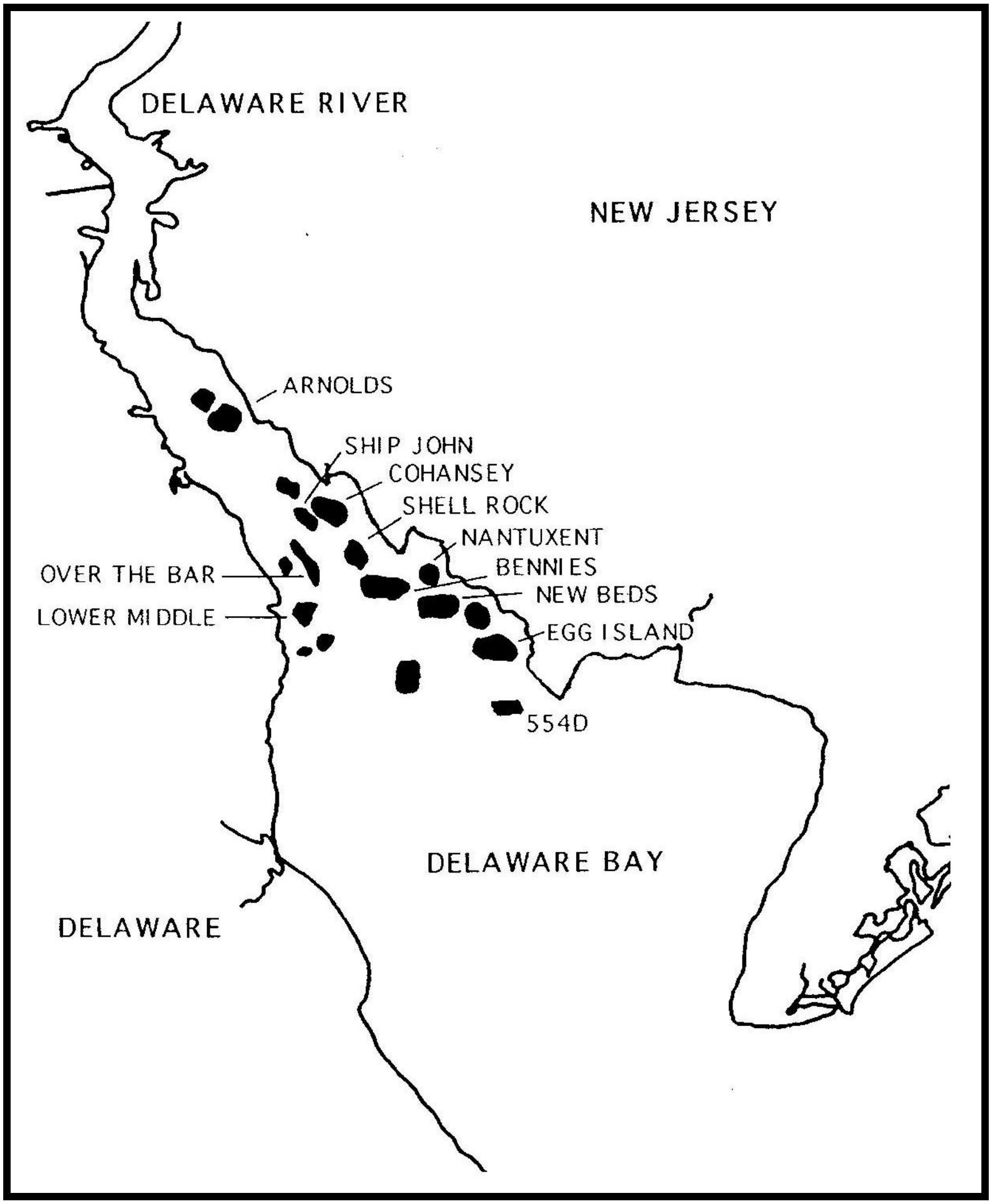
Executive Orders, Memorandums, etc.	**Compliance w/Proposed Plan**
EO 11988 Floodplain Management	N/A
EO 11990 Protection of Wetlands	N/A
EO 12114 Environmental Effects of Major Federal Actions	Full

2.0. NEEDS AND OBJECTIVES

Oysters inhabit Delaware Bay from the mouth to Bombay Hook on the western side (Delaware) of the estuary, and to just below Artificial Island on the eastern (New Jersey) side, a distance of about 50 miles (Figure 2.1). Oysters have provided a sustainable food supply and contributed to the local economy of Delaware and New Jersey for centuries. From the days of the native American settlements along the shores the American (or Eastern) oyster *Crassostrea virginica* has been an important resource. With the coming of the European settlers, oystering increased dramatically and commercial harvesting towns and markets grew. In 1880, oyster harvesting reached its pinnacle with 2.4 million bushels.

Before the turn of the century, over 500 vessels and over 4,000 people worked in the commercial oystering industry in Cumberland County, New Jersey alone. By 1950, the harvest had dropped to around 1 million bushels. An oyster disease MSX (multinucleated sphere unknown), a protozoan parasite (*Haplosporidium nelsoni*), began to impact oyster populations by the late 1950s. Oyster harvests from planted beds dropped 90-95% while oysters in seed beds suffered a 50% mortality. Oyster harvests fell from 711,000 bushels in 1956 to 49,000 bushels in 1960. The oyster industry recovered during the 1970s and through the mid-1980s, to provide steady employment along the Delaware bayshore of both states. In 1990, a second oyster disease struck. Dermo (*Perkinus marinus*), also a protozoan parasite, invaded the oyster population that had developed a resistence to MSX, and the oyster industry nearly disappeared. A suite of other parasites were observed in a study conducted by Versar, Inc. in 2002. These include gill ciliates, large and small ciliates in the gut and digestive gland, *Bucephalus* trematodes, xenomas, and rickettsial bodies. Rare parasites observed included the trematode *Proctoeces*, nematodes, and parasitic copepods. However, none of these parasites significantly affected the oyster population dynamics or caused significant mortality like Dermo. Today in the Delaware Bay, Dermo disease is the overwhelming cause of adult oyster mortality. Mortality attributed to predation (mostly oyster drills, but also including crabs and dredge damage) was high in higher salinity areas (25%-50%)

<u>Figure 2.1</u>. Map of Delaware Bay showing the locations of oyster beds.



from Egg Island to Bennies but about 15% or less elsewhere (Versar, Inc. 2001). Recent improved estimates put an annual mortality of juvenile oysters at about 25% bay-wide, with higher estimates down-bay (HSRL, 2005).

From 1990 to 1995, the industry provided little in jobs or revenue in New Jersey. Oystering began again in 1996 under a carefully monitored direct market program. Oystering in Delaware did not reopen until 2001. Recognizing the need to address the decline in the oyster resource, the New Jersey Legislature passed a joint resolution (SJR-19, 1996) establishing the “Oyster Industry Revitalization Task Force” (OIRTF) to develop recommendations that could lead to revitalization of the oyster industry and its associated economic benefits in the Delaware Bay. In 2001, representatives from both Delaware and New Jersey, including state regulatory agencies, the Delaware River and Bay Authority, the Delaware River Basin Commission, and interested citizens developed an oyster revitalization initiative based on the OIRTF.

The primary goal was to enhance recruitment by enhancing natural seed supply through the planting of shell (cultch) to provide habitat for recruitment of juvenile oysters (spat). This will increase oyster habitat, expand oyster abundance, and revitalize the natural resource with concomitant improvements in Bay habitat quality from increased habitat complexity brought about by shell planting as well as increased water clarity brought about by the increased filtration by an abundant shellfish resource.

The OIRTF began addressing the oyster population problem in the Delaware estuary in 1996. It was concluded that culture practices need to be modernized to change management of the resource (DRBA, 1999). Analysis of long-term time series data suggest that enhanced abundance can stabilize natural mortality (HSRL, 2005). Recent work has shown that low abundance leads to degradation of the shell bed and eventual loss of the unique habitat of the oyster reef. Thus, a recruitment enhancement program is important for four reasons: 1) recruitment enhancement is needed immediately to stabilize stock abundance imperiled by seven consecutive years of recruitment failure; 2) recruitment enhancement is needed to permit continuation and expansion of the oyster industry; 3) recruitment enhancement leading to increased abundance produces the shell necessary to maintain the bed; and 4) recruitment enhancement is needed to minimize the control of the oyster population dynamics by oyster disease and thereby stabilize stock abundance at a level that will permit the oyster to fulfill its keystone ecological role in the estuary as a filterer.

Since 2001, the condition of the oyster resource has deteriorated despite careful management and a limited controlled fishery, increasing the urgency for augmenting recruitment and providing habitat for oyster spat through a shell planting program. In 2006, Delaware Bay was in its seventh year of below average recruitment (less than 0.5 spat per oyster per year). Seven such consecutive years is unprecedented from the perspective of the 54-year record for which detailed survey data are available (1953-2006). Consistent recruitment failure has resulted in the decline of oyster stocks, endangering the species population dynamics, the continuance of the fishery, and the habitat quality of the oyster beds.

During the 1997-2006 period, through the efforts of the state regulatory agencies, the Shellfish Councils, and the Haskin Shellfish Research Laboratory (HSRL) of Rutgers University, a significant assessment infrastructure has been established that has produced a sustainable industry in Delaware Bay. In New Jersey, this process has been formalized through a stock assessment workshop, a rigorous stock survey, and the development of a coupled shellfisheries-disease model to permit projections of yearly harvest. Through these efforts, a consistent fishery has been established and a stable stock structure has been maintained. The resiliency of Delaware Bay oyster populations was reduced with the advent of Dermo in the 1990s. As a consequence, consecutive years of recruitment failure have significantly endangered the stock.

Aside from the decline in adult oyster abundance due to high mortalities resulting from Dermo disease, there are reduced numbers of oyster spat due to relatively poor natural setting that has also contributed significantly to the demise of the Delaware Bay oyster. After two years of shell planting (and a previous small-scale test plant), results of the annual oyster stock assessment released in March 2007 indicate that throughout the New Jersey waters of Delaware Bay, the stock presents a mixture of positive and negative indicators that approximately balance. Abundance continued to be below target levels in all bay regions but above threshold levels on the medium mortality beds and Shell Rock and near, but below, threshold levels on the high mortality beds. The continued shell-planting program is anticipated to increase abundance on downbay beds in 2007. Abundance has increased each year on the high-mortality beds since reaching a post-1988 low in 2004 and abundance has moved in a positive direction for the last several years on Shell Rock. The stock continues to be disproportionately consolidated on the medium-mortality beds, a process that began in the early 2000s with persistent recruitment failure and the influence of Dermo disease downbay (Powell *et al*., 2007). However, the 2005-2006 shell planting programs have added substantially to bay-wide recruitment and these recruits are expected to underpin increases in oyster abundance in 2007, as was observed in 2006.

3.0. ALTERNATIVES

3.1. No Action

The no action alternative will result in continued deterioration of the oyster stocks, loss of the fishery, and substantial deterioration of habitat quality and water quality in Delaware Bay. Projections of oyster abundance by the 9th[h] SAW (2007 Stock Assessment Workshop) presented by the Haskin Shellfish Research Laboratory in February 2007, indicate that oyster beds continue to suffer net losses in shell that if allowed to continue will lead to the eventual loss of the shell bed. However, the shell-planting program reduced this net loss in 2006 to the lowest value observed during the 1999-2006 time period when data were sufficient to estimate the trend. The decline in abundance is associated with a shift in size frequency so that today’s population is over represented by older individuals. Population dynamics modeling of abundances this low suggest only a limited possibility of recovery without active intervention through recruitment enhancement. Shellfish play a significant role in water quality of the bay by improving water clarity and controlling plankton or algal blooms. Since populations of oysters are near historic lows and showing promising signs after just two years of a shell-planting program, restoring some portion of this lost filter-feeding capacity is identified as a direct improvement on water and habitat quality. Oyster shell degrades over time. Since 2001, estimates show a reduction of native cultch on New Jersey beds by as much as 50%. Oyster beds are sustained, as is the high diversity and complexity of this habitat, by continued addition of shell; without an active abundant oyster population, the quality of this Essential Fish Habitat (EFH) will assuredly also decline. The oyster populations and their habitat are expected to continue to decline unless efforts to continue this program to augment beds to improve habitat quality continue to be made.

3.2. Hatchery Seed

The use of hatchery seed was considered as an alternative plan. An abundant and consistent supply of seed oysters has been a long-standing problem for not only the Delaware Bay industry, but for oyster producers in many other areas as well. Throughout the history of the oyster industry, seed supply has usually been the limiting factor in the output of market oysters (Ford, 1997). Insufficient seed for planting has plagued the Delaware Bay oyster industry for decades. Until the MSX disease epidemic in the late 1950s, seed was imported from outside the estuary to supplement that produced in the bay. In some years, the volume of imported seed exceeded that produced within the bay itself (Ford, 1997). An embargo was placed on imported seed in 1959 and the industry has been forced to rely entirely on native seed because of the presence of MSX disease.

One alternative is to produce seed in hatcheries. Hatchery oyster seed is generally not available in quantity on the East Coast. Hatchery production of large quantities of oyster seed for specific delivery dates is a matter of routine on the west coast; however east coast hatcheries do not have the experience to produce and set oysters on demand (Canzonier, 1992a). Hatchery seed is extremely limited in New Jersey and is non-existent in Delaware. Thus, hatchery seed cannot be produced in sufficient quantities economically in comparison to the number of seed obtained in a shell-planting program. Furthermore, research studies and pilot shell planting programs both suggest that adequate larval supplies exist naturally in the Delaware Bay system to sustain the program without augmentation by hatchery seed. This has been confirmed in 2005 and 2006. Therefore, emphasis during the early stages of the oyster revitalization program should focus on the enhancement of natural seed production. In addition, and more importantly, providing hatchery seed to the system as an alternative fails to provide an important attribute that shell planting does provide-shell planting restores bed habitat quality.

3.3. Selected Plan

Attempts to enhance the seed supply have been made sporadically in the form of shell plantings, to catch natural oyster sets on the seed beds. Oyster harvesters themselves were once required to replace a portion of the shell from oysters they harvested, but this practice was eliminated in 1979. Federal funds were available during the 1960s and early 1970s and several significant shell plantings were made in the bay at this time. The value of planting clean shell at the right time (i.e. when larvae are ready to set) is illustrated by results recorded in 1966 when clean planted shell received a set of 5,000 spat per bushel whereas old shell on the same bed received only 90 spat per bushel (records of D.E. Kunkle, Haskin Shellfish Research Laboratory). Most plantings did not receive this kind of set, but there was little attempt to regularly place the shells in areas of historical good setting. Rather, cultch went to areas that had been recently harvested, which were not necessarily very good setting areas. Prior to 2003, very little clean shell had been replaced on the seed beds since the early 1970s because the only source of funds has been the Oyster Resource Development Account. This account receives fees from oyster growers, but due to low harvests, rarely has sufficient funds for a significant planting (DRBA, 1999).

There is little doubt of the value of shell planting, as long as it is done at the appropriate time, in the areas most likely to catch a set, is of sufficient size, and the resulting set is managed effectively. Long-term records of the Haskin Shellfish Research Laboratory show clearly delineated areas of high set potential on the inshore areas along the New Jersey shore. In 2003, the NJDEP planted downbay and subsequently transplanted upbay two months later 16,000 bushels of clamshell as part of a pilot program. The project resulted in the recovery of 1800 spat per bushel during a year when the average recruitment on the natural beds was below 50 spat per bushel. Two years later, this transplanted shell contributed 58% of the marketable oysters on the receiving bed (Bennies Sand). Thus, the setting potential can be very high given that the spat have adequate substrate and a doubling of abundance on reproductive beds is readily achieved. For shell planting to be successful in the Delaware estuary, it must be done regularly, on a much larger scale, and closer to setting time than it has been in the past. At present, the shells being generated from Delaware Bay harvests would need to be supplemented by other sources of cultch in order to achieve sufficient quantity to make a significant planting. Currently, sources of surf clam and ocean quahog are being obtained from New Jersey shucking houses and oyster shell mining operations in Chesapeake Bay, Maryland.

The shell planting program serves multiple benefits that extend beyond the oysters. Not only do oysters play a major role in improving water quality through filtration, but their biogenic habitats provide refugia, nesting sites, and foraging grounds for a variety of resident and transient marine species. Numerous studies have revealed greater biodiversity associated with oyster reefs than with adjacent sedimentary habitats. Species richness and abundance of organisms in oyster reef habitats are generally comparable to those found in seagrass meadows. Oyster reefs in estuaries provide hard substrate that supports unique assemblages of organisms, and there is further evidence that oyster reefs contribute to enhanced production, not merely a concentration, of finfish and decapod crustaceans.

The shell-planting project is proposed to continue annually for several consecutive years in portions of the natural oyster beds of Delaware Bay in the states of Delaware and New Jersey, as well as the leased beds of both states, as selected by NJDEP and DNREC. Shell-planting location selection criteria include condition of the existing oyster beds to support exposed shell without significant sediment accumulation, probability of spat settlement above the bay-wide average, and ease of recovery of spatted shell for potential subsequent transplanting.

The approach taken in the two states will differ somewhat to maximize use of local conditions. Approximately 700,000 bushels of clean oyster shell, ocean quahog, and surf clam shell purchased from several private sources, will be planted in areas approximately 25 acres in size, consistent with monitoring efforts of previous year plants. Twenty-five acres is the recommended size because it encompasses a 0.2” latitude x 0.2” longitude rectangle, so the design facilitates navigation and survey. This is the minimum sized rectangle needed for vessel maneuverability during planting. It is also equivalent to the size of the sampling unit used in the New Jersey stock survey, thereby facilitating evaluation of project success in comparison to bay-wide oyster production.

The proposed shell-planting program is based on the premise that planted shell density will average 2,000 bu/acre overall or 50,000 bushels per 25-acre plot. Local clam companies generate large quantities of ocean quahog and surf clam shells and these shells provide an adequate substitute for oyster shell, with surf clam being the preferred of the two. Hence, this project will also recycle a waste product into a useful commodity, thereby alleviating present storage and disposal issues.

3.3.1. ***Delaware:*** Shell planting in Delaware sites will provide needed shell cultch on state-owned natural oyster beds. These beds historically have suffered loss in production due to siltation. The shell planting is designed to increase productive area by adding to bed height while expanding available cultch. Shell cultch will consist of oyster shell, surf clam shell or ocean quahog shell, depending on availability. Latitude and longitude coordinates for each corner of the planting site will be recorded using the Global Positioning System. These location data will be converted to Delaware Plane Coordinates using Corpscon software and then inputted into Arc View for calculating total acreage of the planting site.

Previous shell-planting experiences on Delaware's natural oyster beds have demonstrated that a planting density of 2,000 bushels per acre, in general, provides an excellent shell base for promoting oyster larval attachment. Twenty-five acre plots may or may not be contiguous based on results from the pre-plant bottom survey. In addition, shell plantings will occur just prior to the oyster spawning season (July and August) to ensure that shell surfaces remain clean in order to maximize larval retention.

3.3.2. ***New Jersey****:* Adequate oyster bottom is available in New Jersey; therefore, New Jersey will focus on manipulations specifically directed at increasing recruitment rather than those necessary to also reestablish productive bottom. Shell can be stockpiled throughout the year on state-owned property. For cultch planting to be successful, shell must be planted at the appropriate time (i.e., in unison with the oyster's prime spawning period). The latter will be determined by plankton sampling, which will commence approximately in mid-June. The 2007 Stock Assessment Workshop for the New Jersey Delaware Bay Oyster Bed report recommends targeting Ship John, Cohansey, Nantuxent Point, Hog Shoal, Hawk's Nest and Strawberry, bottom conditions permittin,g for the 2007 shell planting program.

As is currently the case with New Jersey's ongoing oyster enhancement programs, NJDEP staff will record site coordinates using a Trimble Differential Global Positioning System (NJ State Plane Coordinates - NAD83). Coordinates will be mapped using Arc View Geographic Information System, from which acreages can easily be calculated. Cultch planting densities will vary depending on bottom hardness or condition, but will typically range from 1,500 to 2,500 bushels per acre.

1). Shell Planting: Approximately 700,000 bushels of both ocean quahog and clam shell will be purchased in 2006/2007 and most of it placed on existing natural oyster beds within Delaware Bay in both Delaware and New Jersey. Shell will also be planted on downbay inshore sites and leased grounds south and east of Egg Island Point to establish good sets of oyster spat. The spatted cultch will be relocated to upbay nursery beds where survivorship rates are higher. The Cape Shore of Delaware Bay has been utilized for the collection of native spat for over 60 years and lease holders routinely plant shell south and east of Egg Island Point. Cape Shore plantings dating back to the 1920s have demonstrated spat counts that often exceeded 7,500 spat per bushel. Set failures (less than 500 surviving spat per bushel) are rare occurrences, seldom exceeding once every 15 years. This activity has proven itself in 2005 and 2006 whereby spat set has continually exceeded natural settlement upbay by a factor of 10 or more. NJDEP personnel will monitor spat set to identify the best time for shell recovery and transplant. Planting will be conducted by barge, dry or suction dredge, or oyster boat using high pressure saltwater hoses to distribute cultch evenly within a 25 acre grid as the vessel is slowly maneuvered over the planting area.

2) Transplant of Seed from Leased Grounds: In recent years, New Jersey lease holders have planted privately-owned shell on leased grounds downbay of the natural oyster beds for the purpose of obtaining spat for growth to market size. These leased areas are often characterized as having high settlement rates, as are other downbay areas in Delaware Bay; however, survival to market size has been low in these leased areas due to high infection intensities of Dermo. As a consequence, in the past few years, some lease holders have sold seed to out-of-state growers. This seed represents a significant resource for the recruitment enhancement program for it is a known quantity of live seed. In addition, the lease holder has already undertaken the cost and risk of shell planting, and only successful plants need be targeted for this program. Under the current program, this seed (approximately 50,000 bushels) will be transplanted from the low-survival recruitment areas on the downbay leased grounds to high survival upbay natural oyster beds to enhance recruitment on these beds. Seed will be harvested from leased beds by suction or dry dredge.

3). Transplant of Brood Stock from Marginal Areas: Oysters occur in the lower reaches of rivers entering Delaware Bay and in the most upbay reaches of the natural seed beds. These oysters are often stunted in size due to marginal environmental conditions and rarely achieve maximum reproductive capacity. Transplant of these oysters downbay can enhance broodstock abundance in those areas where growth rates and reproductive capacity are high, thus enhancing broodstock abundance and ultimately larval availability for recruitment. The 2007 Stock Assessment Workshop has recommended transplanting from Middle and Upper Middle downbay.

4). Monitoring: The shell planting program was designed to specifically address the issue of low recruitment and the inability of recruitment rates on natural oyster beds to sustain population abundance over time and the need to maintain the shell beds while natural addition of shell is low due to low abundance. The monitoring program will acquire the data necessary to evaluate the success of the shell-planting program. The increment in abundance achieved by the program over the abundance that would have been present in the absence of the program at present will be used to establish the degree of success. The Monitoring and Assessment Program will consist of seven components: (1) monitoring of downbay shell plants pursuant to the decision to transplant the spatted shell upbay; (2) the measurement of spat settlement potential carried out from late June through late September; (3) monthly tracking of trends in growth and disease exposure for the shell plants; (4) a quantitative evaluation in October to determine the overall success of each year’s program at season’s end; (5) dredge calibration to determine the applicability of remote sampling by oyster dredge of shell plants; (6) survey of targeted oyster beds to improve bed areal estimates, where required, and (7) the development of a shell budget to evaluate the efficacy of the shell-planting program in maintaining habitat integrity.

4.0. EXISTING ENVIRONMENT

Estuarine environments like Delaware Bay are among the most productive on earth, creating more organic matter each year than comparably-sized areas of forest, grassland, or agricultural fields. It is the productivity of the estuary and the variety of its habitats that fosters such a wide abundance of wildlife and aquatic resources. These organisms are linked to one another through a complex food web. An estuary is critical to many species of aquatic creatures, birds, fish and other wildlife.

4.1. Physiographic Setting

The Delaware estuary lies at the seaward end of the Delaware River, which drains a 12,380 square mile area of the northeastern United States. The study area lies entirely within the Atlantic Coastal Plain Physiographic Province. This coastal area is a relatively flat plain with surface elevations rarely exceeding 100 feet above mean sea level.

4.2. Climate

The climate is considered subtropical in the Delaware Bay region, producing mild summer and winter seasons with only a few short hot, humid periods in summer, and cold, windy periods in winter. The summer weather is dominated by maritime tropical air masses which remain stable for several days at a time, creating high pressure systems. Continental, polar air masses in the winter produce rapidly moving fronts and intense weather patterns. The bay's coastlines are susceptible to strong beach erosion storms as a result of these weather patterns. Noreasters have a frequency of once every 2.5 years, and hurricanes occur about once every 5.5 years, producing an average of one storm every two years. Spring and fall are milder and are dominated by quickly changing air masses. The mean annual temperature in the bay region is a range of 55 to 57 degrees Fahrenheit. The annual precipitation for the area is about 45 inches, with the average monthly rainfall amounting to three or more inches. Temporary droughts, however, are not uncommon in summer.

4.3. Surficial Deposits

Medium-to-coarse sands dominate the mouth of the bay and extend upbay in narrow linear bands that coincide with the axes of the major tidal channels. Generally, the coarsest sands occur in the bottom of the estuary channels. Within any channel, the median grain diameter decreases in the upbay direction and away from the center of the channel. Very fine sands characterize the linear sand shoals, the channel margins, most of the Lower Jersey Platform and the area between Mispillion River and Lewes Harbor. Major departures from the upbay and shoreward fining pattern occur on the Upper Jersey Platform and the Cape May Shoal Complex, where sediments become coarser in the shoreward direction.

The mouth of the bay and the lower bay channels are characterized by poorly sorted medium-to-coarse sands with a low mud content. Sediments of this type also occur near shore along the Upper Jersey Platform. Finer sands with a highly variable mud content are found in most areas of the upper and middle bay and along the margins of the lower bay. Patches of very poorly sorted fine sands with a very high mud content occur throughout the bay, but occur most commonly along the Delaware shoreline of the middle and upper bay.

4.4. Subsurface Geology

The Delaware estuary extends approximately 133 miles from the head of tide at the Fall Line near Trenton, New Jersey to the Atlantic Ocean at Cape May, New Jersey and Cape Henlopen, Delaware. Between Trenton, New Jersey and New Castle, Delaware, the estuary parallels the Fall Line with early metamorphic rocks of the Piedmont on the west and unconsolidated coastal plain sediments on the east. South of New Castle, the lower tidal river and Delaware Bay are underlain by sediments of the Atlantic Coastal Plain. In the vicinity of the bay, a veneer of fluvial Pleistocene sands and gravels up to approximately 100 feet thick covers the older sediments of the Coastal Plain. The Pleistocene sediments form the Columbia Group in Delaware and the Cape May, Pennsauken and Bridgeton Formations in New Jersey. In most cases, Pleistocene sediments form the basal substrate upon which sediments of the Holocene marine transgression have been deposited. However, subsurface data suggest that sediments of the Cohansey Formation and Upper Chesapeake Group (Miocene) may possibly outcrop in Delaware Bay.

4.5. Bottom Substrate

Versar, Inc. (2001) conducted an oyster and water quality monitoring study in the Delaware Bay for the Philadelphia District USACE for the proposed Main Channel Deepening Project. In this study Versar was tasked to characterize the pre-construction conditions of the Delaware Bay through evaluation of water quality and existing oyster population health. The study was completed in collaboration with Rutgers University, Haskin Shellfish Research Laboratory. Nine existing oyster beds in Delaware and New Jersey were monitored on historic oyster beds and selected to cover a range of salinity gradients of naturally occurring oyster beds in both New Jersey and Delaware, thus they represented beds typical of high and low rates of mortality from predation and disease

Sediment grain size ranged from pebbles on the surface of medium-sand to medium-coarse sand to stiff clayey sediments. Versar, Inc. conducted a sediment profile study in 2001 using imagery at 50 stations. The predominant sediment type throughout the study area was fine-sand and occurred at 38% of the sampling stations.

4.6. Water Quality

In the Versar, Inc study (2001) water quality was monitored to assess physical/chemical data for the interpretation of oyster population and habitat health in the bay. The study also served a dual purpose in providing a means to evaluate predictions made using a three-dimensional hydrodynamic model of the estuary's salinity regime.

Water quality monitoring was conducted for nine months (May through November 2000 and March through April 2001) for temperature, pH, dissolved oxygen, salinity, turbidity, TSS (total suspended solids) and nutrient oyster "food"content (chlorophyll concentrations, organic nitrogen proteins, carbohydrates, and lipids). Water temperature was relatively consistent throughout the bay over the 2000/2001 monitoring period. Seasonal changes in water temperature progressed expectedly with spring warming into summer followed by cooling in the fall months.

Salinity was relatively stable in the bay during this same time period within particular sites. Measurements at each station varied within a 5-ppt range throughout the 9-month monitoring period. Although stable on a monthly scale, salinity did follow a seasonal pattern with lower measurements occurring in the warmer months. From May through mid-October, salinity generally ranged from 10 to 20 ppt depending on the station location. Differences in salinity between stations were consistent and reflected relative location in the salinity gradient of the bay. For the most part, salinity throughout the monitoring period was 10 ppt higher in the lower stations than the uppermost stations.

Measurements of pH were very stable in the bay over the 9-month monitoring period. From May to November 2000, pH closely averaged about 8 for the nine stations. In March and April 2001, measures were consistently higher and averaged 8.5 among the stations. Throughout the monitoring period, a slight gradient was apparent along the length of the bay with lower pH measured farther upstream.

Dissolved oxygen levels varied mostly according to season in the bay. From May through July, as water temperatures increase, DO concentrations decreased steadily from about 9 to 7 mg/L. Toward the end of August 2000 through November 2000, concentrations steadily increased to about 10 mg/L and ranged from 11 to 19 mg/L.

Turbidity in the bay was relatively stable over the monitoring period, although occasionally exceedingly high measures of turbidity were recorded. Concentrations at most stations ranged less than 50 NTU. Throughout the summer months (June through September) measures commonly ranged upwards to 100 NTU. During October and November 2000 and March and April 2001, turbidity was usually less than 100 NTU.

Delaware Bay is typically characterized by a strong early spring phytoplankton bloom, followed by low summer concentrations and then occasionally a fall bloom. In the Versar (2001) study, chlorophyll in Delaware Bay remained uniformly low over the summer growing season. Chlorophyll typically ranged less than 20 ug/L in May through November 2000. In contrast, much higher levels were recorded in early spring (2001). In March 2001 overall measures averaged close to 80 ug/L. By April, the number had halved. Thus, 2001 was considered a typical year. Throughout the monitoring period consistent differences were not readily apparent between stations.

Organic constituents of TSS, defining oyster food supply, were measured at four oyster bed monitoring stations. The sediment load supported by the waters of Delaware Bay was largely uniform throughout the bay and all seasons monitored. Concentrations of total suspended solids (TSS) measured in the lower water column ranged roughly less than 40 mg/L. Higher concentrations were more often measured at the two upper Bay stations and may reflect the higher current velocities present in the narrower portion of the estuary as well as their closer proximity to the turbidity maximum zone near the C&D Canal where salt and freshwater meet. Suspended particles tend to flocculate and fall out of the water column in this area. In early June, TSS measured at these two stations averaged 75-mg/L; in August and early September concentrations ranged from 60 to 120 mg/L; and in March of the following year the two stations averaged 60 mg/L.

Organic nitrogen (Total Kjeldahl Nitrogen) varied as chlorophyll concentrations in the lower water column. Higher concentrations were observed during early spring. The concentrations of lipids, proteins, and carbohydrates followed similar patters over the nine month sampling period. Concentrations of lipids were usually several times greater than other nutrients and averaged around 5 mg/L. Concentrations were variable and reflected a peak in productivity (around 10 mg/L in summer). Proteins averaged around 2.5 mg/L. Carbohydrates were consistently at or below 1 mg/L throughout the nine month monitoring period. The highest concentrations were measured at an upper bay station during mid-summer and ranged to 3.5 mg/L. These data are important for oysters for two reasons: 1) Oyster larvae require high lipid content food and the lipid:protein:carbohydrate ratio observed demonstrates a good food resource; and 2) The concentrations are highest during late summer when reproduction taxes adult oysters and when oyster larvae require high food concentrations for success (Versar, 2001).

4.7. Aquatic Invertebrates

Other than the American oyster (*C. virginica*) notable benthic aquatic organisms in the study area include the blue crab (*Callinectes sapidus*), and the horseshoe crab (*Limulus polyphemus*). A number of studies have been conducted on benthic invertebrate communities in Delaware Bay (Maurer *et al*., 1978; Kinner *et al*., 1974; Howe and Leathem, 1984; Leathem and Maurer, 1980; Howe *et al*., 1988). As is common in marine benthic systems, there is considerable spatial and temporal heterogeneity in species composition and organism density. Bottom type and salinity are primary determining factors in community structure. Other commonly occurring species are *Tellina agilis* (bivalve), *Ensis directus* (bivalve), *Glycera dibranchiate* (polychaete), *Heteromastus filimformis* (polychaete), *Gemma gemma* (bivalve), *Nethtys picta* (polychaete), *Mulinia lateralis* (bivalve), *Neomysis americana* (crustacean), *Nucula proxima* (bivalve), and *Protohaustorius wegleyi* (crustacean).

Hard clams (*Mercenaria*) are distributed from Port Mahon to Cape Henlopen. They are currently not commercially harvested in Delaware Bay. The blue crab (*C. sapidus*) is ubiquitous in Delaware Bay and functions as a predator in the estuarine ecosystem. Blue crabs support a commercial industry in the bay. A pot fishery occurs in the near shore region north of Port Mahon, primarily during the warmer months (May to

October). A winter crab dredging fishery takes place in the lower bay when the crabs have dug into the sediments in deeper waters to over-winter (U.S. Fish and Wildlife Service).

A small lobster fishery is located primarily on the outer breakwater near Cape Henlopen. The lobsters find favorable cover among the rocks, and the associated fish and invertebrates are a good source of food. Harvesting occurs mostly during the summer and to a lesser extent during the cooler seasons. This is a cyclic fishery that has been low during most recent years (Delaware Divison of Fish and Wildlife).

Four species of mud crab were collected in the Versar, Inc. study (2001). *Rithropanopeus harrisii* was relatively uncommon. The other three species *Dyspanopeus sayi, Eurypanopeus depressus,* and *Panopens herbstii* were more common. *D. sayi* and *P. herbstii* were collected from the higher salinity beds from Bennies downbay. *E. depressus* was more widespread in abundance across the salinity gradient. Mud crab abundance increased with increasing salinity. Seasonal cycles in abundance were not dramatic or consistent among sites.

Horseshoe crabs (*L. polyphemus*) are ancient arthopods that play a very prominent and vital role in Delaware Bay. Each spring, horseshoe crabs migrate into the bay to spawn within the intertidal zone of sandy beaches. Eggs are laid in tightly bundled clumps in nests dug 2-8 inches below the sand surface. The high concentration of horseshow crab eggs is vital to migratory shorebirds, who feed on the eggs unintentionally excavated by other spawning horseshoe crabs, to fuel the remainder of their trip to Arctic nesting grounds.

4.7.1. Parasitism and Health

Common oyster parasites include two disease-causing organisms, *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (Dermo), and the relatively benign *Nematopsis.* A suite of other less common parasites were also identified (Versar, 2001). These include gill ciliates, large and small ciliates in the gut and digestive gland, *Bucephalus* trematodes, xenomas, and rickettsial bodies. Rare parasites include the trematode *Proctoeces,* nematodes and parasitic copepods. In addition to parasites, ceroid bodies were also observed in abundance. Ceroid bodies are thought to be indicative of stress, although cause and effect is not well established.

At one time, *H. nelsoni* was the principal cause of mortality in market-size oysters in Delaware Bay. Prevalences of this parasitic infection have been low however, since 1990. Delaware Bay oysters are believed to have built up immunity to this disease. In 2000, prevalence rarely exceeded 20%, and typically at sites with the highest salinity. Generally, prevalences peaked in early spring and again in June. This pattern is typical of the life history dynamics of this organism (Ford *et al*., 1999).

Perkinsus marinus is presently the primary cause of adult oyster mortality in the bay. Prevalence and infection intensity decline with lower salinities. Prevalence and infection intensity typically peak in late summer and early fall when temperatures are highest (Hofmann *et al*., 1995). Mortality rates for this disease typically run from <10% up-bay to >50% down-bay with the bay-wide average between 10-35%. Dermo epizootics have occurred in half of the years, on average since 1990.

Nematopsis spp. is the most prevalent oyster parasite on the East and Gulf coasts of the U.S. Although infection intensities can reach hundreds of cells per tissue section, the parasite appears to produce little or no pathological effect. The final host is the mud crab. In 2000 *Nematopsis* was found at all sites (Versar, 2001). Highest infection intensities occurred on Ship John and Bennies. Larger oysters tended to have infection intensities similar to smaller oysters, indicating that infection intensity increased linearly with size. Little seasonality was observed in infection intensity.

Bucephalus trematodes were rare and encountered principally in late summer and early fall (Versar, 2001). Rickettsial bodies were most common in June and in oysters from Ship John, but otherwise, rarely observed. Ciliates were more commonly and consistently encountered. Small gill ciliates were most abundant in spring and in oysters from Bennies and Lease 544D. Large ciliates were found in the gut, gill, mantle and digestive gland. These ciliates were observed through the year on all oyster beds. Small oysters had a disproportionate infection intensity, indicating that infections lessen with age.

4.7.2. Predators

Predation accounts for a significant fraction of total mortality (mostly spat and juveniles) (Versar, 2001). Although identified predatory events never account for the majority of observed deaths, the focus of predators should be on the smaller and more easily overlooked individuals. Thus, emphasizing the importance of disease in controlling adult oyster population dynamics. Nevertheless, predatory mortality accounts for upwards of 30% of the juvenile oyster population annually (E. Powell, pers. comm.). Like the diseases MSX and Dermo, the distribution of predators is consistent with the higher mortality rates down-bay at the higher salinity sites. Predators include mud crabs, blue crabs, and drills. Blue crabs were relatively rare and sporadic in the oyster dredge captures as these were insufficient sampling devices for blue crabs (Versar, 2001). Drills were mostly caught on higher-salinity sites: Bennies, New Beds, Egg Island, and Lease 554D. Numbers tended to be highest in the summer because drills migrate into deeper water or burrow into the sediment as the weather cools. Two drill species captured, *Urosalpinx cinerea* and *Eupleura caudate* were collected at the same sites. *E. caudata* tended to be present in early and late summer. *U. cinerea* tended to be present more uniformly over the year.

4.7.3. Fouling Organisms

Most bionts were observed on the outer surface of the shell (Versar, Inc., 2001). Bionts on the inner surface were limited to borers. *Polydora* was the most abundant borer species observed. Outer shell bionts included bryozoans, encrusting polychaetes, and sabellariids. Other bionts included egg cases, fungi, green algae, hydroids, and molluscs. Generally, temporal trends were not apparent over all sites. Coverage tended to increase with increasing salinity.

Molluscan epibionts included oysters, ribbed mussels (*Brachidontes* spp.), and *Crepidula* gastropods. Molluscan bionts were most common at the two Delaware sites, Over-the-Bar and Lower Middle. *G. demissa* was also commonly found on New Beds and Bennies. The time series showed distinctively lower coverages during the summer months. Oysters were routinely found as "bionts" on other oysters. Their occurrence was particularly common at the two Delaware sites where the vertical "clump" structure typical of reefs best developed. Temporal trends were not observed.
Encrusting polychaetous bionts include sabellariids, serpulids, and mudtube-dwelling polychaetes such as terebellids. Coverage was highest in spring and declined during the summer months. Mudtubes increased in abundance with increasing salinity in a nearly monotonic fashion. Sabellariid polychaetes were most common at two Delaware sites and a leased bed site. However no time-dependent trends were present. Serpulid tubes were much more common on the lease bed site than elsewhere. Coverage increased with increasing salinity at the other sites and showed a decline in late summer.
Barnacles were most abundant at Arnolds, and somewhat more abundant at Ship John and Nantuxent Point than at other sites. Coverage did not show a significant temporal trend.

Bryozoans were both of the encrusting form (e.g. *Electra*, *Membranipora*) and the erect forms (e.g. *Bugula*, *Alcyonidium*, *Amathia*). Total bryozoan coverage was highest at Arnolds, Bennies, Nantuext Point and Lease 554D. Erect bryozoans were most common at the highest salinity sites, Egg Island and Lease 554D.   Encrusting sponges (e.g. *Microciona*) were present in highest abundance at the higher salinity sites but not all of them. Coverage at Bennies, New Beds, and Egg Island was much higher than at other sites. Coverage peaked in late summer in 2000 and then peaked again in March 2001 Hydroids were present in greatest abundance on the New Jersey side of the bay. Abundance was high at five of seven New Jersey sites. A few anemones and tunicates were present. The organisms were present in highest abundance on Lease 554D.

The boring sponges are most significant in impacting habitat complexity because these species rapidly degrade oyster shell over time. Consequently, healthy oyster beds require a resupply of shell by natural mortality or shell planting. This continued need increases down-bay because boring sponges are so abundant, as does the inherent productivity of non-diseased oyster populations that tend to balance shell losses. Disease destabilizes this system by reducing natural shell production in areas where natural shell destruction is greatest, thus resulting in long-term reduction in habitat quality.

It should be noted that of these bionts, mussels are most significant in influencing oyster population dynamics in that they compete with oysters for food. Their abundances are rarely sufficient however, to influence oyster growth and reproduction. Overall, the overwhelming impact of all bionts is the loss of shell area for oyster larval attachment. Most shell surface is already occupied, hence the successful planting of clean shell provides or enhances the available surface area for larval settlement.

4.7.4. Oyster Population Characteristics

Oyster seed beds in Delaware Bay have been recognized as a public resource for over 150 years. They have been regulated as a single entity although it is clear that they have differing characteristics depending on their location along the salinity gradient. New Jersey natural seed oyster beds are separated into four separate salinity regions. Oysters on the uppermost beds typically survive well because they are rarely affected by predation and do not experience high levels of disease-related mortality. However, upper bed oysters are thin-shelled, and low growing. These oysters frequently grow in clusters, which makes them less desirable for market because of increased handling. Survival on these upper beds (Round Island, Upper Arnolds, and Arnolds) is primarily controlled by low salinities. Mean salinity in this range is approximately 10.8 parts per thousand (ppt). This salinity is below the threshold for predator and MSX disease activity, but within the tolerance limits for Dermo. Because of the general physiological condition of these oysters, they are rarely harvested by the oyster industry for transplanting. The contribution of these beds to the total harvest has been less than 5%. These beds are currently in a long-term state of decline due to recruitment rates that have been below average for more than a decade (HSRL, 2005).

Oysters at the downbay sites are characterized by good growth and market quality. However, stocks in this range are frequently exposed to intense predation and disease activity. During periods of high disease activity, oyster populations on the lowermost beds (Egg Island, Ledge, and to a somewhat lesser extent New Beds) can be severely reduced. Mean salinity in this region is approximately 19.9 ppt. Since 1996, these beds have provided less than 5% of the total oyster harvest as well.

Typically, the majority of the annual oyster harvest comes from the beds distributed within a region classified as the intermediate zone. This zone includes all the beds from New Beds to Upper Middle. Survival, growth, and market quality can vary widely within this region but are best within these beds. These beds account for over 90% of the total harvest in New Jersey. Mean salinity for this bed region ranges from 16.1 ppt in the lower end to 12.8 ppt in the upper portion.

In addition to differences in oyster growth and survival, there are also differences in the setting patterns of oyster larvae over the range of beds. Although setting will occur throughout the range of the seed beds, the most reliable setting areas are along the nearshore. With the greatest set potential below Ben Davis Point.

4.8. Fish

The Delaware estuary is home to over 100 species of finfish, many of which are commercially and recreationally important. This great diversity is the result of the overlap between northern and southern species in the mid-Atlantic coastal region. Many species use the estuary as a breeding ground and nursery area for their young. The warm, shallow, near-shore and marsh nursery waters shelter small fish from predators and provide them with food while the deeper, cooler waters serve as feeding grounds for larger fish. The majority of adult fish species in the Delaware estuary are predators at or near the top of the food web, eating plankton, smaller fish, and invertebrates such as crabs, snails, and worms. Surveys of the finfish of Delaware Bay have been conducted by the Delaware Division of Fish and Wildlife for years. Abundant finfish species in the bay include the red hake (*Urophycis chuss*), northern sea robin (*Prionotus carolinus*), spot (*Leiostomus xanthurus*), windowpane flounder (*Scopthalmus aquosus*), silver hake (*Merluccuns bilinearis*), bluefish (*Pomatomis saltatrix*), croaker (*Pogonias cromis*), summer flounder (*Paralichthys dentatus*), clearnose skate (*Raja eglanteria*), hogchoker (*Trinectes maculates*), and weakfish (*Cynocion regalus*). Many of these species use oyster beds as a source of food and are directly dependent on the maintenance of shell surface area to support the food resources important to their survival.

4.9. Threatened and Endangered Species

The shortnose sturgeon (*Acipenser brevirostrum*), an endangered fish species within the purview of the National Marine Fisheries Service, migrates through the project area in the spring from the sea to spawn in the upper estuary. Most of the fish have been observed in the upper tidal freshwater area of the Delaware River, but they also access the bay, especially during winter months.

Sea turtles, especially the loggerhead (*Caretta caretta*), the Kemp's ridley (*Lepidochelys kempii)*, green (*Chelonia mydes*), and leatherback (*Dermochelys coriacea*) may occur in the lower Delaware Bay from June to November.

Six species of endangered whales have been observed migrating along the Atlantic Coast, and are occasionally seen in the lower bay. These whales include the sperm whale (*Physeter catadon*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), blue whale (*Balaenoptera musculus*), sei whale *(Balaenoptera borealis*), and black right whale (*Balaena glacialis*). All marine mammals are protected by Federal law.

4.10. Cultural Resources

There are no known shipwrecks or deeply buried prehistoric or historic archaeological deposits in the project area. Shallow archaeological deposits, if they ever existed, would likely have been removed by past oyster harvesting.

5.0. ENVIRONMENTAL EFFECTS

The goal of this project is to increase Eastern oyster abundance in Delaware Bay. The historical role of the Eastern oyster is widely appreciated as a keystone species in the Delaware estuary. Oysters control phytoplankton abundance and alter estuarine food webs through benthic-pelagic coupling and serve an important role in improving water quality within the system. The Eastern oyster constructs biogenic habitats that provide refugia, nesting sites, and foraging grounds for a variety of resident and transient species. Numerous studies reveal greater biodiversity associated with oyster reefs than with adjacent sedimentary habitats. Species richness and abundance of organisms in oyster reef habitats are generally comparable to those found in seagrass meadows (Coen and Luckenback, 1999). The objective of this project to increase oyster abundance within Delaware Bay is the same as the goal of the Oyster Industry Revitalization Task Force (OIRTF): to enhance recruitment by enhancing natural seed supply through the planting of shell (cultch) in a timely fashion, thus providing habitat for recruitment of juvenile oysters (spat). Delaware Bay is now in its seventh year of well below average recruitment (less than 0.5 spat per oyster per year). Seven such consecutive years is unprecedented for the 54-year record for which detailed survey data are available (1952-2005). A secondary goal is to provide shell to maintain the shell beds. Delaware Bay oyster reefs have lost, on average, about 500,000 bushels of shell per year to dynamic processes and oyster abundance is now too low to replace this shell naturally, thus endangering the future of the shell bed.

The proposed project will continue the shell-planting program that was initiated in 2005 (USACE 2005, USACE, 2006). The plan will have minimal effects on bottom topography and substrate as shells will be planted only on existing oyster shell beds or oyster lease areas. The approach differs somewhat between the two states to take advantage of local conditions conducive to the enhancement of oyster spat productivity. There are significant differences in the setting patterns of oyster larvae over the range of natural seed beds, as well as some inshore areas within state leased grounds. Although setting will occur throughout the range of the seed beds, the most reliable setting areas are nearshore and downbay on the New Jersey side of the bay. The greatest set potential occurs in the nearshore areas below Ben Davis Point. Even greater consistency in yearly recruitment occurs downbay in the Cape Shore area. However, historically consistent setting in these areas does not result in historically high abundances of marketable oysters due to high predator mortalities of spat and juveniles. Hence, spat recruited to these areas must be moved to more productive grounds soon after settlement. This reality guides the three-prong approach to be used.

Adequate oyster bottom habitat is available in New Jersey, however habitat quality is low on some beds due to limited oyster abundance. In addition, shell loss has become a significant issue for some beds. These beds offer excellent opportunities for enhancement and simultaneously shell planting can repair the shell deficit that exists. Thus, the primary goal on the New Jersey beds will be directed at increasing recruitment rather than re-establishing productive bottom and simultaneously address the shell loss issue. Shell will be planted at the time of maximum setting potential. The 2007 Stock Assessment Workshop for the New Jersey Delaware Bay Oyster Beds recommends the Ship John region, the Cohansey, as well as Nantuxent Point, Hawk's Nest, Hog Shoal, Vexton, and Strawberry as optimum planting locations. The 2005 and 2006 shell plants demonstrated that recruitment can be enhanced by direct addition of shell to existing oyster beds in this region. NJDEP Division personnel will survey prospective areas. These areas will then be planted with clean cultch at the appropriate time to provide a suitable substrate for oyster larval attachment. As management of the New Jersey beds focuses on sustaining and increasing adult abundance, this proposal will also result in a long-term increase in oyster abundance.

In addition to nearshore areas, downbay inshore sites will also be planted with shell in shallow nearshore areas of the lower bay off Cape May County and on leased grounds south and east of Egg Island Point. The Cape Shore of Delaware Bay has been utilized for the collection of native spat for over 60 years and lease holders routinely plant shell south and east of Egg Island Point. The outstanding feature of this area of the bay is the consistent, high-density setting of oysters that occurs in mid-summer. Cape Shore plantings dating back to the 1920s have demonstrated spat counts that often exceeded 7,500 spat per bushel. Set failures (less than 500 surviving spat per bushel) are rare occurrences, seldom exceeding once every 15 years. A pilot study planting of 40,000 bushels in this area in 2003 was highly successful and 2005 and 2006 shell plants produced >800 spat/bushel. Selected plots will be planted with clean cultch at the appropriate time to provide a suitable substrate for oyster larval attachment. NJDEP Division personnel will monitor spat set to identify the best time for shell recovery and transplant upbay. When a desired number is present, spatted cultch will be recovered by dry dredge or suction dredge and moved to upbay nursery areas.

The natural seed beds from north of Arnold's Point to False Egg Island Point (the intermediate areas and inshore) will also undergo direct shell planting to enhance settlement. The seed beds in this area of the bay are identified as Bennies, Bennies Sand, Shell Rock, Sea Breeze, Cohansey, Ship John and Middle, Strawberry, Vexton, Hawk's Nest and Hog Shoal seed beds.

The shell planting program in Delaware will provide needed shell cultch on state-owned natural oyster bars such as Ridge, Lower Middle, Over the Bar, Silver, Drum, or Pleasanton's Rock. Surveying prior to planting will be used to determine which sites will receive shell in the 2007. These beds historically have suffered loss in production due to siltation. Recruitment has been at record low levels since 2000 on all natural oyster beds in Delaware. The Ridge was not harvested for 15 years prior to opening in 2001. There has been some limited harvesting on the other beds during the period between 1991 and 1995 but all Delaware beds were closed during the period between 1996 and 2000. The shell planting is designed to increase the productive area by adding to bed height while expanding available cultch.

Planting methodologies entail the use of barges for shell transport and raw-water pumps to spray a thin layer of shell overboard on the beds. Transplant methods entail the use of traditional oyster dredge, suction or dry dredge vessels and a raw-water pump for re-planting. Powell *et al*. (2001, 2004) conducted studies to assess the impact of these dredging mechanisms for shell transplanting. Impacts on both the oyster reef and bay bottom as well as to the viability of the oysters were evaluated. No significant effects could be discerned on oyster growth, disease pressure, and mortality from repeated dredging. With respect to the type of dredging equipment used, although catch rates vary with equipment utilized, neither method proved deleterious to bottom complexity, cultch availability, oyster growth, mortality, or population health.

5.1. Water Quality

The project will generate very limited short-term impacts on water quality and in the long-term, the project will positively affect water quality. An increase in oyster abundance will increase water clarity through filtration. Short-term, nominal adverse impacts to water quality may result from the actual placement of shell in the immediate area of the placement activities. Placement of shell on the bay bottom will result in a temporary elevation of turbidity during operations but this will dissipate very quickly upon completion because the particle size is large (>20mm) with a high sinking rate. No adverse impacts to water quality, including oxygen depletion or the release of chemical substances are anticipated as shell is a natural substance that is already present in high concentrations within the bay and carries with it a very low oxygen demand and inconsequential levels of contaminant risk. To minimize the impact on oxygen demand, only cured shell will be used: shell stored on land for a sufficient amount of time as to insure that any associated shellfish meat left by the shucking process will have decomposed prior to shell planting. Mobile organisms such as fish and crabs can temporarily vacate the area whereas benthic organisms associated with the existing oyster beds will only be temporarily impacted by the increased turbidity levels during the shell planting procedure. Shell planting for recruitment enhancement requires planting shell in a thin veneer to optimize surface area in contact with the water, consequently burial and mortality of benthic biota will be low; typically near zero. No previous studies, to date, have identified a negative environmental impact of shell planting.

5.2. Air Quality

The Delaware Bay Oyster Restoration Project would take place in Delaware Bay in portions of the States of New Jersey and Delaware. This area is classified as moderate nonattainment for ozone (oxides of nitrogen [NOx] and volatile organic compounds [VOCs]). Delaware Bay, New Jersey and Delaware is within the Philadelphia-Wilmington-Trenton Nonattainment Area (PA-NJ-DE-MD). The 1990 Clean Air Act Amendments include the provision of Federal Conformity, which is a regulation that ensures that Federal Actions conform to a nonattainment area's State Implementation Plan (SIP) thus not adversely impacting the area's progress toward attaining the National Ambient Air Quality Standards (NAAQS). Appendix B provides a General Conformity Analysis for this project.

The total estimated emissions that would result from construction of the Delaware Bay Oyster Restoration Project are 1.85 tons of NOx and 0.29 tons of VOCs. These emissions are below the General Conformity trigger levels of 100 tons of NOx and 50 tons VOCs per year. General Conformity under the Clean Air Act, Section 176 has been evaluated for the project according to the requirements of 40 CFR 93, Subpart B. The requirements of this rule are not applicable to this project because the total direct and indirect emissions from the project are below the conformity threshold values established at 40 CFR 93.153 (b) for ozone (NOx and VOCs) in a Moderate Nonattainment Area (100 tons NOx and 50 tons VOCs per year). The project is not considered regionally significant under 40 CFR 93.153 (i).

5.3. Threatened and Endangered Species

From June through November, Delaware Bay is inhabited by transient sea turtles, especially the loggerhead (Federally-listed threatened *C. caretta*) or Kemp's ridley (Federally-listed endangered *L. kempii*). The shortnose sturgeon (*A. brevirostrum*), although usually present in the upper freshwater reaches of the estuary, uses the bay for migration in the spring. Sea turtles and the endangered shortnose sturgeon are under the purview of the National Marine Fisheries Service (NMFS). They are very mobile species and would be expected to vacate the immediate area where shell planting will take place and are not expected to be adversely impacted by the proposed project.

5.4. Essential Fish Habitat

Under provisions of the reauthorized Magnuson-Stevens Fishery Conservation and Management Act of 1996, the Delaware River and Bay from New Castle, DE and Pennsville, NJ to the mouth of the Bay at the Atlantic Ocean is designated as Essential Fish Habitat (EFH) for species with Fishery Management Plans (FMP's), and their important prey species. The National Marine Fisheries Service has identified EFH within 10 minute X 10 minute squares (Table 5-1). Since this study encompasses the entire Delaware Bay, in the essence of time, the Essential Fish Habitat assessment for the Delaware River Main Channel Project is provided here for review. The Main Channel Deepening study area contains EFH for various life stages for 26 species of managed fish and shellfish. Table 5-2 presents the managed species and their life stage(s) that EFH is identified for within the 10 x 10 minute squares that cover the study area. The habitat requirements for identified EFH species and their representative life stages are provided in Table 5-3.

TABLE 5-1. 10 MINUTE X 10 MINUTE SQUARES THAT CONTAIN ESSENTIAL FISH (NOAA, 1999)				
Square Number	**Coordinates**			
	North	**East**	**South**	**West**
31	39° 40,0' N	75° 30,0' W	39° 30.0' N	75° 40.0' W
38	39° 30.0' N	75° 30.0' W	39° 20.0' N	75° 40.0' W
39	39° 30.0'N	75° 20.0' W	39° 20.0' N	75° 30.0' W
48	39° 20.0' N	75° 20.0' W	39° 10.0' N	75° 30.0' W
49	39° 20/0' N	75° 10.0' W	39° 10.0' N	75° 20.0' W
50	39° 20.0' N	75° 00.0' W	39° 10.0' N	75° 10.0' W
59	39° 10.0' N	75° 20.0' W	39° 00.0' N	75° 30.0' W
60	39° 10.0' N	75° 10.0' W	39° 00.0' N	75° 20.0' W
61	39° 10.0' N	75° 00.0' W	39° 00.0' W	75° 10.0' W
70	39° 00.0' N	75° 10.0' W	38° 50.0' N	75° 20.0' W
71	39° 00.0' N	75° 00.0' W	38° 50.0' N	75° 10.0' W
80	38° 50.0' N	75° 10.0' W	38° 40.0' N	75° 20.0' W
81	38° 50.0' N	75° 00.0' W	38° 40.0' N	75° 10.0' W
90	38° 40.0' N	75° 00.0' W	38° 30.0' N	75° 10.0' W

Habitat Areas of Particular Concern (HAPC) . A review of EFH designations and the corresponding 10 x 10 minute squares, which encompasses numbers 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, and 90 contain areas designated as "Habitat Areas of Particular Concern" (HAPC) for the sandbar shark. HAPC are areas of EFH that are judged to be particularly important to the long-term productivity of populations of one or more managed species, or to be particularly vulnerable to degradation (NOAA, 1999).

Sandbar sharks use the shallows of Delaware Bay as an important seasonal nursery ground. The juvenile sharks (1 to 6 yr. old) return to the Bay from wintering grounds in the Carolinas, in mid May. Adult females visit the Bay to pup (deliver live-born young) in the first weeks of June. This has not been directly observed yet, many young caught in June bear fresh umbilical cord remnants and all have open umbilical scars indicating very recent birth. Newborns weigh about 1.5 pounds and are about 1.5 feet in length. Tag returns show that they stay in the bay feeding throughout the summer and depart for their winter (secondary) nurseries when the waters turn cool in mid October. Most newborns are found on the shallow flats in the Southwestern Bay although they seem to radiate out and use more of the Bay during the summer, as they get larger. Telemetry studies show that juveniles cross the bay mainly on the bottom. They are bottom feeders, preying on fish, particularly flat fish, crabs (blue crabs and spider crabs) and other benthic organisms.

TABLE 5-2. SUMMARY OF SPECIES WITH EFH DESIGNATION IN THE 10 min. x 10 min. SQUARES OF 31, 38, 39, 48 49, 50, 59, 60, 61, 70, 71, 80, 81, and 90 and Mixing Zone (MZ) (NOAA, 1999)				
MANAGED SPECIES	**EGGS**	**LARVAE**	**JUVENILES**	**ADULTS**
Atlantic cod *(Gadus morhua)*				81
Red hake *(Urophycis chuss)*	31,71, 81	31, 71, 81	71, 81	59,60,61,70, 71, 80, 81
Red fish (*Sebastes fasciatus*)	90			
Winter flounder (*Pleuronectes americanus*)	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, MZ	31, 38,39,48, 49, 50, 59, 60, 61, 70, 71,80, 81, 90, MZ	31, 38,39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, MZ	31,38,39,48, 49,50,59,60,661, 70, 71,80,81, 90, MZ*
Windowpane flounder *(Scopthalmus aquosus)*	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81,90, MZ	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81,90, MZ	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, MZ	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, MZ*
American plaice (*Hippoglossoides platessoides*)			MZ	
Atlantic sea herring *(Clupea harengus)*			48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, MZ	48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90
Monkfish *(Lophius americanus)*	81, 90	81, 90		
Bluefish *(Pomatomus saltatrix)*			31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, MZ	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, MZ
Long finned squid *(Loligo pealei)*	n/a	n/a		71
Short finned squid *(Illex ilecebrosus)*	n/a	n/a		
Atlantic butterfish *(Peprilus tricanthus)*		59, 60, 61, 70, 71, 80, 81	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, MZ	59, 60, 61, 70, 71, 80, 81, 90
Summer flounder *(Paralicthys dentatus)*		90	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, MZ	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, MZ
Scup *(Stenotomus chrysops)*	n/a	n/a	31, 38, 39, 48, 49, 50,59, 60, 61, 70, 71, 80, 81, 90, MZ	31, 38, 39, 48, 49, 50, 90
Black sea bass *(Centropristus striata)*	n/a	81	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, MZ	59, 60, 61, 70, 71, 80, 81, 90
Ocean quahog *(Artica islandica)*	n/a	n/a		
Spiny dogfish *(Squalus acanthias)*	n/a	n/a	71	81
King mackerel *(Scomberomorus cavalla)*	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90
Spanish mackerel *(Scomberomorus maculatus)*	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90
Cobia *(Rachycentron canadum)*	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90	31, 38, 39, 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90
Sand tiger shark *(Odontaspis taurus)*		50, 59, 60, 61, 70, 71, 80, 81, 90		59, 60, 61, 70, 71, 80, 81, 90
Atlantic angel shark *(Squatina dumerili)*		71, 81, 90	71, 81, 90	71, 81, 90
Dusky shark *(Charcharinus obscurus)*		48, 49, 50, 60, 61, 70, 71, 80, 81, 90		
Sandbar shark *(Charcharinus plumbeus)*		**HAPC** , 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90	**HAPC** , 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90	**HAPC** , 48, 49, 50, 59, 60, 61, 70, 71, 80, 81, 90
Scalloped hammerhead shark (*Sphyrna lewini)*			71, 81, 90	
Atl. Sharpnose shark (*Rhizopriondon terraenovae*)		71, 81, 90	71, 81	71, 81, 90

"n/a": species either have no data available on designated lifestages, or those lifestages are not present in the species reproductive cycle. HAPC: (Habitat Areas of Particular Concern): EFH that is judged to be particularly important to the long-term productivity of populations of one or more managed species, or to be particularly vulnerable to degradation.

TABLE 5-3. HABITAT UTILIZATION OF IDENTIFIED EFH SPECIES AND THEIR SUMMARY OF SPECIES WITH EFH DESIGNATION IN THE 10 min. x 10 min. SQUARES OF 31, 38, 39, 48 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, and Mixing Zone (NOAA, 1999)

MANAGED SPECIES	EGGS	LARVAE	JUVENILES	ADULTS
Atlantic cod *(Gadus morhua)* (Fahay, 1998)				**Habitat:** Bottom (rocks, pebbles, or gravel) winter for Mid-Atlantic **Prey:** shellfish, crabs, and other crustaceans (amphipods) and polychaetes, squid and fish (capelin redfish, herring, plaice, haddock).
Red hake *(Urophycis chuss)* (Steimle et al. 1998)	**Habitat:** Surface waters, May – Nov.	**Habitat:** Surface waters, May –Dec. Abundant in mid- and outer continental shelf of Mid-Atl. Bight. **Prey:** copepods and other microcrustaceans under floating eelgrass or algae.	**Habitat:** Pelagic at 25-30 mm and bottom at 35-40 mm. Young inhabit depressions on open seabed. Older juveniles inhabit shelter provided by shells and shell fragments. **Prey:** small benthic and pelagic crustaceans (decapod shrimp, crabs, mysids, euphasiids, and amphipods) and polychaetes).	
Red fish (*Sebastes fasciatus*)	n/a			
Winter flounder (*Pseudopleuronectes americanus)* (NOAA, 1999); Pereira et al, 1998; McClane, 1978)	**Habitat:** Mud to sand or gravel; from Jan to May with peak from Mar to April in 0.3 to 4.5 meters inshore; 90 meters or less on Georges Bank. 10 to 32 ppt salinity.	**Habitat:** Planktonic, then bottom oriented in fine sand or gravel, 1 to 4.5 m inshore. 3,2 to 30 ppt. salinity. **Prey:**nauplii, harpacticoids, calanoids, polychaetes, invertebrate eggs, phytoplankton.	**Habitat:** Shallow water. Winter in estuaries and outer continental shelf. Equally abundant on mud or sand shell. **Prey:** copepods, harpacticoids, amphipods, polychaetes	**Habitat:** 1-30 m inshore; less than 100m offshore; mud, sand, cobble, rocks, boulders. **Prey:** omnivorous, polychaetes and crustaceans.
Windowpane flounder *(Scopthalmus aquosus)* (Chang, 1998)	**Habitat:** Surface waters, peaks in May and October.	**Habitat:** Pelagic waters.	**Habitat:** Bottom (fine sands) 5-125m in depth, in nearshore bays and estuaries less than 75 m **Prey**: small crustaceans (mysids and decapod shrimp) polychaetes and various fish larvae	**Habitat:** Bottom (fine sands), peak spawning in May, in nearshore bays and estuaries less than 75 m **Prey**: small crustaceans (mysids and decapod shrimp) polychaetes and various fish larvae

Atlantic sea herring *(Clupea harengus)* (Reid et al., 1998)			**Habitat:** Pelagic waters and bottom, < 10 C and 15-130 m depths **Prey:** zooplankton (copepods, decapod larvae, cirriped larvae, cladocerans, and pelecypod larvae)	**Habitat:** Pelagic waters and bottom habitats; **Prey:** chaetognath, euphausiids, pteropods and copepods.
Monkfish *(Lophius americanus)* (Steimle et al., 1998)	**Habitat:** Surface waters, Mar. – Sept. peak in June	**Habitat:** Pelagic waters in depths of 15 – 1000 m along		

TABLE 5-3. HABITAT UTILIZATION OF IDENTIFIED EFH SPECIES AND A SUMMARY OF SPECIES WITH EFH DESIGNATION IN THE 10 min. x 10 min. SQUARES OF 31, 38, 39, 48 49, 50, 59, 60, 61, 70, 71, 80, 81, 90, and Mixing Zone (NOAA, 1999)

MANAGED SPECIES	EGGS	LARVAE	JUVENILES	ADULTS
	in upper water column of inner to mid continental shelf	mid-shelf also found in surf zone **Prey:** zooplankton (copepods, crustacean larvae, chaetognaths)		
Bluefish *(Pomatomus saltatrix)*			**Habitat:** Pelagic waters of continental shelf and in Mid Atlantic estuaries from May-Oct.	**Habitat:** Pelagic waters; found in Mid Atlantic estuaries April – Oct.
Long finned squid *(Loligo pealei)*	n/a	n/a		
Short finned squid *(Illex ilecebrosus)*	n/a	n/a		
Atlantic butterfish *(Peprilus tricanthus)*		**Habitat**: Pelagic waters, greater than 33 ft deep	**Habitat:** Pelagic waters in 10 – 360 m	**Habitat:** Pelagic waters
Summer flounder *(Paralicthys dentatus)*		**Habitat:** Pelagic waters, nearshore at depths of 10 – 70 m from Nov. – May	**Habitat:** Demersal waters (mud and sandy substrates)	**Habitat:** Demersal waters (mud and sandy substrates). Shallow coastal areas in warm months, offshore in cold months
Scup *(Stenotomus chrysops)*	n/a	n/a	**Habitat:** Demersal waters	**Habitat:** Demersal waters offshore from Nov – April
Black sea bass *(Centropristus striata)*	n/a	**Habitat**: Pelagic and estuarine.	**Habitat:** Demersal waters over rough bottom, shellfish and eelgrass beds, man-made structures in sandy-shelly areas, *Sabellaria* reefs	**Habitat:** Demersal waters over structured habitats (natural and man-made), and sand and shell areas, *Sabellaria* reefs.
Ocean quahog *(Artica islandica)*	n/a	n/a		
Spiny dogfish *(Squalus acanthias)*	n/a	n/a		
King mackerel *(Scomberomorus cavalla)*	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone.	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone
Spanish mackerel *(Scomberomorus maculatus)*	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory

Cobia *(Rachycentron canadum)*	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory	**Habitat:** Pelagic waters with sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters from the surf to the shelf break zone. Migratory
	break zone. Migratory	break zone. Migratory		
Sand tiger shark *(Odontaspis taurus)*		**Habitat:** Shallow coastal waters, bottom or demersal		**Habitat:** Shallow coastal waters, bottom or demersal
Atlantic angel shark *(Squatina dumerili)*		**Habitat:** Shallow coastal waters,	**Habitat:** Shallow coastal waters	**Habitat:** Shallow coastal waters, bottom (sand or mud near reefs)
Dusky shark *(Charcharinus obscurus)*		**Habitat:** Shallow coastal waters		
Sandbar shark *(Charcharinus plumbeus)* Pratt, 1999		**Habitat:** Shallow coastal waters; submerged flats (1-4 m). Important nursery area off Broadkill and Primehook beaches.	**Habitat:** Shallow coastal waters; submerged flats (1-4 m) Important nursery area off Broadkill and Primehook beaches.	**Habitat:** Shallow coastal waters; submerged flats (1-4 m)
Scalloped hammerhead shark *(Sphyrna lewini)*			**Habitat:** Shallow coastal waters	
Atl. sharpnose shark *(Rhizopriondon terraenovae)*		**Habitat:** Shallow coastal waters	**Habitat:** Shallow coastal waters	**Habitat:** Shallow coastal waters
Clear nose skate (*Raja eglanteria)*		**Habitat:** Shallow Coastal waters	**Habitat:** Shallow Coastal waters	**Habitat:** Shallow Coastal waters
Little skate (*Leucoraja erinacea)*		**Habitat:** Shallow Coastal waters	**Habitat:** Shallow Coastal waters	**Habitat:** Shallow Coastal waters
Winter skate (*Leucoraja ocellata)*		**Habitat:** Shallow Coastal waters	**Habitat:** Shallow Coastal waters	**Habitat:** Shallow Coastal waters

The sharks' main nursery areas on the East Coast are in Delaware and Chesapeake bays. Pup and juvenile sharks use submerged flats for residence and feeding in water depths of from 1 to 4 meters. On the Delaware coast they extend from Roosevelt Inlet at the southern terminus of Broadkill Beach to Port Mahon in the north. The greatest concentrations of young sharks occur off Broadkill and Primehook beaches, Delaware. They also are found in great numbers on submerged flats off the New Jersey shore (1-4 m) between Villas and Reed's Beach and shoal areas throughout the Bay such as Deadman and Hawksnest Shoal. They are limited by salinity to areas south of the latitude of Fortescue, NJ. Juveniles and pups may be caught almost anywhere in the bay, but the southwest coastal areas have the greatest consistent numbers as reflected in Catch per Unit Effort (CPUE) data (Merson and Pratt, 1998).

EFH is designated for the skate species for juveniles and adults. The Little skate and Winter skate are broadly distributed from Newfoundland to Cape Hatteras. Juveniles and adults mostly prefer sand or gravelly bottoms and mud. During the spring they move into shallow water and during winter head into deeper water. The Clearnose skate is broadly distributed along the eastern United States from Nova Scotia to Northeastern Florida.

Juvenile and adult Clearnose skates are most abundant in summer months and less abundant in the cooler months of fall, winter, and spring. They prefer soft bottom habitats but can also be found in rocky or gravelly bottoms. Skate diets consist primarily of polychaetes, amphipods, decapod crustaceans, squid, bivalves, and small fish. Turbidity during the placement or transplant of shell may impact sight feeding but the skates will flee the area to feed in neighboring waters and the elevated turbidity is temporary. Therefore, no more than minimal impact to feeding success should occur.

Effect Analysis. It is anticipated that all fish species, being mobile organisms will vacate the proposed shell planting sites during the time of construction and not be adversely impacted by the proposed work. Elevated turbidity levels due to construction, are anticipated to lower fairly quickly following completion of the shell planting. Improved habitat quality of the oyster beds, due to the proposed shell planting is expected to enhance the habitat quality for fish species which use the oyster beds, particularly during larval or juvenile stages. Many fish species rely on healthy oyster beds for a source of food and are directly dependant on the maintenance of shell surface area to support the food resources important to their needs.

There are a number of Federally-managed fish species where Essential Fish Habitat (EFH) was identified for one or more life stages within the project impact areas. Fish occupation of waters within the project impact areas is highly variable spatially and temporally. Some of the species are strictly offshore, while others may occupy both nearshore and offshore waters. In addition, some species may be suited for the open ocean or pelagic waters, while others may be more oriented to bottom or demersal waters. This can also vary between life stages of Federally-managed species. Also, seasonal abundances are highly variable, as many species are highly migratory. For most of the fish species in Delaware Bay, no adverse effect is anticipated on adults and juveniles because both stages can move away from the project impact area. Minimal adverse effect on eggs and larvae is expected as they are demersal at these life stages. All shell placements will occur on existing natural oyster beds. No impact to soft bottom habitat will occur.

The shortnose sturgeon is a Federally-endangered fish that lives in the Delaware Estuary. Likewise, any sturgeon in the proposed shell planting areas are anticipated to vacate the shell planting area during actual construction and a temporary post-construction period until elevated turbidity levels dissipate.

5.5. Monitoring

The proposed project seeks to implement a shell-planting program that will substantially promote improvements in the oyster resource of Delaware Bay and in the economics of the Delaware Bay oyster fishery. The program is not revolutionary, in the sense that the approach has been used successfully by other states as well as in several previous initiatives within Delaware Bay. Several oyster reef restoration projects are underway on the East and Gulf coasts of the U.S. Monitoring is essential and research critical to improving our understanding of genetic implications of restoration strategies, larval dispersal patterns, factors affecting early post-settlement survival, disease dynamics, and landscape-level patterns in restoring oyster reef habitat (Coen and Luckenback, 1999). The program is revolutionary in that it is the first program developed based on detailed measurements of shell budgets and comprehensive stock surveys permitting targeted shell planting to optimize ecological return on investment. The current program has a proven track record. In 2003, as part of a pilot shell planting program, the NJDEP planted shell in the vicinity of Reeds Beach in the lower Delaware Bay. Approximately one month later, 16,000 bushels were transplanted to Bennies Sand, an area which has supported the majority of the 1990s oyster harvest. Preliminary monitoring results indicate that these 16,000 bushels increased bed abundance of market size oysters in 2005 by more than half (58% of the market size oysters on Bennies Sand in 2005 came from this 2003 planting) (E. Powell, pers. comm.). This supports what evidence has shown previously: that the biological potential for oyster production in the Delaware estuary remains high (Haskin *et al*., 1983; Ford, 1997; and Canzonier, 1992b). Resource management practices are in place and designed to stabilize adult abundance in times of decline and expand adult abundance when needed, using different techniques designed to enhance oyster productivity even in the face of diseases.

The shell planting program was designed to specifically address the issue of low recruitment and the inability of recruitment rates on natural oyster beds to sustain population abundance over time. The monitoring program consists of seven components: (1) monitoring of downbay shell plants pursuant to the decision to transplant the spatted shell upbay; (2) measurement of spat settlement potential carried out from late June through late September; (3) monthly tracking of trends in growth and disease exposure for the shell plants; (4) a quantitative evaluation in October to determine the overall success of each year's program at season's end; (5) dredge calibration to determine the applicability of remote sampling by oyster dredge of shell plants; (6) survey of targeted oyster beds to improve bed areal estimates, where required, and (7) the development of a shell budget to evaluate the efficacy of the shell-planting program in maintaining habitat integrity.

2005. The U.S. Army Corps of Engineers, Philadelphia District initiated its first year of shell planting, in collaboration with the non-Federal sponsors (NJDEP and DNREC) and the DRBA, DRBC, PDE, CCEZ, the NJ Shellfisheries Council, and HSRL in 2005. This 2005 planting added significantly to bay recruitment in 2005. The 2005 program consisted of six shell plants in New Jersey and two shell plants in Delaware. Surf clam and ocean quahog obtained from New Jersey shucking houses as well as oyster shell from shell mining operations in Maryland's Chesapeake Bay were planted.

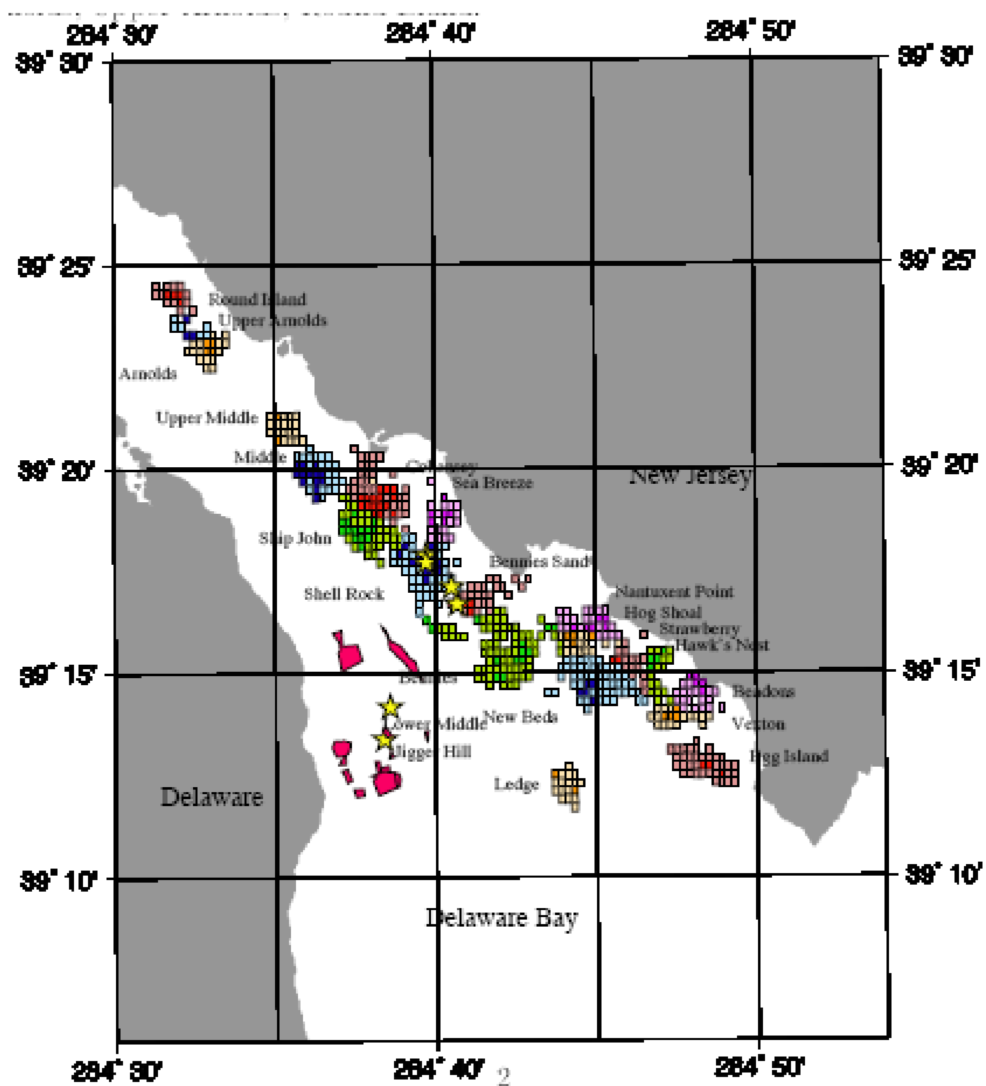
Three 25-acre grids (a 0.2" latitude x 0.2" longitude rectangle) received direct shell in New Jersey at Shell Rock 4, 12, and 43 in early July 2005. A fourth plant off Reed's Beach was moved upbay in September to Bennies Sand 11. These size grids facilitate navigation and the minimum sized rectangle needed for vessel maneuverability during planting. It is also equivalent to the size of the sampling unit used in the New Jersey stock survey, thereby facilitating evaluation of project success in comparison to bay-wide oyster production over a long data collection period.

All three shell types were planted in New Jersey. Two 25-acre areas were planted in Delaware on Jigger Hill and Lower Middle beds. Maryland oyster shell was planted at the two Delaware areas. Ocean quahog was also planted on Lower Middle. A total of 111,837 bushels were planted on New Jersey beds and 118,811 bushels were planted on Delaware beds. A summary of the shell-planting activities for 2005 is provided in Table 5-4. Figure 5.1 shows the location of the New Jersey and Delaware oyster beds.

<u>Table 5-4.</u> Summary of shell planting activities for 2005.

Location	Type of Shell Planted	Bushels Planted	Spat Collected	Spat/Bu	I
New Jersey					
Benny Sand 11	Replant of surf clam	22,500	12,713,461	565	
Shell Rock 4	Maryland oyster	36,752	8,051,590	219	
Shell Rock 12	Ocean quahog	18,248	13,503,520	740	
Shell Rock 12	Maryland oyster	18,737	2,678,540	143	
Shell Rock 43	Surf clam	8,000	2,492,214	312	
Shell Rock 43	Ocean quahog	7,600	3,116,607	410	
Delaware					
Lower Middle	Maryland oyster	46,382	1,793,637	38	
Lower Middle	Ocean quahog	17,778	195,037	11	
Jigger Hill	Maryland oyster	54,651	3,122,950	57	
Total		230,648	47,667,556		

<u>Figure 5.1</u>: Map of Delaware Bay showing the New Jersey and Delaware oyster beds and the locations of the 2005 shell plants (indicated by yellow stars). The grids on the New Jersey beds represent the 0.2" x 0.2" longitude squares used as the template for the New Jersey stock survey. The same areal scale was used on both sides of the bay for shell planting (i.e. 25 acres). In the depiction below, the footprint for New Jersey beds show the locations of high-quality (dark shade) and medium-quality (light shade) grids.



New Jersey beds are defined as follows: <u>High mortality</u>: Beadons, Nantuxent Point, Strawberry, Hog Shoal, Vexton, Hawk's Nest, New Beds, Egg Island, Ledge, Bennies, Bennies Sand; <u>Medium mortality</u>: (less Shell Rock): Ship John, Cohansey, Sea Breeze, Middle, Upper Middle; <u>Low mortality:</u> Arnolds, Upper Arnolds, Round Island.

<u>2006</u>. The 2006 program consisted of eight shell plant locations in New Jersey and three

larger shell plants in Delaware. The total volume of shell planted in New Jersey was higher than in Delaware due to additional shell purchased by New Jersey using matching funds provided by the Bridgeton/Port Norris Empowerment Zone. Two types of shell were planted: surf clam and ocean quahog, both obtained from New Jersey shucking houses. The total bushels of shell planted on Delaware beds was 206,284. On New Jersey beds, the total bushels of shell planted was
272,366 for a total of 478,650 bushels.

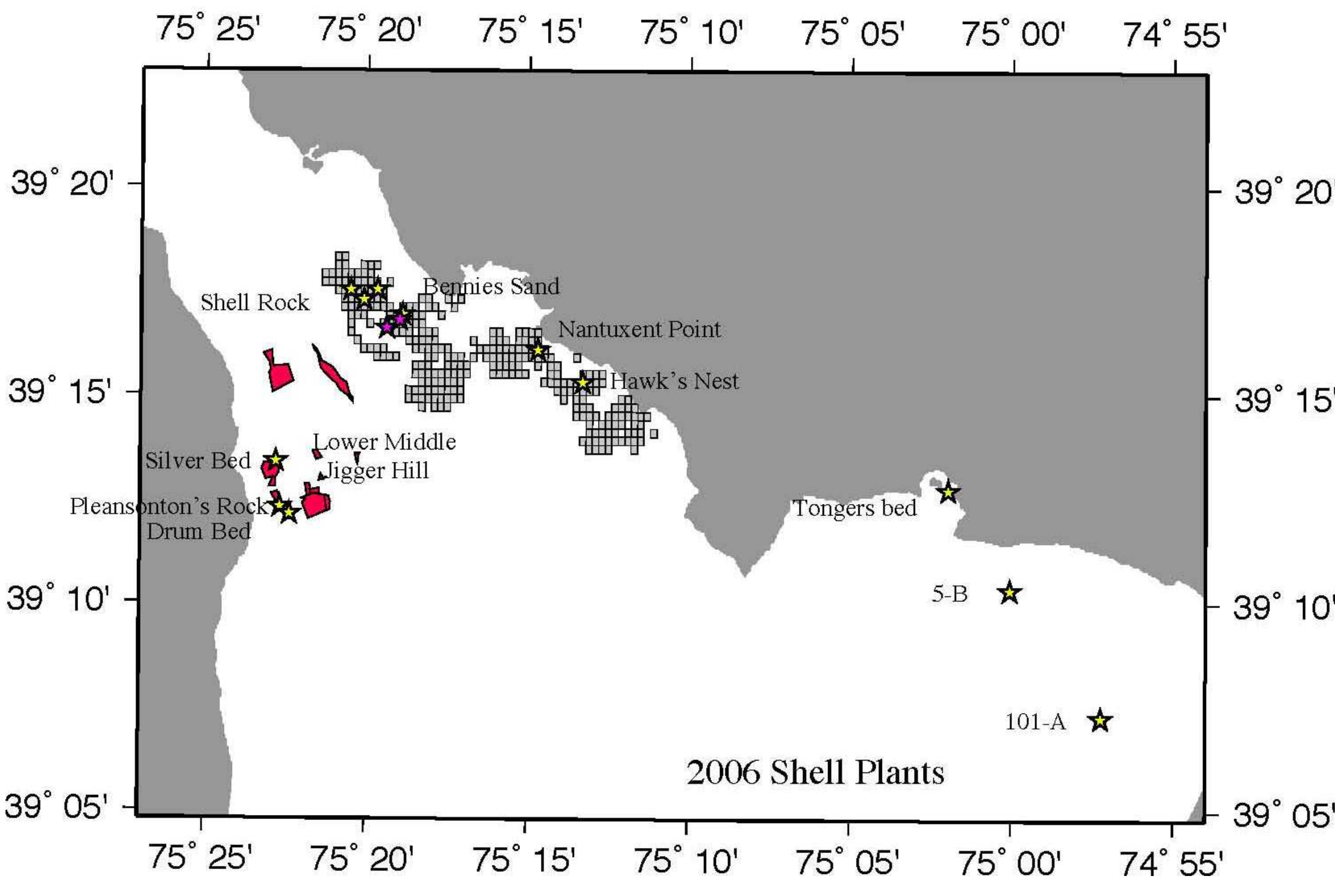
Planting occurred in June-July 2006. Six 25-acre grids received plants in New Jersey: Hawk's Nest 1, Nantuxent Point 25, Bennies Sand 7, and Shell Rock 20, 24, and 32. Two other sites were replants, one off Reeds Beach and one off Thompson's Beach. Both were moved upbay in late August to Bennies Sand 6 and 12. Three 25-acre areas were planted on Delaware beds: on Drum Bed, Silver Bed, and Pleasanton Rock. Specifics of the distribution of shell are provided in Table 5-5 and locations shown on Figure 5.2.

Table 5-5. Summary of shell-planting activities for 2006.

Location		Type of Shell Planted	Bushels Planted	Spat Collected	Spat/Bu
Drum Bed		Quahog mix*	49.149	‡0	0
Silver Bed		Quahog mix*	82.661	7.646.143	93
Pleasanton Rock		Quahog mix*	74.474	6.806.179	91
Hawk's Nest	1	Surf Clam	17.850	3.672.102	206
Nantuxent	25	Quahog mix*	49.488	10.766.609	218
Bennies Sand	6	Surf Clam replant	14.811	24.709.636	1668
Bennies Sand	7	Quahog mix*	49.037	27.669.127	564
Bennies Sand	12	Surf Clam replant	15.826	43.653.647	2758
Shell Rock	20	Quahog mix*	48.472	10.330.353	213
Shell Rock	24	Quahog mix*	53.193	8.030.015	151
Shell Rock	32	Quahog mix*	23.689	10.859.748	458
Total			478.650	154.143.559	

***Quahog mix + Quahog and surf clam processed to same small size.**

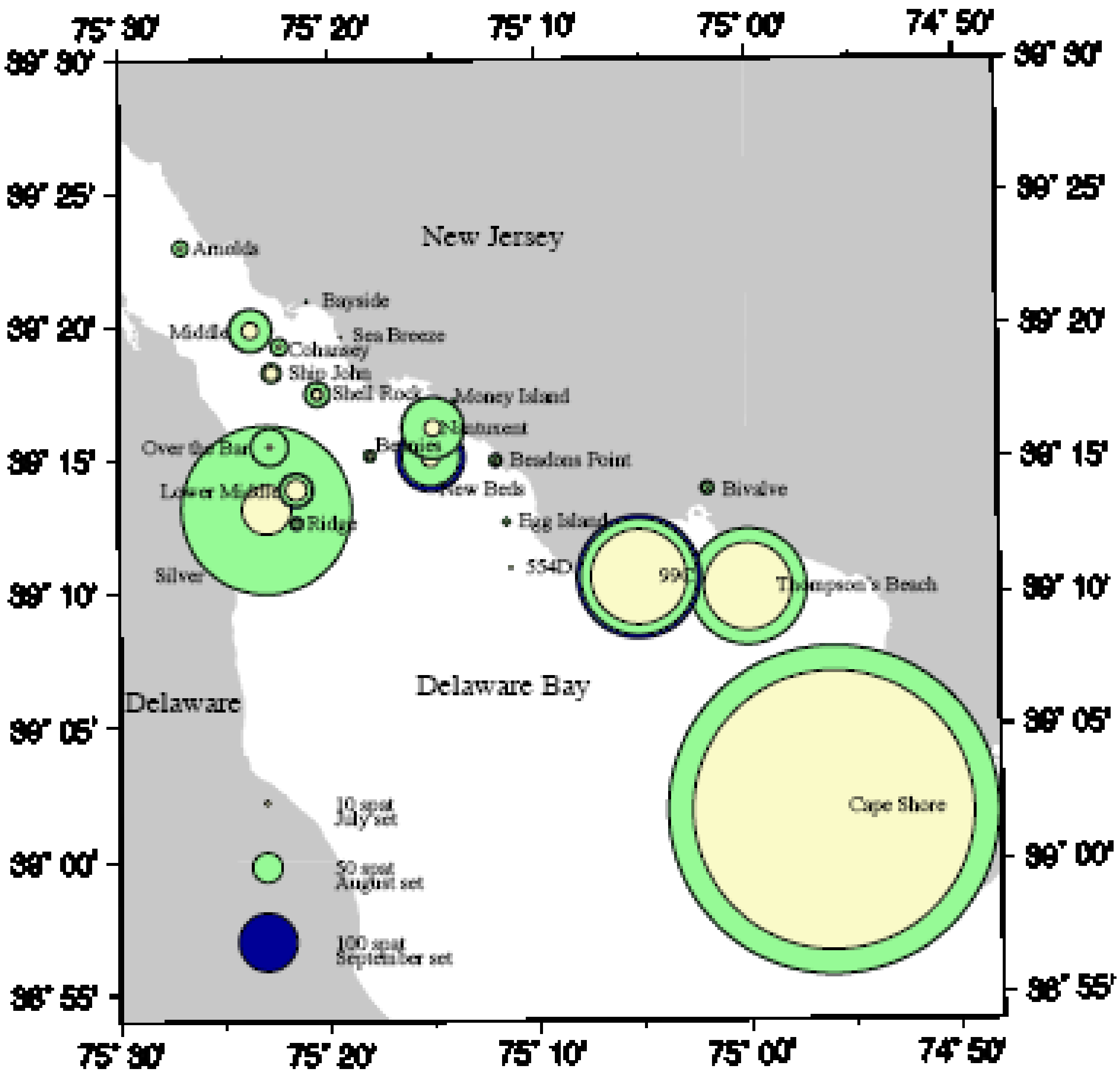
<u>Figure 5.2.</u> Location of 2006 shell plants, indicated by yellow stars. New Jersey downbay plants are on leased grounds (5-B, 101-A). Selected high-quality oyster grounds in New Jersey are denoted by shaded 25-acre grids. Red delineates state of Delaware oyster beds. A complete map of the New Jersey oyster beds can be seen in Figure 5.1.



5.5.1. Monitoring Results.

New Jersey conducts a monitoring program to track recruitment potential and in 2006, this program was extended to Delaware portions of the bay. Locations are shown in Figure 5.3.

Figure 5.3. Cumulative number of spat recruiting to 20 oyster-shell-bags deployed at the end of June 2006 and collected bi-weekly through September 2006. Colors identify the month of settlement. Increment in circle diameter indicates the number of spat that settled during that time period. Total diameter indicates the cumulative number of spat. Circle diameter bears a nonlinear relationship to total spat counts.

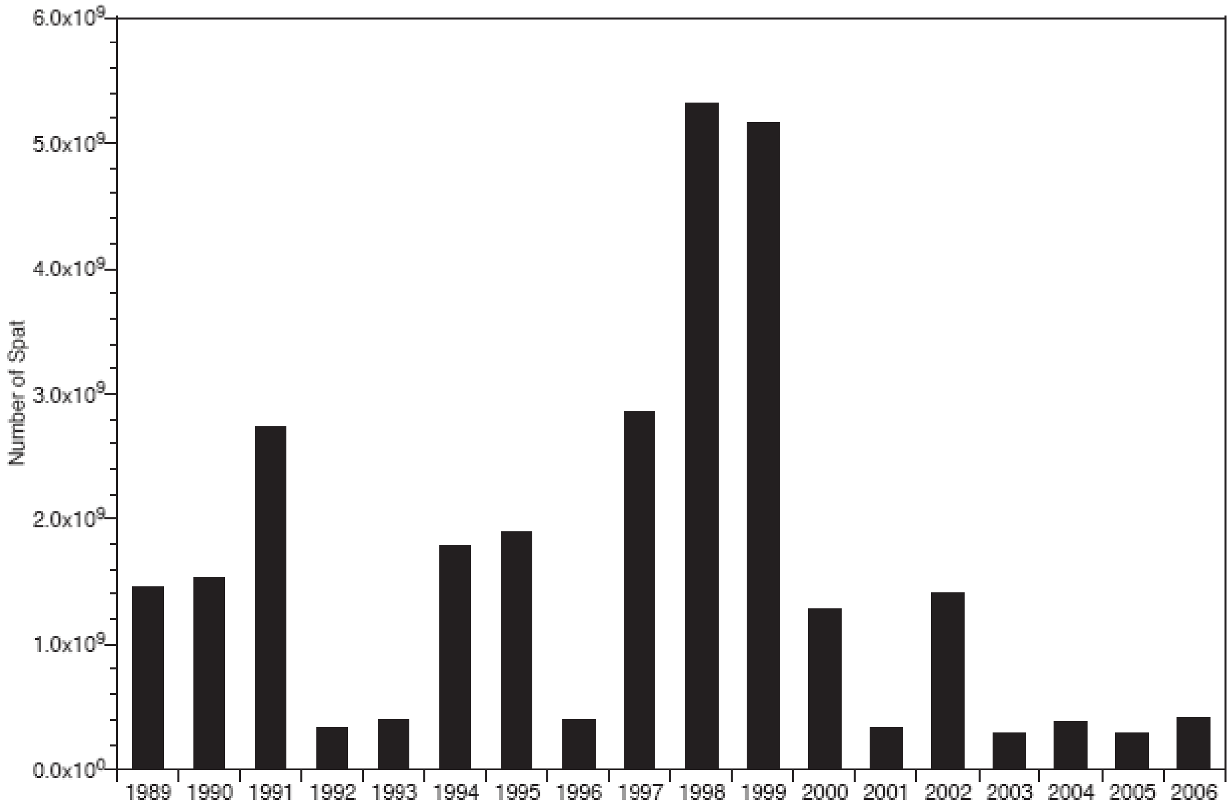


The 2006 program showed greater spat availability downbay but a lower setting potential overall than in 2005. The monitoring program showed two recruitment waves occurring in 2006: one early in July downbay and one in August upbay. High settlement potential in the Cape Shore region confirms the observed higher settlement rates on shell planted in this area and subsequently replanted upbay. As in 2005, direct shell plants significantly out-performed native shell with an average of 302 spat per bushel. Native shell on Bennies Sand attracted 54 spat per bushel and on Shell Rock, 48 spat per bushel in comparison; thus, the increase in recruitment on directly planted shell was about a factor of 5.9 over native shell. Dowbay plants average 2,213 spat per bushel. Thus, in contrast to 2005, downbay plants returned more than seven times the spat per bushel of direct plants (see Table 5-5) and about 44 times that of native shell. Results of the Delaware survey showed that the mean number of spat per bushel of native shell for Silver Bed was 14, for Drum Bed 7, and for Pleasanton Rock 9. The values for Silver Bed and Pleasanton Rock for shell plants were 93 and 91, respectively, indicating that the planted shell possessed considerably more spat than native shell in Delaware as was also observed in New Jersey (Powell, 2007).

Success of recruitment enhancement (spat-per-planted-bushel) was higher in New Jersey than Delaware. Delaware values were 90 spat-per-bushel whereas the New Jersey values were in the range of 150-550 spat-per-bushel. However, recruitment on native shell differed significantly as well. In Delaware, in areas of shell plants, values on native shell ranged from 7-14 spat-per-bushel, whereas in New Jersey, the values were 48-54 spat-per-bushel. Thus both native and planted shell differed by as much as a factor of 5 between the two sides of the bay in 2006. This differential between the two sides of the bay in recruitment potential was also observed in 2005.

Recruitment remains low bay-wide (Figure 5.4) and was particularly low on the low-mortality beds, high-mortality beds, and Shell Rock in 2006 (see Figure 5.3). A near-average recruitment event occurred on the medium-mortality beds. However, recruitment did not reach the value of 0.5 spat per adult on any beds. The ratio of spat to oysters has been lower than 0.5 over six of the last 7 years. Shell-planting increased recruitment on Shell Rock and the high-mortality beds and this increase brought spat-per-adult ratio above 0.5 on Shell Rock and up to 1.0 on the high-mortality beds. Both ratios are normally associated with increasing abundance in the following year. Evidence suggests that low spat abundance is associated with low adult abundance, and data analyses suggest that the explanation involves the contribution of live oyster shell to the cultch resource preferred for settlement. This implies that high recruitment may be less likely under current conditions of low abundance and emphasizes further the need for continual shell planting to increase oyster abundance.

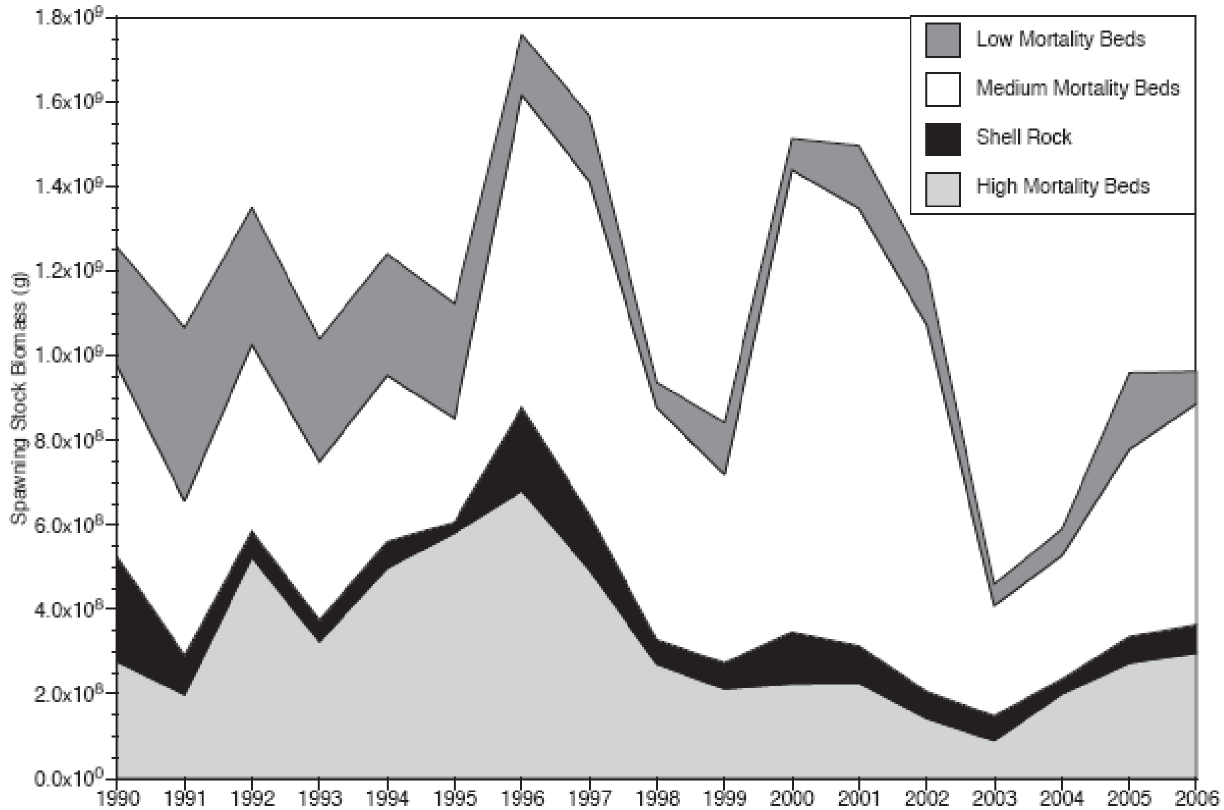
<u>Figure 5.4</u>. Number of spat recruiting per year for the 1989-2006 time series.



Overall, recruitment enhancement programs were successful in 2006. In New Jersey, shell planting in 2006 enhanced recruitment by a factor of 1.34 bay-wide, providing 26% of total recruitment on New Jersey beds. On Shell Rock, shell plants accounted for 50% of total recruitment. On the high mortality beds, shell plants accounted for 58% of total recruitment. An increase in abundance can be anticipated on Shell Rock with beds downbay in 2007, barring an unusual mortality event or overharvesting. For more information on recruitment monitoring, refer to the 2006 Report to the U.S. Army Corps of Engineers in Appendix A (Powell, 2007).

Spawning stock biomass rose in 2006. Increases were observed in all bay regions except upbay on the low-mortality beds. Spawning stock biomass has increased steadily on the high-mortality and medium-mortality beds over the last three years and has risen for the last two years on Shell Rock (Figure 5.5). Spawning stock biomass was above the biomass target in three of 4 bay regions and near the threshold for the low-mortality beds.

<u>Figure 5.5</u>. Time series of spawning stock biomass by bay region. Bed distributions by region are shown in Figure 2.1.



<u>Growth and Mortality</u>. *Perkinsus marinus* (Dermo) prevalences in the area of the bay used for shell planting are typically above 50%. In 2006, oysters on the 2005 shell plants were monitored for Dermo infection. The stock survey conducted by New Jersey obtained bed average infection intensity for October for both Shell Rock and Bennies Sand. The bed-average prevalence was 100% and 90% for these two sites, respectively. These compare closely to the values obtained in October 2005 for the previous year's shell plants Table 5-6. The evidence suggests that Dermo infection is lower on oysters obtained from shell plants relative to oysters naturally occurring on the bed.

<u>Table 5-6</u>. The prevalence of *Perkinsus marinus* (Dermo) in oysters on the shell planted in 2005. ND: not determined.

	Jigger Hill	Lower Middle	Shell Rock 4	Shell Rock 12	Shell Rock 43 ocean quahog	Shell Rock 43 surf clam	Bennies Sand 11
Prevalence							
Jul-06	0.0%	0.0%	5.0%	15.0%	0.0%	0.0%	0.0%
Aug-06	55.0%	40.0%	35.0%	70.0%	20.0%	30.0%	50.0%
Sep-06	40.0%	15.0%	80.0%	90.0%	80.0%	95.0%	75.0%
Oct-06	55.0%	30.0%	80.0%	100.0%	90.0%	95.0%	85.0%
Nov-06	ND	30.0%	100.0%	90.0%	90.0%	95.0%	100.0%

Dermo disease rose to moderate levels in 2006 and natural mortality rates were above average. Fishery exploitation levels since 1989 have been low (<2% of abundance per year). Recent improvements in collection of fishery-dependent data indicate that exploitation in terms of biomass has been <3% over most of that time. Low exploitation rates indicate that the fishery does not have a significant effect on the stock and that fishing mortality is not responsible for the current conditions of low abundance.

Growth rates were measured for spat that settled on 2005 shell plants (Tables 5-7 and 5-8). Growth rates were high on Lower Middle and Jigger Hill and generally Delaware oyster growth rates exceeded those in New Jersey waters. For more information on Growth and Mortality, refer to the 2006 Report to the U.S. Army Corps of Engineers in Appendix A (Powell, E, 2007).

<u>Table 5-7</u>. Average size (mm) in 2006 of spat settled on clam shell planted in 2005. ND: not determined.

	Jigger Hill	Lower Middle	Shell Rock 4	Shell Rock 12	Shell Rock 43 ocean quahog	Shell Rock 43 surf clam	Bennies Sand 11
Sep-05	20.86	16.63	23.67	14.89	18.13	20.04	25.62
Dec-05	18.46	27.30	27.70	ND	25.89	ND	30.38
Mar-06	32.50	26.93	27.34	20.55	29.33	28.27	32.43
Apr-06	32.12	32.46	28.10	23.04	15.93	25.71	26.51
May-06	36.43	35.51	31.82	25.46	27.90	30.36	35.02
Jun-06	40.83	40.59	35.02	31.34	32.91	32.32	38.42
Jul-06	44.73	44.20	39.28	35.76	36.08	35.96	44.01
Aug-06	47.73	43.96	41.46	40.54	36.67	39.04	45.04
Sep-06	53.64	50.30	44.05	43.07	42.11	42.07	47.79
Oct-06	55.50	50.72	42.08	39.09	39.72	45.42	48.95
Nov-06	ND	65.78	ND	39.98	42.14	40.08	49.73

<u>Table 5-8</u>. Minimum and maximum size (mm) in 2006 of spat settled on clam shell planted in 2005. ND: not determined.

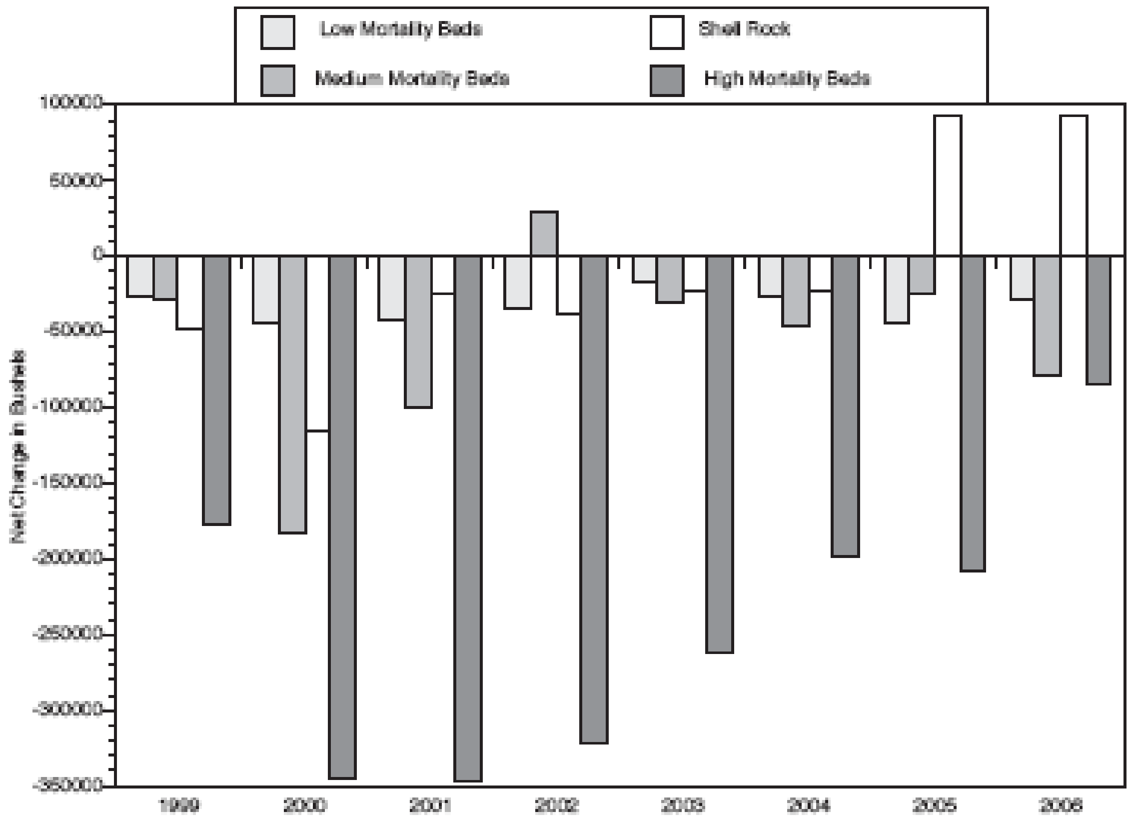
	Jigger Hill	Lower Middle	Shell Rock 4	Shell Rock 12	Shell Rock 43 ocean quahog	Shell Rock 43 surf clam	Bennies Sand 11
Minimum							
Apr-06	11.60	9.60	ND	5.01	14.85	6.04	ND
May-06	21.61	20.99	19.49	7.24	13.98	7.98	11.14
Jun-06	24.91	24.39	18.17	13.83	15.81	13.96	11.68
Jul-06	25.10	25.31	23.85	18.04	20.51	17.87	19.87
Aug-06	31.91	18.70	23.14	20.00	12.50	16.13	14.68
Maximum							
Apr-06	49.57	52.93	ND	48.60	18.08	51.99	ND
May-06	48.25	50.52	47.52	48.72	42.43	50.26	35.25
Jun-06	50.87	53.22	49.92	47.20	48.76	53.39	54.38
Jul-06	60.93	58.66	58.48	55.91	51.12	66.40	61.83
Aug-06	62.66	64.06	63.09	66.83	55.36	62.85	77.12

<u>Shell Budgets</u>. A shell budget was constructed using bed-specific half-life estimates for shell (Powell *et al.*, 2006). New Jersey oyster beds have been losing 250,000 to 500,000 bushels of shell annually since 1999 (1998 was the first year that full survey data was available) (Table 5-9). The shell budget demonstrated a substantial reduction in shell loss in 2005 and 2006 as a result of the shell-planting program that has reduced the yearly deficit by at least two-thirds. Similar estimates for Delaware cannot yet be made, as quantitative information on shell content is unknown. By region, the low-mortality beds have been losing about 20,000-40,000 bushels annually and the medium-mortality beds are losing 30,000-100,000 bushels annually due to higher loss rates and larger total area. Shell Rock had a net gain since 2005 due to shell planting. The high-mortality beds are losing 175,000 to 350,000 bushels annually due mostly to the larger area of coverage. A reduction in the rate of loss in 2006 is due to the substantial shell planting that occurred downbay of Shell Rock (Figure 5.6).

<u>Table 5-9</u>. 2006 shell balance (net change from 2005) for oyster beds (in kg per bed). Arrows identify locations receiving 2006 shell plants.

Location	Net Change in Shell	
Upper Arnolds	-424,397	
Arnolds	-1,616,357	
Middle	-908,253	
Cohansey	-151,022	
Ship John	-4,670,979	
Shell Rock	6,881,596	⟵
Bennies Sand	6,002,242	⟵
Bennies	-5,638,249	
Nantuxent Point	963,856	⟵
New Beds	-1,154,274	
Hawk's Nest	210,086	⟵
Hog Shoal	-1,863,915	
Strawberry	-858,048	
Beadons	21,264	
Vexton	-1,388,771	
Egg Island	-1,722,509	
Ledge	-733,859	

Figure 5.6. Estimated net change in surficial shell content in bushels by bay region for the New Jersey oyster beds for the time period 1999-2006. Positive values on Shell Rock in 2005 and 2006 reflect the addition of shell through shell planting to offset shell loss.



Although the beds continued to suffer a net loss of shell in 2006, the shell-planting program reduced this net loss to the lowest value during the 1999-2006 time period. The shell budget estimates identify the importance of shell planting in maintaining the integrity of the beds during times of disease when low abundance limits the amount of shell added to the beds through natural mortality. Shell plants provide substrate to enhance recruitment. The shell budget also permits more effective planning for future shell plants. Most beds that did not receive shell plants in 2006 suffered losses of surficial shell. For more information on shell budget estimates and dredge sampling efficiency, refer to the 2006 Report to the U.S. Army Corps of Engineers in Appendix A (Powell, E, 2007).

In summary, low-mortality beds are not showing significant improvement but beds in other bay regions appear to have improved since 2004. However, the fact that all bay regions fall below their abundance targets indicates that actions to enhance abundance are needed in all bay regions. A continued need exists to minimize shell loss to reinforce the maintenance of biomass at or above target levels. Abundance has been enhanced on the high-mortality beds and Shell Rock by downbay transplants.

The Monitoring and Assessment Program will acquire the data necessary to evaluate the success of the shell-planting program. The increment in abundance achieved by the program over the abundance that would have been present in the absence of the program at present will be used to establish the degree of success. Each year the total number of oysters supported by the shell planting will be assessed. The addition of shell should augment the production of the Delaware Bay oyster fishery. Each state sets its quota to determine the number of bushels permissible for harvest in the coming year based on a formal stock assessment. The monitoring program will compare the quotas set each year to the quota that would have been established had the shell-planting program not been carried out. A shell plant is expected to substantially increase larval settlement in the year that it occurs. However, the shell added will continue to serve as substrate over future years. The usable life span of a shell plant is likely to exceed 10 years (Powell, pers. comm., 2007). The 2007 Stock Assessment Workshop report established that the 2005 shell plant provided equivalent substrate to make shell in 2006 and will contribute an additional increment to adult abundance in 2008. Therefore, it is likely that the benefit of the original shell plant will be underestimated. That is, the gain in abundance or bushel of quota per dollar invested at any time will underestimate the true gain over the usable life span of the shell plant.

A secondary aspect of the proposed project is to seek a wider constituency in the revitalization of the oyster population and continued interest in improvements to habitat quality within Delaware Bay. Improvements to the overall health of the bay support the potential for a rebirth of the oyster industry in Delaware Bay. Increasing estuary-wide awareness through a multifaceted education and outreach program is proposed to bring together stakeholders from across the region to build stewardship for this natural resource. A successful resource management program depends upon the support of the general public. In time, this stewardship and public awareness should mobilize additional involvement and resources for the revitalization process.

5.6. Socioeconomic Resources

Multiple agencies are involved with the restoration plan for the Delaware Bay oyster population. The proposed plan is expected to increase oyster habitat, expand oyster abundance, and revitalize the natural resource with concomitant improvements in Bay habitat quality from increased habitat complexity brought about by shell planting as well as increased water clarity brought about by the increased filtration by an abundant shellfish resource. Expansion of oyster abundance provides increased substrate and expanded habitat complexity for a variety of other species, which in turn increases recreational value of the estuary.

Recovery of oyster abundance to the abundance at maximum sustainable yield (msy) would increase stock abundance by about a factor of 4. Currently there is a rebuilding program ongoing for the Delaware Bay oyster fishery. Due to this program and the current msy, only 1-3% of the available stock is fished per year. At msy, 7% of the stock can be harvested. The economic value of the oyster fishery at msy is estimated to be $165,615,141 yearly. The present value is about $12,000,000 yearly. The proposed shell-planting project will not achieve msy values, but, as an example, a doubling of oyster abundance is worth more than the simple multiplier of 2 because the allowable fishing rate increases disproportionately. A factor of 4 increase in abundance would allow a factor of about 7 increase in fishing or a factor of 28 increase in total value. 2007 allocations were above the long-term, on average, and estimates of future harvests suggest that the 2005-2006 programs may double harvests in 2008-2009, relative to the long-term average E. Powell, pers. comm.).

5.7. Cultural Resources

The planting of additional oyster shell should have no effect on significant cultural resources. The periodic harvesting of oysters does involve the shallow disturbance of the sea floor at the time of harvesting. However, oyster harvesting has been carried out in these areas for hundreds of years. This project's indirect effect of promoting the future harvesting of oysters while sustaining the existence of the oyster beds will sustain the cultural significance of the bayshore communities that have been a focal point of this area since the 1700s.

5.8. Unavoidable Adverse Environmental Impacts

The long-term adverse impact of the no action alternative would be decline in both the natural environment and the ecological value of the Delaware Estuary to the regional economic environment. Decimated by disease and low recruitment since 2000, oyster populations of Delaware Bay are not expected to recover without intervention. Oyster spat are not presently recruiting in numbers large enough to replace the number of oysters lost to harvest, predators and disease and shell bed deterioration has reached alarming levels. It is anticipated that unless the decline in oyster populations are reversed, oyster beds may be closed to harvesting and habitat quality will most likely continue to decline.

The impacts anticipated to occur as the result of a shell planting are positive. Shell planting will provide oysters the needed hard substrate of a sufficient elevation above the sediments to settle and grow. Shell planting has been conducted on a smaller, trial-basis in the past and has proven successful. Approximately 235,000 bushels of shell were planted in 2005 and approximately 479,000 bushels of shell were planted in 2006 in this multi-year effort to revitalize the oyster population in Delaware Bay and preliminary monitoring suggests that the results are promising.

5.9. Short-term Uses of the Environment and Long-term Productivity

All shell placements will occur on existing natural oyster beds. No impact to soft bottom habitat will occur. The shell planting operation may entail temporary and localized increases in turbidity in the water column but this is expected to dissipate quickly. Revitalization of the oyster in Delaware Bay will contribute to the overall economy of Delaware Bay shore communities. The ecological benefits associated with a viable oyster resource are far reaching for the general health of the estuary. Oyster beds provide protective habitat for various economically important invertebrates and finfish species; and the filtering capacity of oysters will result in improved water quality. Furthermore, increased abundance is necessary to generate shell to retain bed integrity and maintain habitat complexity.

5.10. Irreversible and Irretrievable Commitments of Resources

The selected plan proposes to use oyster and clam shell generated from shucking companies through their oyster, ocean quahog and surf clam shell processing. Clam shell provides an adequate substitute for oyster shell for oyster larvae settlement. Hence, the proposed project is recycling a waste product as a useful commodity, thereby alleviating present storage and disposal requirements. In the absence of oyster harvesting, the majority of oyster shell was readily available on natural beds for the establishment of new spat. With the additional pressure on oysters due to harvesting, it is critical that an active replacement program be implemented to ensure adequate shell cultch for successful future settlements.

5.11. Cumulative Effects

Cumulative effects of the proposed shell planting program are all anticipated to be positive. Oysters provide a sustainable food supply that can be restored under proper augmentation and management conditions. Recovery of oyster abundance to a level at maximum sustainable yield (msy) will achieve an even greater harvesting rate because natural mortality from disease is expected to decline and the natural recruitment rate is expected to increase with positive impacts occurring over many years. Planted oyster shell beds are anticipated to have approximately a 10-year life span. As additional spat survive to reproductive age, successive year broodstock will increase. In addition to the economic value gained, the oyster is a keystone species in the estuary and an increase in the oyster population translates to improved water quality as a result of enhanced filtering capacity and expanded habitat complexity and diversity of estuarine species, as oyster beds provide habitat to a variety of benthic organisms that in turn provide food for recreationally and commercially important invertebrate and finfish species.

6.0. COORDINATION

Coordination for this project was done with Federal, state and local resource agencies. Agencies notified of this proposed project included the U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, the National Marine Fisheries Service, the New Jersey Department of Environmental Protection, and the Delaware Department of Natural Resources and Environmental Control.

A public notice was issued describing the selected plan and the availability of the draft Environmental Assessment. All comments received on the draft report during the comment period will be included in an Appendix of the final report.

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8.0. EVALUATION OF 404(b)(1) GUIDELINES

I. Project Description

A. Location:

The project site is the Delaware Bay between Bombay Hook on the western side (Delaware), and to just below Artificial Island on the eastern side (New Jersey) to the mouth, a distance of about 50 miles. The proposed shell planting would take place on portions of the natural oyster beds of Delaware Bay in both the states of Delaware and New Jersey, as well as the leased beds off the New Jersey Cape Shore of Delaware Bay. The exact locations will be selected by the New Jersey Department of Environmental Protection (NJDEP) and the Delaware Department of Natural Resources and Environmental Control (DNREC) based on bottom surveys to be carried out at the inception of the project.

B. General Description:

The approach taken in the two states will differ somewhat to maximize use of local conditions. The objective is to plant approximately 700,000 bushels of clean surf clam, ocean quahog or oyster shell in areas approximately 25 acres in size, which is the recommended size because it encompasses a 0.2" latitude x 0.2" longitude rectangle, so the design facilitates navigation. This is the minimum size rectangle needed for vessel maneuverability during planting. It is also equivalent to the size of the sampling unit used in the New Jersey stock survey, thereby facilitating evaluation of project success in comparison to bay-wide oyster production.

C. Purpose

Since 2001, the condition of the oyster resource in Delaware Bay has deteriorated despite careful management and a limited controlled fishery, increasing the urgency for establishing a recruitment and enhancement program based on shell planting. Delaware Bay is now in its seventh year of well below average recruitment (less than 0.5 spat per oyster per year). Seven such consecutive years is unprecedented from the perspective of the 54-year record for which detailed survey data are available (1952-2005). Consistent recruitment failure has resulted in the decline of oyster stocks, endangering the species population dynamics, the continuance of the fishery, and the habitat quality of the oyster beds. Shell planting in Delaware Bay will provide needed shell cultch on state-owned natural oyster beds. The Delaware oyster beds historically have suffered loss in production due to siltation. The shell planting is designed to increase productive area by adding to bed height while expanding available cultch. Adequate oyster bottom is available in New Jersey, therefore, New Jersey will focus on manipulations specifically directed at increasing recruitment rather than those necessary to also reestablish productive bottom.

D. General Description of Dredged or Fill Material:

The proposed placement material is clean (processed) surf clam, ocean quahog and oyster shell. Oyster harvesters themselves were once required to replace a portion of the shell from oysters they harvested, but this practice was eliminated in 1979. Recently, very little clean shell has been replaced on the seed beds because the only source of funds has been the Oyster Resource Development Account. This account receives fees from oyster growers, but due to low harvests, rarely has sufficient funds for a significant planting. Local clam companies generate large quantities of ocean quahog and surf clam shells and these shells provide an adequate substitute for oyster shell, with surf clam being the preferred of the two. Hence, this project will also recycle a waste product into a useful commodity, thereby alleviating present storage and disposal issues.

E. Description of Placement Method:

Clean shell will be brought on site by barge or oyster boat and washed overboard with a high pressure hose.

II. Factual Determination

A. Physical Substrate Determinations:

1 Clean oyster shell and clean clam shell. Shell is "cured" by storing on land for a sufficient amount of time to insure that any associated shellfish meat or other biotic growth has decomposed prior to shell planting.

2 Other effects would include a temporary increase in suspended sediment load during the construction period. The substrate in the project area is large-grained (>20mm) nontoxic sand and projected turbidity increases are not anticipated to be high or of long duration.

3 Actions taken to minimize impacts include selection of clean, inert clam and oyster shell.

B. Water Circulation, Fluctuation and Salinity Determinations

1. Water. Consider effects on:

a. Salinity - No effect.
b. Water Chemistry - No significant effect.

c. Clarity -Minor short-term increase in turbidity during construction.
d. Color - No effect.

e. Odor - No effect.
f. Taste - No effect.
g. Dissolved gas levels - No significant effect.
h. Nutrients - Minor short-term effect
i. Eutrophication - No effect.
j. Others as appropriate - None

2. Current patterns and circulation

a. Current patterns and flow - Circulation would not be significantly impacted by the proposed work as placement of shell will not significantly alter the existing bathymetry of the area.

b. Velocity - No effect on tidal velocity and longshore current velocity regimes.

c. Stratification – N/A. Thermal stratification typically does not occur within relatively shallow, well-mixed, high tidal energy areas of Delaware Bay. Some minor stratification in deeper areas during summer months.

d. Hydrologic regime - The regime is estuarine. This would remain the case following construction of the proposed project.

3. Normal water level fluctuations – N/A

1 Salinity gradients - There would be no effect on the existing salinity gradients.

2 Actions that would be taken to minimize impacts - Utilization of clean, inert oyster and clam shell will minimize water chemistry impacts.

C. Suspended Particulate/Turbidity Determinations

1 Expected changes in suspended particulate and turbidity levels in the vicinity of the placement site - There would be a short-term, minimal elevation of suspended particulate concentrations during construction phases in the immediate vicinity of the work area.

2 Effects (degree and duration) on chemical and physical properties of the water column:

a. Light penetration - Short-term, limited reductions would be expected at the shell placement sites due to construction activities in the water.

b. Dissolved oxygen - There is a potential for a slight decrease in dissolved oxygen levels but the anticipated low levels of organics in the turbidity generated during construction should not generate a high, if any, oxygen demand.

c. Toxic metals and organics - Because the fill material is essentially all clean, inert shell, no toxic metals or organics are anticipated.

d. Pathogens - Pathogenic organisms are not present on clean, inert shell.

e. Aesthetics - Construction activities associated with the fill site would result in a minor, short-term degradation of aesthetics.

3. Effects on Biota

a. Primary production, photosynthesis - Minor, short-term effects related to turbidity.

b. Suspension/filter feeders - Minor, short-term effects related to suspended particulates outside the immediate deposition zone. Sessile organisms typically present on existing oyster beds have evolved to withstand a limited level of suspended particulate matter. The project will result in an increased elevation of the existing oyster beds, thereby reducing siltation and/or suffocation of inhabitants.

c. Sight feeders - Minor, short-term effects related to turbidity.

4. Actions taken to minimize impacts include selection of clean, inert oyster and clam shell. Standard construction practices would also be employed to minimize turbidity and erosion.

D. Contaminant Determinations

The discharge material (shell) is not expected to introduce, relocate, or increase contaminant levels at the placement site. This is assumed based on the characteristics of the materials, the proximity of the placement site to sources of contamination, the area's hydrodynamic regime, and existing water quality.

E. Aquatic Ecosystem and Organism Determinations

1. Effects on plankton -The effects on plankton should be minor and mostly related to light level reduction due to turbidity. Significant dissolved oxygen level reductions are not anticipated.

Effects on benthos - There would be a minor disruption of the benthic community in the immediate placement area due to the addition of more shell to the existing shell bottom. The loss is offset by the expected rapid opportunistic recolonization from adjacent areas that would occur in the improved (elevated) shell bed habitat following cessation of construction activities and the importance of added shell in sustaining the habitat for the shell bed benthos. The new benthic community will be the same in composition due to the nature of the project (i.e. bottom habitat type will not change).

2. Effects on Nekton - Only a temporary displacement is expected as nekton would probably avoid the active work areas. Many fish species use oyster beds as a source of food and are directly dependent on the maintenance of shell surface area to support the food resources important to their needs. The proposed project will enhance habitat quality of the oyster beds by providing more available substrate.

3. Effects on Aquatic Food Web - Only a minor, short-term impact on the food web is anticipated. This impact would extend beyond the construction period until recolonization of the filled area has occurred. A positive impact on the food web is anticipated following the placement of additional shell on the shell beds to increase surface area of available substrate.

4. Effects on Special Aquatic Sites - No wetlands would be impacted by the project.

5. Threatened and Endangered Species - Several species of threatened and endangered sea
turtles might be in the project area during the period of construction. Sea turtles may be present in the project area but it is unlikely that construction activities will have an adverse effect. Shortnose sturgeon, an endangered fish species within the purview of the National Marine Fisheries Service, migrates through the project area in the spring from the sea to spawn in the upper estuary. However, most fish are observed in the upper tidal freshwater areas of the estuary and are not expected to be impacted by the proposed project.

6. Other wildlife - The proposed plan would not adversely affect other wildlife. The
proposed project is anticipated to provide a positive impact to habitat availability within existing natural oyster beds.

7. Actions to minimize impacts - Impacts to benthic resources will be minimal at the
placement site considering the anticipated recolonization. No impacts to Federal and state threatened and endangered species are anticipated due to the short-term nature and location of the proposed project. The project area is not considered spawning habitat for winter flounder due to high velocity currents.

F. Proposed Placement Site Determinations

1. Mixing zone determination

a. Depth of water - < 20 feet

b. Current velocity – current velocities can exceed 100 cm/sec.

c. Degree of turbulence – Moderate to high due to high velocity currents

d. Stratification - None

e. Discharge vessel speed and direction - Not applicable

f. Rate of discharge – Not applicable

g. Dredged material characteristics – Not applicable

h. Number of discharge actions per unit time – Not applicable

2. Determination of compliance with applicable water quality standards - Prior to construction a Section 401 Water Quality Certificate and Federal consistency concurrence with the State of New Jersey's Coastal Zone Management Program will be obtained. Under a current agreement with the State of Delaware, a Section 401 Water Quality Certification can be waived for actions which qualify under Nationwide Permit #4. A Federal consistency determination with the Delaware Coastal Zone Management Program will be obtained.

3. Potential effects on human use characteristics

a. Municipal and private water supply - No effect

b. Recreational and commercial fisheries – Positive effect after construction as the project will directly increase habitat quality of the oyster beds and indirectly result in improved water quality in Delaware Bay.

c. Water related recreation – No effect.

d. Aesthetics - Short-term effect during construction.

e. Parks, national and historic monuments, national seashores, wilderness areas, etc. – No effect.

G. Determination of Cumulative Effects on the Aquatic Ecosystem – Positive impacts are anticipated to oyster populations, benthic habitat quality, and water quality within the Delaware Bay.

H. Determination of Secondary Effects on the Aquatic Ecosystem – the proposed project offers positive impacts to the aquatic ecosystem present within Delaware Bay.

III. Finding of Compliance or Non-Compliance with the Restrictions on Discharge

A. No significant adaptation of the Section 404(b)(1) Guidelines was made relative to this evaluation.

B. The alternative measures considered for accomplishing the project are detailed in Section 3.0 of the document of which this 404(b)(1) analysis is part.

C. A water quality certificate will be obtained from the New Jersey Department of Environmental Protection. A Nationwide General Permit applies to this project according to an agreement with the state of Delaware.

D. The proposed project will not violate the Toxic Effluent Standards of Section 307 of the Clean Water Act.

E. The proposed project is in compliance with the Endangered Species Act of 1973. Informal coordination procedures have been completed.

F. The proposed project will not violate the protective measures for any Marine Sanctuaries designated by the Marine Protection, Research, and Sanctuaries Act of 1972.

G. The proposed project will not result in significant adverse effects on human health and welfare, including municipal and private water supplies, recreation and commercial fishing, plankton, fish, shellfish, wildlife, and special aquatic sites. Significant adverse effects on life stages of aquatic life and other wildlife dependent on the aquatic ecosystem; aquatic ecosystem diversity, productivity, and stability; and recreational, aesthetic, and economic values will not occur.

H. Appropriate steps to minimize potential adverse impacts of the project on aquatic systems include selection of clean, inert shell fill material.

I. On the basis of the guidelines, the placement sites for the fill material is specified as complying with the requirements of these guidelines, with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects on the aquatic ecosystem.

APPENDIX A

2006 Shell-Planting Program in Delaware Bay

Report to the U.S. Army Corps of Engineers

Eric Powell
(for the Oyster Revitalization Task Force:
DRBC, DRBA, DNREC, NJDEP, Delaware Estuary Program,
RU/NJAES/HSRL[♮], Partnership for the Delaware Estuary)

This report provides information specific to the 2005 and 2006 shell-planting programs. The importance of these programs, for New Jersey, is reviewed in the report of the 9^{th} SAW that is attached to this document as an addendum[⊘]. This is possible because New Jersey carries out a quantitative stock assessment and, as a consequence, can place the recruitment obtained for New Jersey in the context of the quantitative estimates for the native shell on these oyster beds. However, trends in population dynamics are very similar on both sides of the bay, so that generalities concerning the shell-planting program evinced through quantitative methods in New Jersey waters are very likely to be applicable to Delaware waters.

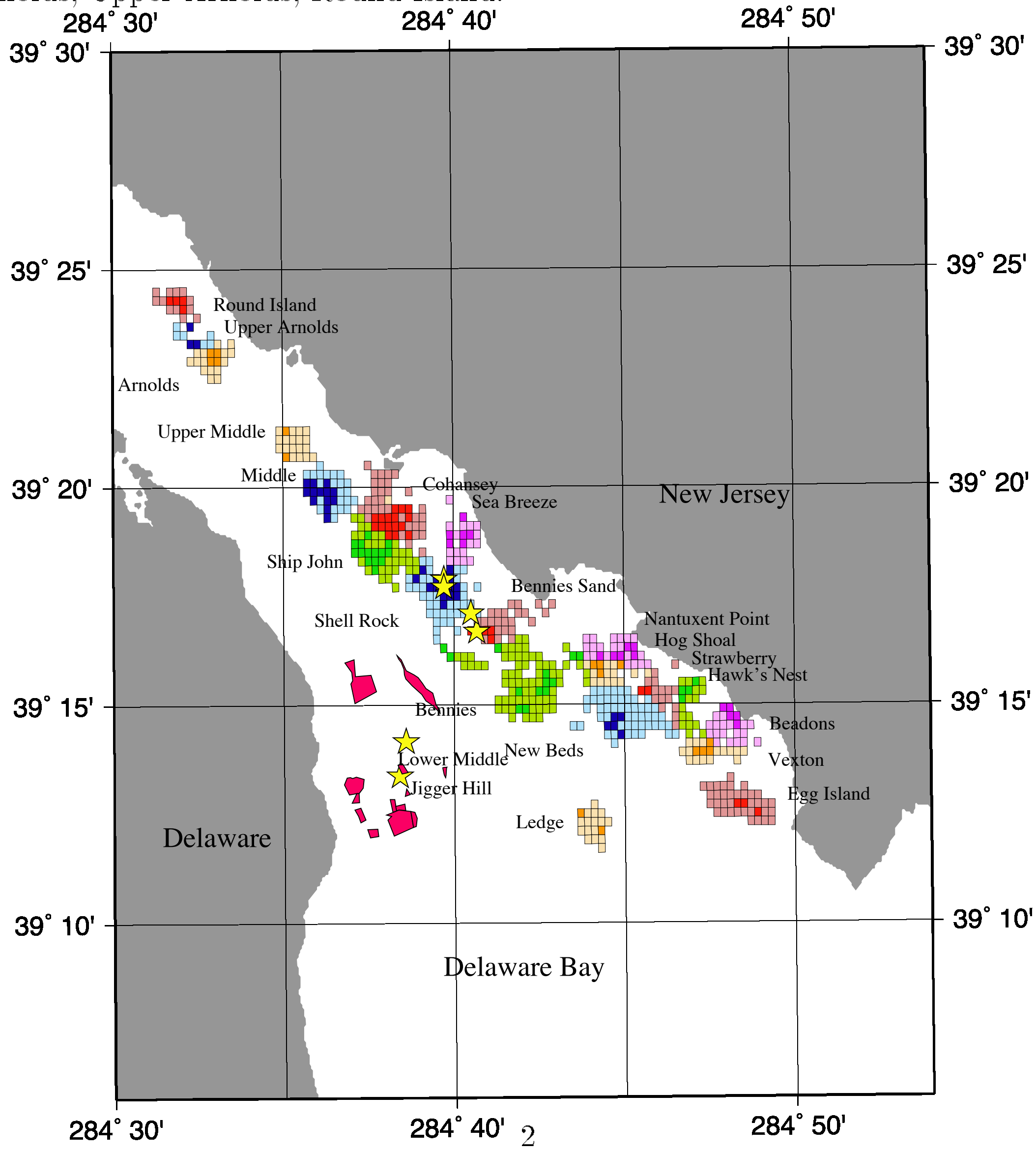
The attached report of the 9^{th} SAW summarizes the status of the New Jersey stock in 2006. Comparison to the Delaware stock survey suggests that similar trends occurred on both sides of the Bay. The 9^{th} SAW found that oyster abundance increased in 2006 from a two-year low that was the lowest abundance level since the onset of Dermo disease circa 1989 and one of the lowest levels in the 1953 to 2006 record. In 2006, abundance was at the 16^{th} percentile of the 1953-2006 time series and the 19^{th} percentile for the post-1988 era. Abundances also rose on the high-mortality beds and on Shell Rock in 2006. See Figure 1 for location of beds and definition of bed groups. The high-mortality beds and Shell Rock ranked at the 18^{th} and 37^{th} percentiles, respectively, for the 54-year time series and at the 25^{th} and 40^{th} percentiles post-1988. Abundance in 2006 on the high-mortality beds rose from 2005, by a factor of 1.29. This is the second consecutive year abundance has increased on these beds. Abundance rose also on Shell Rock, by a factor of 1.67, and for the second consecutive year. The large increase on Shell Rock was partly due to the 2005 shell-planting program.

2006 was the seventh consecutive year of low recruitment in the New Jersey stock. The same seven-year stretch is apparent in the time series for the Delaware

[♮] DRBC, Delaware River Basin Commission; DRBA, Delaware River and Bay Authority; DNREC, Delaware Department of Natural Resources and Environmental Control; NJDEP, New Jersey Department of Environmental Protection; RU, Rutgers University; NJAES, New Jersey Agricultural Experiment Station; HSRL, Haskin Shellfish Research Laboratory

[⊘] HSRL. 2007. Report of the 2007 Stock Assessment Workshop (9^{th} SAW) for the New Jersey Delaware Bay Oyster Beds. 94 pp.

Figure 1. Map of Delaware Bay showing the New Jersey and Delaware oyster beds and the locations of 2005 shell plants, indicated by stars. Note that the Delaware beds are not completely shown, nor is the bed footprint equivalently defined in comparison to New Jersey. The grids on the New Jersey beds represent the 0.2″ latitude × 0.2″ longitude squares used as the template for the New Jersey stock survey. The same areal scale was used on both sides of the bay for shell planting, namely approximately 25 acres or 0.2″ latitude × 0.2″ longitude. For New Jersey beds, the footprint shows the locations of the high-quality (dark shade) and medium-quality (light shade) grids. New Jersey bed groups are defined as follows: High mortality: Beadons, Nantuxent Point, Strawberry, Hog Shoal, Vexton, Hawk's Nest, New Beds, Egg Island, Ledge, Bennies, Bennies Sand; medium mortality (less Shell Rock): Ship John, Cohansey, Sea Breeze, Middle, Upper Middle; low mortality: Arnolds, Upper Arnolds, Round Island.



oyster stock. The number of spat per >20-mm oyster was 0.32; insufficient to sustain the present population. Population dynamics modeling indicates that the market-size component of the population is no longer in a period of negative surplus production, however. Abundance of $\geq 3''$ oysters is expected to increase in 2007, unless fishery exploitation or natural mortality rates[‡] are unusually high. Natural mortality accounted for 16.9% of the New Jersey stock in 2006, a relatively high, but still non-epizootic, mortality rate. An increasing trend in Dermo disease suggests that an increase in natural mortality rate can be expected in 2007, possibly reaching epizootic levels.

The 2006 shell-planting program was designed specifically to address the issue of low recruitment and occurred in a timely fashion, as 2006 recruitment on the natural oyster beds again was insufficient to sustain population abundance over the long term. The 2006 program to monitor the 2006 shell plants and the one-year status of the 2005 shell plants was composed of six components: (1) a small monitoring program for a downbay shell plant pursuant to the decision to transplant the spatted shell upbay; (2) a monitoring program to measure spat settlement potential carried out through late September; (3) a monthly monitoring program to track trends in growth and disease exposure for the 2005 and 2006 shell plants; (4) a quantitative evaluation in October to determine the overall success of the project as of season's end in 2006; (5) a dredge calibration component to determine the applicability of remote sampling by oyster dredge of shell plants; and (6) the development of a shell budget to evaluate the effectiveness of the shell-planting program in maintaining habitat integrity.

Summary of Shell-planting Program

The 2005 program consisted of six shell plants in New Jersey and two shell plants in Delaware. The New Jersey program was larger due to the additional support from funds provided by the State of New Jersey; however, as these plants contributed to the program as a whole, they are included in this report. Three types of shell were planted: surf clam shell obtained from New Jersey shucking houses, ocean quahog shell obtained from New Jersey shucking houses, and Maryland oyster shell obtained from shell mining operations in Chesapeake Bay.

Shell planting was carried out in July, 2005. Three 25-acre grids received direct plants in New Jersey: Shell Rock 4, 12, and 43. A fourth plant off Reed's Beach was moved upbay in September to Bennies Sand 11. All three types of shell were planted in New Jersey. Two 25-acre areas were planted in Delaware, on Jigger Hill and Lower Middle beds. Maryland oyster shell was planted in both areas. Ocean

‡ Throughout, the term 'mortality rate' applies to the fraction dying per year. Values given are not true rates; rather, they are equivalent to e^{-mt} in the equation $N_t = N_o e^{-mt}$ with m in units of yr^{-1} and $t = 1\,yr$.

quahog shell was also planted on Lower Middle. Specifics of the distribution of shell are provided in Table 1. Locations are provided in Figure 1.

Table 1. Summary of shell-planting activities for 2005. Shell-planting was carried out in July, 2005. Three 25-acre grids received direct plants, Shell Rock 4, 12, and 43. A fourth plant off Reeds Beach was moved upbay in September to Bennies Sand 11. Maryland oyster shell, ocean quahog shell, and surf-clam shell were used. Two harvest projections are shown. The 2005 projection was made at the end of 2005 based on spat counts from that year. Projections of marketable bushels assumed a 3-year time to market size and natural mortality at the juvenile rate in year 1 and at the adult rate in years 2 and 3. The mortality estimates used were the 50^{th} percentiles of the 1989-2005 time series: for Shell Rock, 0.443, 0.182, 0.182; for Bennies Sand: 0.529, 0.267, 0.267. Delaware sites were estimated using Shell Rock mortality rates. Bushel conversions assume 263 oysters per bushel. The 2006 updated projections (right-most column) are based on the observed mortality rates for 2006 (Table 2) and projected mortality rates for years 2 and 3 as above and, therefore, can be considered to be more accurate than those made in the previous year.

Location	Type of Shell Planted	Bushels Planted	Spat Collected	Spat/Bu	2005 Projected Harvest	2006 Projected Harvest
New Jersey						
Benny Sand 11	Replant of surf clam	22,500	12,713,461	565	10,610	20,206
Shell Rock 4	Maryland oyster	36,752	8,051,590	219	10,845	17,952
Shell Rock 12	Ocean quahog	18,248	13,503,520	740	18,189	28,377
Shell Rock 12	Maryland oyster	18,737	2,678,540	143	3,607	5,629
Shell Rock 43	Surf clam	8,000	2,492,214	312	3,356	5,478
Shell Rock 43	Ocean quahog	7,600	3,116,607	410	4,198	6,994
Delaware						
Lower Middle	Maryland oyster	46,382	1,793,637	38	2,415	4,298
Lower Middle	Ocean quahog	17,778	195,037	11	262	467
Jigger Hill	Maryland oyster	54,651	3,122,950	57	4,207	7,039
Total		230,648	47,667,556		57,689	96,440

The Maryland oyster shell proved hard to track as time went on and essentially impossible in year 2. Hence the 2006 status of the 2005 shell plants is determined solely from the clam shell plants.

The 2006 program consisted of eight shell plants in New Jersey and three larger shell plants in Delaware. The total volume of shell planted in New Jersey

Table 2. Observed yearling mortality rates for 2005 shell plants. Data are from monthly counts of new boxes from April to October, 2006. Sampling was not conducted on Delaware sites in May and June. In order to obtain a yearly value, comparable values for New Jersey beds for these two months were applied, Shell Rock 43 for Jigger Hill; Bennies Sand 11 for Lower Middle.

Shell Plant Location	Shell Type Planted	Fraction Dead (yr^{-1})
New Jersey		
Benny Sand 11	Replant of surf clam	0.103
Shell Rock 4	Maryland oyster	0.078
Shell Rock 12	Ocean quahog	0.131
Shell Rock 43	Surf clam	0.091
Shell Rock 43	Ocean quahog	0.072
Delaware		
Lower Middle	Maryland oyster	0.009
Jigger Hill	Maryland oyster	0.068

was higher than Delaware because some additional shell was purchased by New Jersey using matching funds provided by the Bridgeton/Port Norris Empowerment Zone. As these plants contributed to the program as a whole, they are included in this report. Two types of shell were planted: surf clam shell and ocean quahog shell, both obtained from New Jersey shucking houses.

Shell-planting was carried out in June-July, 2006. Six 25-acre grids received direct plants in New Jersey: Hawk's Nest 1, Nantuxent Point 25, Bennies Sand 7, and Shell Rock 20, 24, and 32. Two others were replants, one off Reeds Beach and one off Thompson's Beach. Both were moved upbay in late August to Bennies Sand 6 and 12. Three 25-acre areas were planted in Delaware, on Drum Bed, Silver Bed, and Pleasanton Rock. Specifics of the distribution of shell are provided in Table 3. Locations are provided in Figure 2.

Monitoring of Recruitment and Recruitment Potential

New Jersey carries out a program designed to monitor recruitment potential. In 2006, this program was extended into Delaware waters. Locations are shown in Figure 3. This program records the number of spat settling on 20 oyster valves in deployed bags for consecutive two-week periods at selected sites representative of the natural oyster beds and areas of shell planting in Delaware Bay. The 2006 program showed the anticipated trend of greater spat availability downbay, but a lower setting potential overall than in 2005. The monitoring program suggested that two recruitment waves occurred in 2006, one early, in July, and downbay and another later, in August, and upbay. High settlement potential in the Cape Shore region conforms to the observed higher settlement rates on shell planted in this area and subsequently replanted upbay.

Table 3. Summary of shell-planting activities for 2006. Shell-planting was carried out in late June-early July, 2006. Six 25-acre grids received direct plants, Hawk's Nest 1, Nantuxent Point 25, Bennies Sand 7, and Shell Rock 20, 24, and 32. Two others were replants of shell planted off Reeds Beach and Thompson's Beach and moved upbay in late August to Bennies Sand 6 and 12. Ocean quahog shell and surf-clam shell were used. Projections of marketable bushels assumed a 3-year time to market size and natural mortality at the juvenile rate in year 1 and at the adult rate in years 2 and 3. The mortality estimates used were the 50^{th} percentiles of the 1989-2006 time series: for Shell Rock, 0.451, 0.180, 0.180 for years 1, 2, and 3, respectively; for the remainder: 0.559, 0.252. 0.252. Bushel conversions assume 263 oysters per bushel.

Location		Type of Shell Planted	Bushels Planted	Spat Collected	Spat/Bu	Projected Harvest
Drum Bed		Quahog mix*	49,149	♯0	0	0
Silver Bed		Quahog mix*	82,661	7,646,143	93	10,215
Pleasanton Rock		Quahog mix*	74,474	6,806,179	91	9,093
Hawk's Nest	1	Surf Clam	17,850	3,672,102	206	3,054
Nantuxent	25	Quahog mix*	49,488	10,766,609	218	8,954
Bennies Sand	6	Surf Clam replant	14,811	24,709,636	1668	20,551
Bennies Sand	7	Quahog mix*	49,037	27,669,127	564	23,012
Bennies Sand	12	Surf Clam replant	15,826	43,653,647	2758	36,307
Shell Rock	20	Quahog mix*	48,472	10,330,353	213	13,801
Shell Rock	24	Quahog mix*	53,193	8,030,015	151	10,728
Shell Rock	32	Quahog mix*	23,689	10,859,748	458	14,508
Total			478,650	154,143,559		150,223

*Quahog mix = Quahog and surf clam processed to same small size.

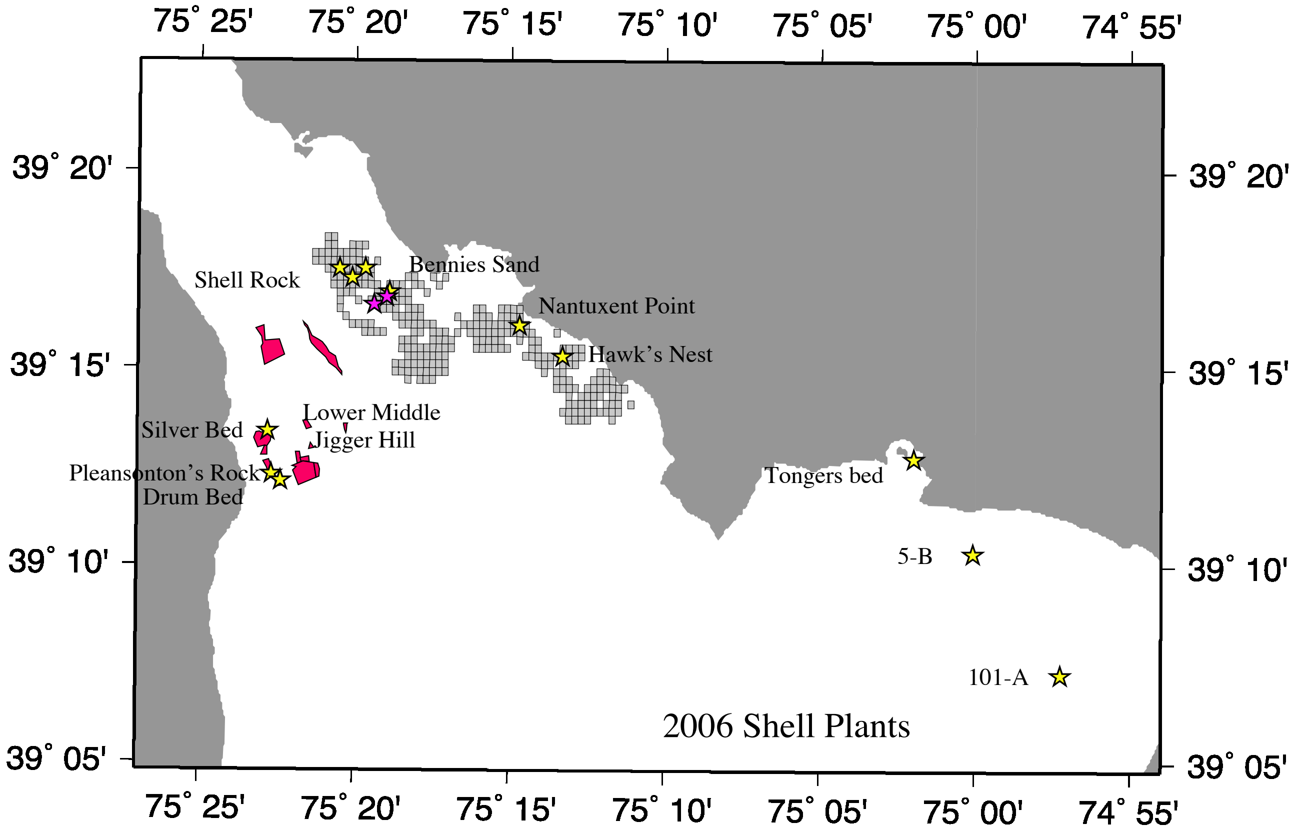
♯Early October sampling by the Dermo monitoring program recovered some spat on this bed; however recruitment was low in comparison to other plants.

Recruitment estimates for 2006 shell plants were obtained from two sampling sources. In October, samples were taken by oyster dredge in survey mode as a component of the oyster stock assessment program. In October, diver samples and closed dredge samples were obtained as a component of the dredge calibration program. Recruitment in 2006 on shell planted in 2005 was only obtained for clam shell plants. These data were obtained during the October stock survey.

Spat sizes at the end of the year generally ranged up to 30 mm. Unlike 2005, a single settlement event produced most the of the spat. Size-frequency distributions were rarely bimodal (Figures 4-7).

In New Jersey, shell was planted directly on the oyster beds and downbay off

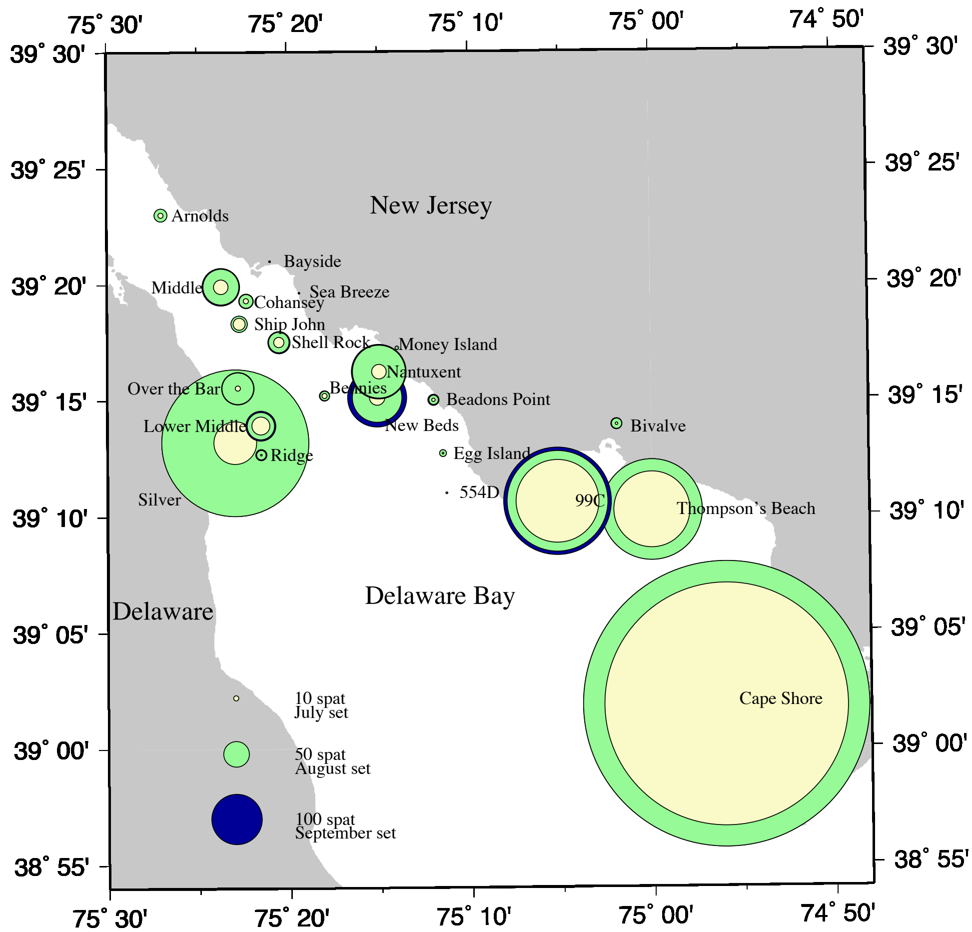
Figure 2. Location of 2006 shell plants, denoted by yellow stars. New Jersey downbay plants are on leased grounds (5-B, 101-A). Transplant locations for these downbay plants are denoted by purple stars. Selected high-quality oyster grounds in New Jersey are denoted by shaded 25-acre grids. Red delineates State of Delaware beds. A complete map of the New Jersey beds is contained in Figure 1.



Cape Shore. These latter plants were replanted upbay. As in 2005, even direct plants significantly out-performed native shell, with an average of 302 spat per bushel. Native shell on Bennies Sand attracted 54 spat per bushel and on Shell Rock, 48 spat per bushel in comparison; thus, the increase in recruitment on directly planted shell was about a factor of 5.9 over native shell. Downbay plants average 2,213 spat per bushel (Table 3). Thus, in contrast to 2005, downbay plants returned more than seven times the spat per bushel of direct plants (Table 3) and about 44 times that of native shell.

Results of the Delaware survey showed that the mean number of spat per bushel of native shell for Silver Bed was 14, for Drum Bed, 7, and for Pleasanton Rock,

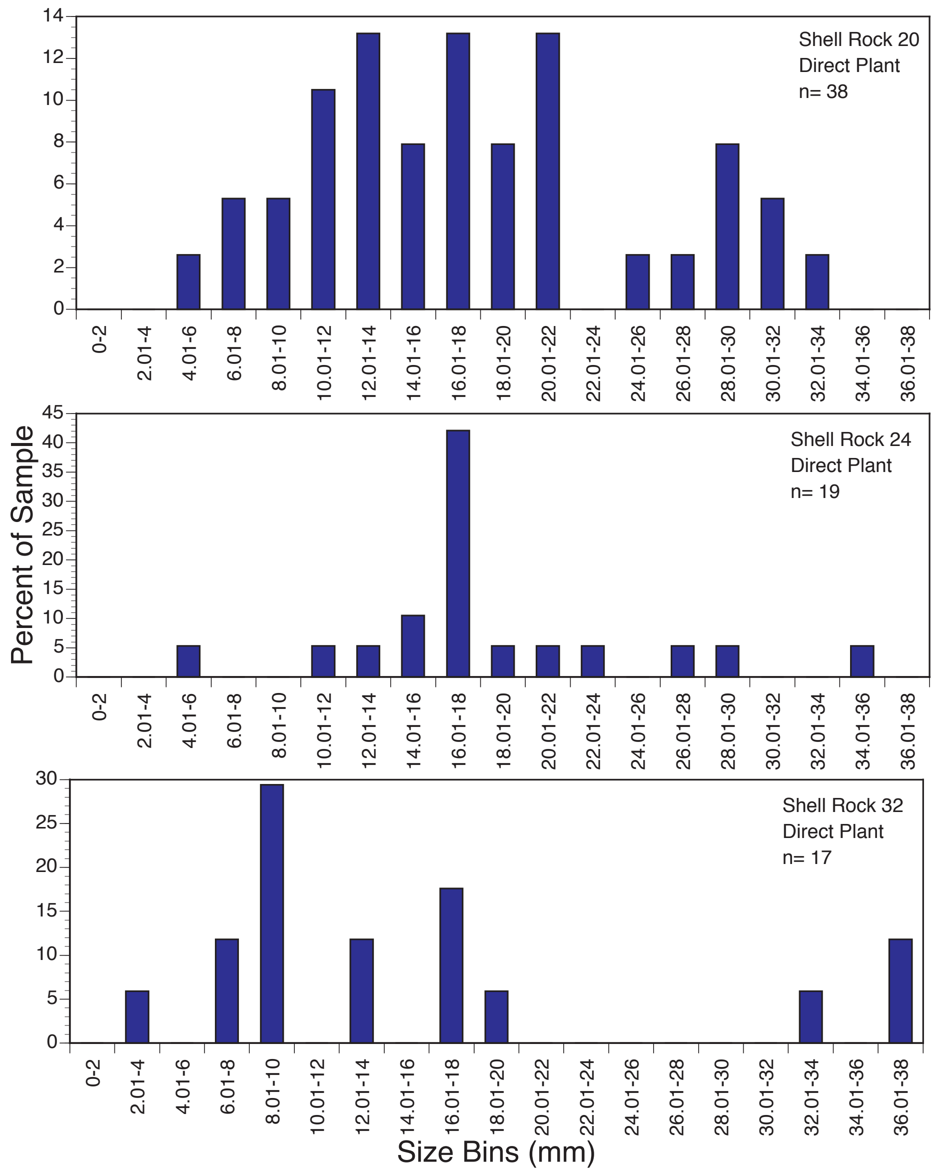
Figure 3. Cumulative number of spat recruiting to 20-oyster-shell bags deployed in the last week of June and collected bi-weekly through September. Colors identify the month of settlement. Increment in circle diameter indicates the number of spat that settled during that time period. Total diameter indicates the cumulative number of spat. Note that circle diameter bears a nonlinear relationship to total spat counts.



9. The values for Silver Bed and Pleasanton Rock for shell plants were 93 and 91, respectively (Table 3), indicating that the planted shell caught considerably more spat than native shell in Delaware as was observed in New Jersey.

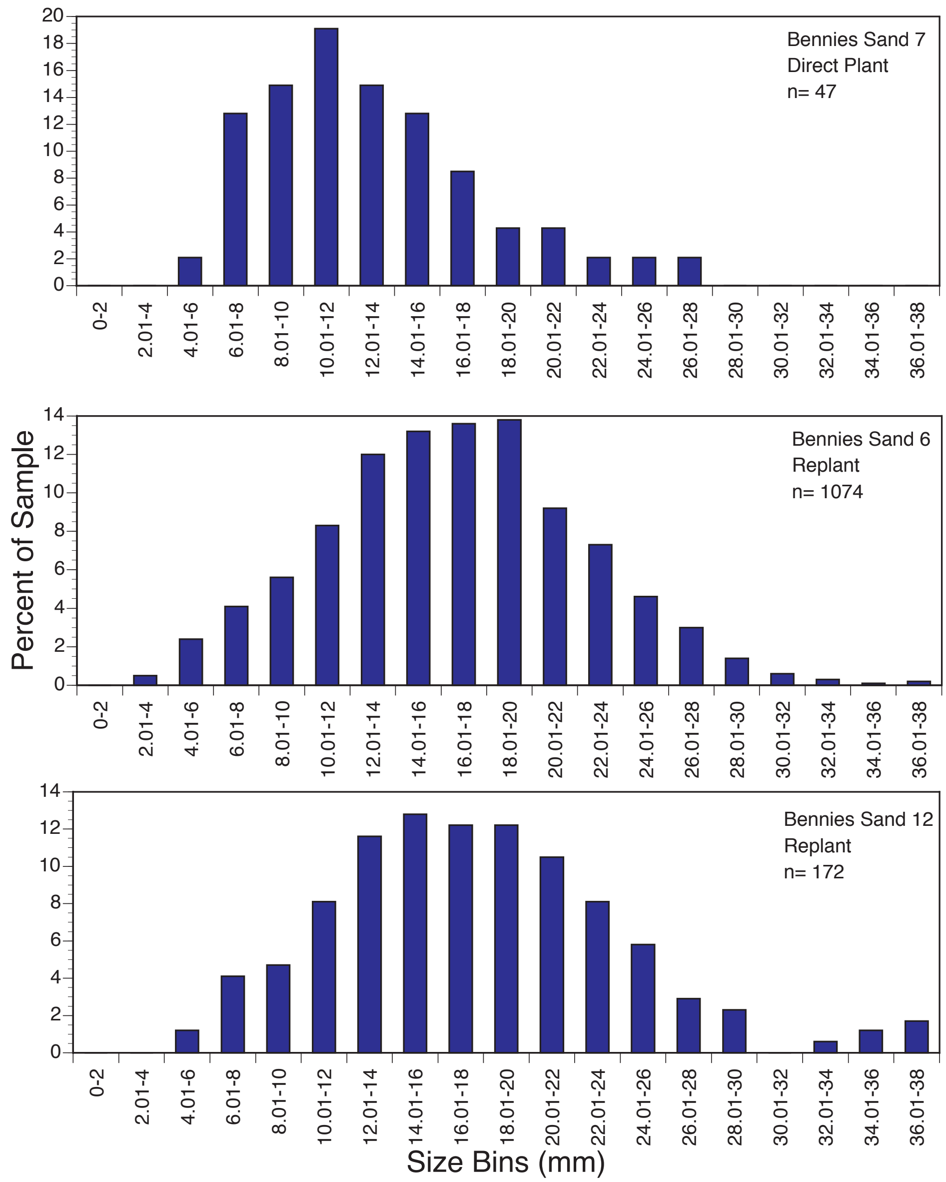
The overall success of recruitment enhancement on a spat-per-planted-bushel basis was better in New Jersey than Delaware. Values in Delaware were around 90 spat per bushel whereas values in New Jersey were in the range of 150-550.

Figure 4. Size-frequency distribution of spat on Shell Rock shell plants.



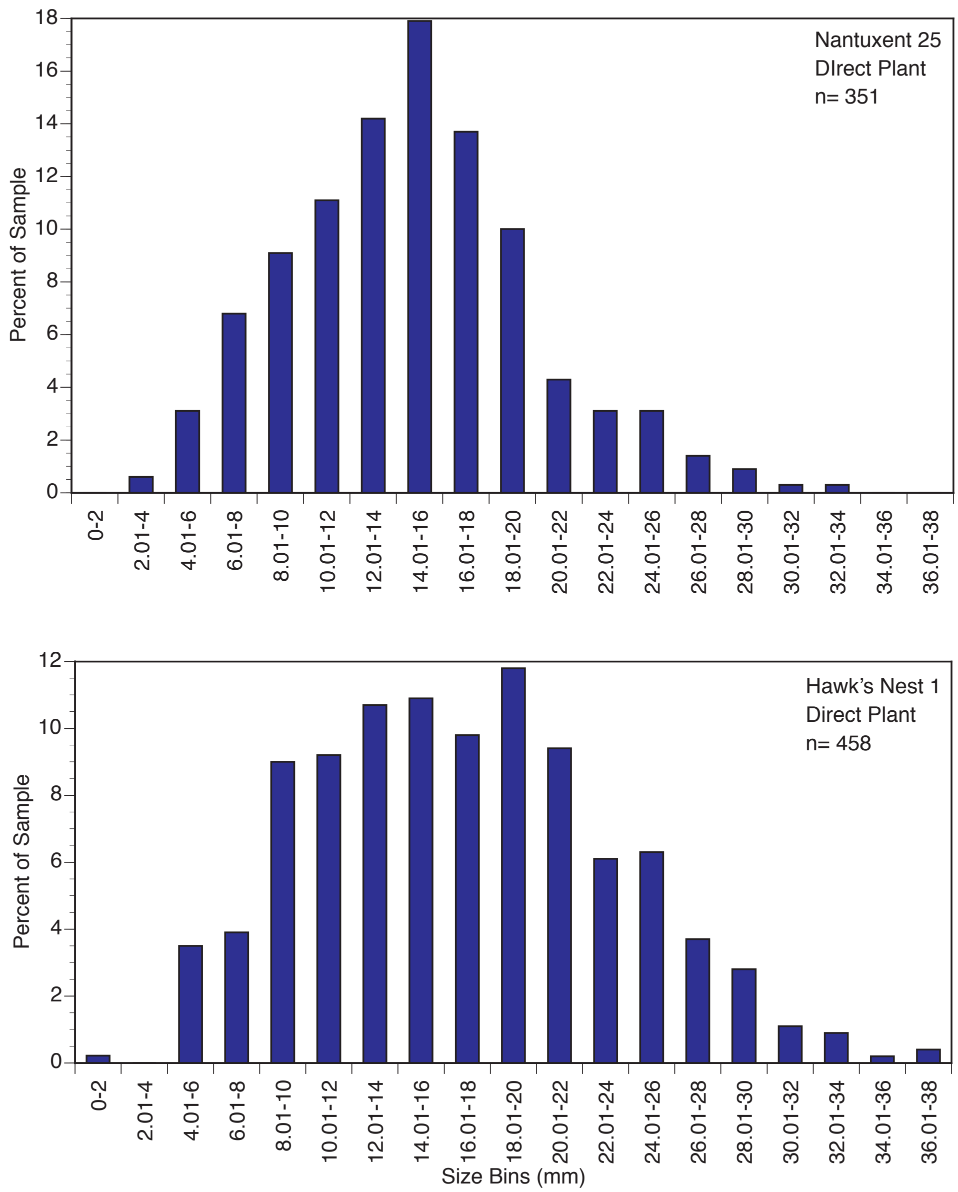
However, recruitment on native shell differed significantly as well. In Delaware, in the areas of the shell plants, values on native shell ranged from 7-14 spat per bushel, whereas in New Jersey, the values were 48-54. Thus both native and planted shell

Figure 5. Size-frequency distribution of spat on Bennies Sand shell plants.



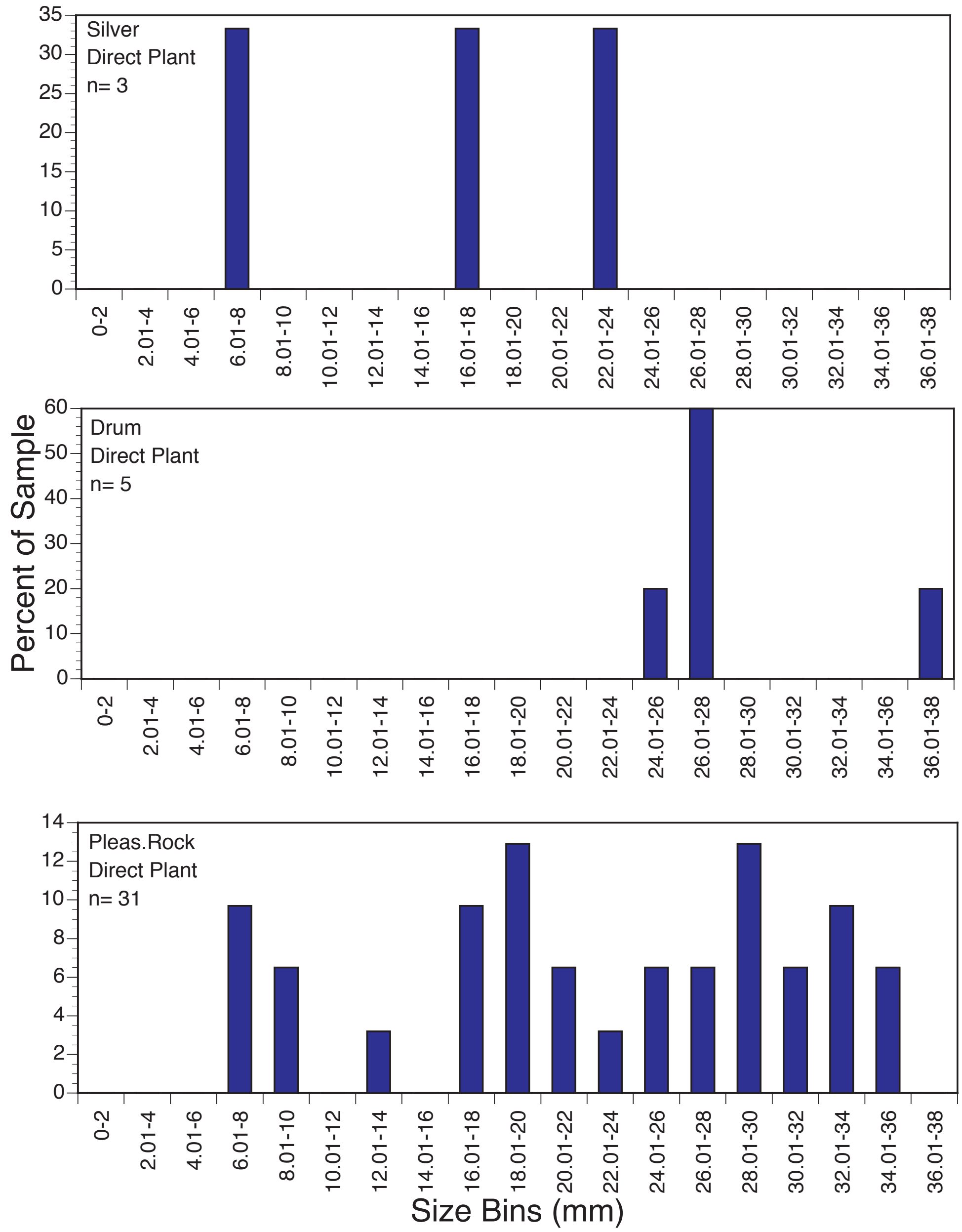
differed by on the order of a factor of 5 between the two sides of the bay in 2006. The differential between the two states would appear to be primarily a function of the greater recruitment potential on the New Jersey side. The same trend was

Figure 6. Size-frequency distribution of spat on Nantuxent Point and Hawk's Nest shell plants.



observed in 2005. As yet, the reason for this gradient in recruitment potential cannot be explained.

Figure 7. Size-frequency distribution of spat on Delaware shell plants.



Overall, recruitment enhancement programs were successful in 2006. In New

Jersey, where quantitative evaluation is easier, shell planting in 2006 enhanced recruitment by a factor of 1.34 bay-wide, providing 26% of total recruitment on New Jersey beds. On Shell Rock, shell plants accounted for 50% of total recruitment. On the high-mortality beds, shell plants accounted for 58% of total recruitment. Spat-per-adult ratios, after including the shell plants, rose to 0.64 on Shell Rock and 1.00 on the high-mortality beds, with percentile positions, respectively, of 50^{th} and 60^{th} for the post-1988 period, in comparison to the ratios of 0.32 and 0.42 on the native shell, respectively, with percentile ranks of 25^{th} and 14^{th}. Spat-per-adult ratios ≥ 1 are desirable because they are always associated with stock expansion. An increase in abundance can be anticipated on Shell Rock and beds downbay in 2007, barring an unusual mortality event or overharvesting.

Downbay Shell Plants

Shell was planted off Reed's Beach in two areas of high setting potential (Figure 2) and then monitored carefully for recruitment. The goal was to transplant this shell back upbay when total recruitment was maximal. As the number of living spat is always a function of the rate of larval settlement and the rate of spat mortality, typically the shell would be moved when spat counts begin to decline. These downbay shell plants were monitored from mid-July until the last two weeks of August, at which time replanting began. This decision was based on the time series of spat counts shown in Table 4, and was constrained by the availability of the suction dredge prior to the last two weeks of August. The end-of-July recruitment event observed in these data is consistent with the results of the spat-bag monitoring program (Figure 3).

Table 4. Time series of spat counts on the downbay shell plants located in Figure 2 prior to their replant upbay in the last two weeks in August.

Sampling Day	Lease 101-5 Spat per Bushel	Lease 5-B Spat per Bushel
July 14	185	0
July 24	370	111
July 30	962	167
August 3	21,669	10,545
August 8	18,697	4,421
August 10	8,010	4,662

Note that the estimates of spat per bushel during the replant (Table 5) fall below the final estimates obtained in October after sampling the upbay site (Table 3). The increment in spat counts is consistent with the later recruitment event upbay that added additional spat to this shell. Note in Figure 5 that these two replants, on Bennies 6 and 12, have spat with an expanded size-frequency distribution relative to that of the direct plant on Bennies 7, supporting the likelihood that the replanted shell continued to attract spat during the later recruitment event after transplanting upbay.

Table 5. Average spat counts of shell replanted upbay from the downbay shell plants located in Figure 2. Shell from lease 101-5 was transplanted upbay on three days in August; transplanting shell from lease 5-B took five days.

Sampling Day	Spat per Bushel
Lease 101-5	
August 15	2,117
August 16	523
August 17	667
Lease 5-B	
August 18	1,527
August 22	851
August 23	1,720
August 28	1,414
August 29	940

Harvest Projections

At the end of 2005, we projected an eventual harvest of 57,689 bushels from the shell-planting program of 2005 (Table 1). The yearly mortality rate† for yearlings from the 2005 shell plants in 2006 was much below the rate typically observed (Table 2). Assuming marketable size is reached in year 3 and that the mortality rate will average at the 50^{th} percentile of the 1989-2006 time series in years 2 and 3 permits a revision of the projected harvest from the 2005 program as shown in Table 1 to a total of 96,440 bushels. The yearlings from these shell plants represent an important source of the abundance increase observed on these beds by the New Jersey survey (see the 2007 SAW report).

Projections of marketable bushels from the 2006 shell plants were obtained by assuming a 3-year time to market size and natural mortality at the juvenile rate in year 1 and at the adult rate in years 2 and 3. The mortality rates used were the 50^{th} percentiles of the 1989-2006 time series: for Shell Rock and Delaware beds, 0.451, 0.180, 0.180, for years 1, 2, and 3, respectively; for Bennies Sand: 0.559,

† The method used is described in: Ford, S.E., M.J. Cummings and E.N. Powell. 2006. Estimating mortality in natural assemblages of oysters. *Estuaries Coasts* 29: 361-374.

0.252, 0.252. 2006 shell plants are expected to provide 150,223 bushels for market in 2009 (Table 3).

The shell planted in 2005 was expected to contribute to the spat set in 2006 also. Only clam shell could be tracked over this period of time. Shell planted in 2005 continued to attract spat in 2006; however the rate of attraction (67/bu) was little better than native shell on the same grids (47/bu). Nevertheless, the net addition of shell to these beds sustained an increased recruitment rate for a second year. Year 2 recruitment will contribute minimally an additional 4,659 marketable bushels in New Jersey in 2009. Because oyster shell primarily was planted in Delaware in 2005 and this shell could not be tracked in year 2, a similar calculation cannot be made for Delaware waters; however a similar outcome is assumed to have occurred.

Monitoring of Growth and Mortality

Perkinsus marinus prevalences in the area of the bay used for shell planting are typically above 50%. In 2006, oysters on the 2005 shell plants were monitored for *P. marinus* infection. Prevalence was lower on the Delaware shell plants, suggesting that disease exposure, as expected, is lower on that side of the bay at a given river-mile marker. Weighted prevalences were substantially lower (Table 6)[∅]. The stock survey conducted by New Jersey obtained bed average infection intensity for October for both Shell Rock and Bennies Sand. Similar data are not available for Jigger Hill and Lower Middle. The bed-average prevalence was 100% and 90% for Shell Rock and Bennies Sand, respectively. These compare closely to the values obtained in October for the animals on the 2005 shell plants (Table 6). The bed-average weighted prevalence was 3.275 and 1.800 for Shell Rock and Bennies Sand, respectively. These values are comparable to the October values for the Bennies Sand shell plant, but substantially above the October values for the Shell Rock shell plants. The evidence suggests that *P. marinus* infection is, if anything, lower on animals obtained from shell plants relatively to animals naturally occurring on the bed and that *P. marinus* infection is lower on the Delaware side. Both suggest that average mortality rates will be below the values used for years 2 and 3 in estimating the number of bushels to be marketed from the 2005 plants (Table 1), assuming overall average mortality rates; that is, the values given in Table 1 are likely to be underestimates.

The 9th SAW determined that Dermo increased in intensity in 2006 over 2005. Although the impact of disease on the animals obtained from shell plants cannot

[∅] Weighted prevalence is based on Mackin's 0-to-5-point scale, where 0 is uninfected and 5 is heavily infected: Ashton-Alcox, K.A., Y. Kim and E.N. Powell. 2006. Chapter 3. *Perkinsus marinus* assay. *In*: Kim, Y., K.A. Ashton-Alcox and E.N. Powell, Eds., Histological techniques for marine bivalve molluscs: Update. *NOAA Tech. Mem.* NOS NCCOS 27:53-64.

Table 6. The prevalence and weighted prevalence of *Perkinsus marinus* in oysters on the shell planted in 2005. ND, not determined.

	Jigger Hill	Lower Middle	Shell Rock 4	Shell Rock 12	Shell Rock 43 ocean quahog	Shell Rock 43 surf clam	Bennies Sand 11
Prevalence							
Jul-06	0.0%	0.0%	5.0%	15.0%	0.0%	0.0%	0.0%
Aug-06	55.0%	40.0%	35.0%	70.0%	20.0%	30.0%	50.0%
Sep-06	40.0%	15.0%	80.0%	90.0%	80.0%	95.0%	75.0%
Oct-06	55.0%	30.0%	80.0%	100.0%	90.0%	95.0%	85.0%
Nov-06	ND	30.0%	100.0%	90.0%	90.0%	95.0%	100.0%
Weighted Prevalence							
Jul-06	0.0	0.0	0.1	0.3	0.0	0.0	0.0
Aug-06	0.4	0.2	0.5	1.0	0.1	0.5	0.7
Sep-06	0.4	0.1	2.3	3.2	2.0	3.1	1.3
Oct-06	0.5	0.3	1.9	1.9	2.1	2.0	1.9
Nov-06	ND	0.6	2.4	2.6	2.5	2.8	3.3

yet be determined fully, the data suggest that an above average exposure will occur in 2007 and that anticipated natural mortality rates will be higher than the long-term average. If this materializes, then the estimated yields in Table 1 will be overestimated because the 50^{th} percentile of natural mortality was applied.

Growth rates were measured for spat that settled on the 2005 shell plants (Tables 7 and 8). These spat averaged about 30 mm in size in March, 2006 and grew to an average of about 40-60 mm by November, 2006. Growth rates were exceptional on Lower Middle and Jigger Hill. In general, growth rates in Delaware waters exceeded those in New Jersey waters. The harvest estimates in Table 1 assume three full years of growth to market size, whereas growth rates shown in Tables 7 and 8 indicate that many of these animals will be marketable prior to the end of year three. Maximum sizes indicate that a fraction of these animals will reach market size in 2007 (Table 8) and that most of the remainder will reach market size within the 2008 season. Thus, these data suggest that the estimated harvests generated by the 2005 shell plants provided in Table 1, already increased relative to year-1 estimates due to low yearling mortality rates, likely remain underestimates.

Shell Budget Projections

A shell budget was constructed using bed-specific half-life estimates for shell[♮].

[♮] Powell, E.N., J.N. Kraeuter and K.A. Ashton-Alcox. 2006. How long does oyster shell last

Table 7. Average size (mm) in 2006 of 2005 spat settled on clam shell planted in 2005. ND, not determined.

	Jigger Hill	Lower Middle	Shell Rock 4	Shell Rock 12	Shell Rock 43 ocean quahog	Shell Rock 43 surf clam	Bennies Sand 11
Sep-05	20.86	16.63	23.67	14.89	18.13	20.04	25.62
Dec-05	18.46	27.30	27.70	ND	25.89	ND	30.38
Mar-06	32.50	26.93	27.34	20.55	29.33	28.27	32.43
Apr-06	32.12	32.46	28.10	23.04	15.93	25.71	26.51
May-06	36.43	35.51	31.82	25.46	27.90	30.36	35.02
Jun-06	40.83	40.59	35.02	31.34	32.91	32.32	38.42
Jul-06	44.73	44.20	39.28	35.76	36.08	35.96	44.01
Aug-06	47.73	43.96	41.46	40.54	36.67	39.04	45.04
Sep-06	53.64	50.30	44.05	43.07	42.11	42.07	47.79
Oct-06	55.50	50.72	42.08	39.09	39.72	45.42	48.95
Nov-06	ND	65.78	ND	39.98	42.14	40.08	49.73

Table 8. Minimum and maximum size (mm) in 2006 of 2005 spat settled on clam shell planted in 2005. ND, not determined.

	Jigger Hill	Lower Middle	Shell Rock 4	Shell Rock 12	Shell Rock 43 ocean quahog	Shell Rock 43 surf clam	Bennies Sand 11
Minimum							
Apr-06	11.60	9.60	ND	5.01	14.85	6.04	ND
May-06	21.61	20.99	19.49	7.24	13.98	7.98	11.14
Jun-06	24.91	24.39	18.17	13.83	15.81	13.96	11.68
Jul-06	25.10	25.31	23.85	18.04	20.51	17.87	19.87
Aug-06	31.91	18.70	23.14	20.00	12.50	16.13	14.68
Maximum							
Apr-06	49.57	52.93	ND	48.60	18.08	51.99	ND
May-06	48.25	50.52	47.52	48.72	42.43	50.26	35.25
Jun-06	50.87	53.22	49.92	47.20	48.76	53.39	54.38
Jul-06	60.93	58.66	58.48	55.91	51.12	66.40	61.83
Aug-06	62.66	64.06	63.09	66.83	55.36	62.85	77.12

Half lives ranged generally between 3 and 10 years (Table 9). The analyses are subject to substantial yearly variations when analyzed retrospectively because not all beds were sampled each year in the first two-thirds of the time series, because the addition of shell beginning in 2004 increases the difficulty of analysis as industry

on an oyster reef? *Estuar. Coast. Shelf Sci.* 69:531-542.

dredging redistributes the shell beyond its original grid placement, and because the half-lives for surf clam and ocean quahog shell may diverge substantively from that for oyster shell. Outlier half-life values occurred on beds poorly sampled in the first two-thirds of the survey or beds heavily impacted by shell planting in 2005-2006. Three beds have negative half-life estimates: Round Island, Upper Middle, and Sea Breeze. All three were surveyed in alternate years from 1996-2003; thus the time series for these beds is inadequate.

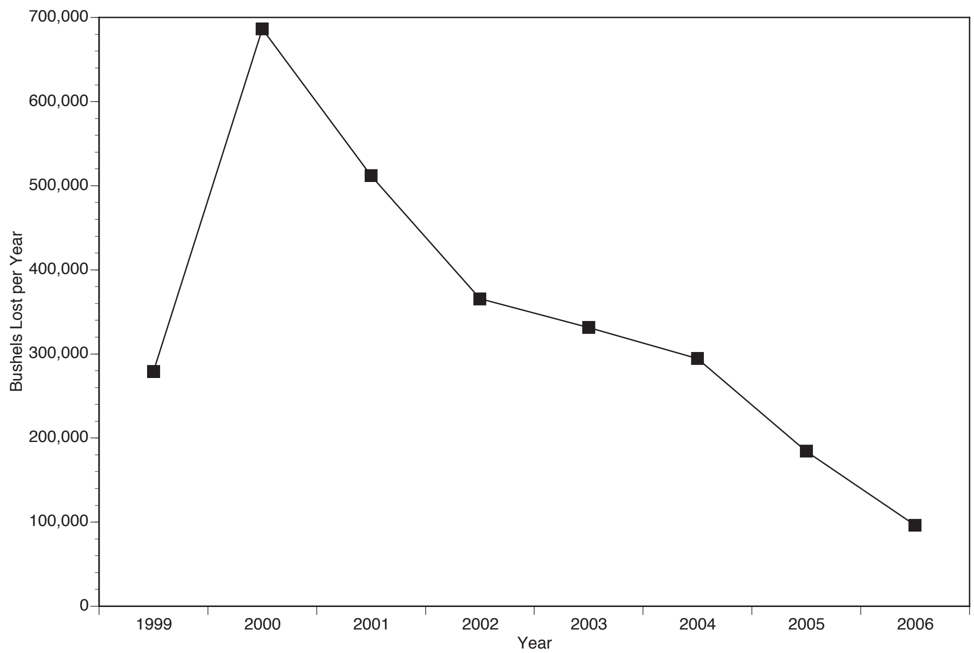
Table 9. Average half-lives for surficial oyster shell on Delaware Bay oyster beds, for the 1999-2006 time period.

Location	Half-life (yr)	Location	Half-life (yr)
Round Island	-5.36	Bennies	5.32
Upper Arnolds	8.28	Nantuxent Point	3.31
Arnolds	4.24	Hog Shoal	4.64
Upper Middle	-1.64	Hawk's Nest	6.20
Middle	7.95	Strawberry	4.28
Cohansey	13.91	New Beds	15.63
Ship John	5.52	Beadons	570.81
Sea Breeze	-78.01	Vexton	6.99
Shell Rock	4.61	Egg Island	8.78
Bennies Sand	55.03	Ledge	9.15

New Jersey oyster beds have been losing on the order of 250,000 to 500,000 bushels of shell annually since 1999 (Figure 8). 1999 is the first year an estimate can be made as 1998 is the first year that full survey data are available. The shell budget shows a substantial reduction in shell loss in 2005 and 2006 as a result of the shell-planting program that has reduced by at least two-thirds the yearly deficit. Similar estimates for Delaware cannot yet be made, as quantitative information on shell content is unknown. However, loss rates observed on Middle, Shell Rock, Ship John and Cohansey are likely indicative of loss rates on Delaware beds, as the location of the Delaware beds in the salinity gradient is similar to the named New Jersey beds.

By region, the low-mortality beds have been losing about 20,000-40,000 bushels annually (Figure 9). This lower level of shell loss is due to low taphonomic loss rates. The medium-mortality beds are losing 30,000 to 100,000 bushels annually due to higher loss rates and larger total area. Shell Rock has shown a net gain since 2005 due to shell planting. The high-mortality beds are losing 175,000 to 350,000 bushels annually due mostly to the larger area of coverage. A reduction in the rate of decline in 2006 is due to the substantial shell planting that occurred downbay of Shell Rock.

Figure 8. Estimated number of bushels of shell lost from the New Jersey oyster beds for the time period 1999-2006. Lower estimates in 2005 and 2006 reflect the addition of shell through shell planting to offset the shell loss.

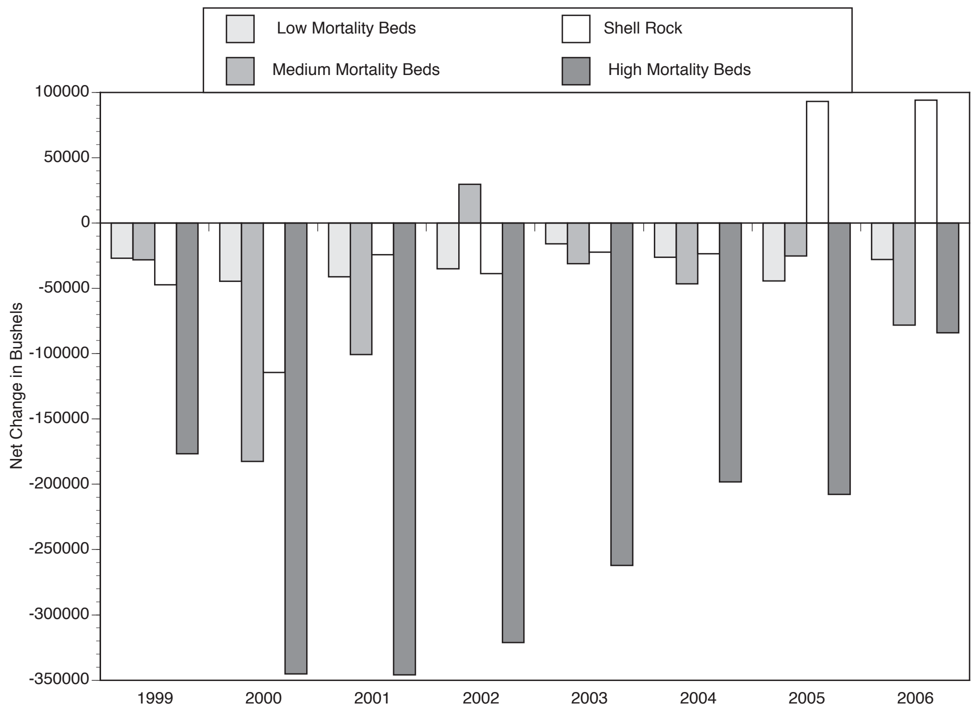


By bed, Ship John and Bennies have the largest negative numbers, Bennies due to its large size and Ship John due to its high loss rate (Table 10). Other beds exceeding a loss of 1 million kg per year include Arnolds, New Beds, Hog Shoal, Vexton, and Egg Island. Four of these beds are high-mortality beds with low abundance and thus low rates of natural shell addition. Five beds had positive balances in 2006; four of these were the beds on which shell planting occurred. The fifth is Beadons.

The shell budget estimates identify the importance of shell planting in maintaining the integrity of the beds during times of disease when low abundance limits the amount of shell added to the beds naturally as animals die. The shell budget also permits more effective planning for future shell plants in New Jersey waters.

Most beds not receiving shell plants in 2006 suffered a loss of surficial shell. Continued shell planting is essential to maintain habitat quality as well as provide substrate to enhance recruitment. Shell plants should target areas where marketable oysters grow but where cultch loss exceeds the addition of shell through natural mortality. The Ship John region is such a case. Due to the enhanced survival of

Figure 9. Estimated net change in surficial shell content in bushels by bay region for the New Jersey oyster beds for the time period 1999-2006. Positive values on Shell Rock in 2005 and 2006 reflect the addition of shell through shell planting to offset the shell loss.



juveniles in this region, replants from downbay plants should be moved to selected areas of Ship John in 2007. This will maximize the return from this more costly endeavor. The same region, and Cohansey as well, have the lowest fraction of small oysters in the size-frequency distribution of any bay region. Hence, these beds also should be considered for direct shell plants in 2007. Downbay plants and replants should be expanded to the extent funds permit to enhance recruitment.

Shell Rock and Bennies Sand should not be planted in 2007.

The high-mortality beds have the fastest growth rates and best oysters for marketing, but increasing abundance in this region increases the risk of epizootics. The shell-planting program should not exclusively target this area; however, Nantuxent Point, Hawk's Nest, Hog Shoal, Vexton, and Strawberry should be considered as planting locales for direct shell plants. Planting should not occur on Bennies and New Beds as evidence indicates that oysters in this region suffer proportionately higher Dermo mortality for a given disease level than the inshore beds (see 2007

Table 10. 2006 shell balance (net change from 2005) for Delaware Bay oyster beds (in kg per bed). Arrows identify locations receiving 2006 shell plants.

Location	Net Change in Shell	
Upper Arnolds	-424,397	
Arnolds	-1,616,357	
Middle	-908,253	
Cohansey	-151,022	
Ship John	-4,670,979	
Shell Rock	6,881,596	⟵
Bennies Sand	6,002,242	⟵
Bennies	-5,638,249	
Nantuxent Point	963,856	⟵
New Beds	-1,154,274	
Hawk's Nest	210,086	⟵
Hog Shoal	-1,863,915	
Strawberry	-858,048	
Beadons	21,264	
Vexton	-1,388,771	
Egg Island	-1,722,509	
Ledge	-733,859	

SAW report).

Dredge Efficiency

A series of experiments to determine dredge efficiencies were again conducted to ascertain the continued reliability of the survey quantification and to evaluate the efficiency of capture of planted shell.

Comprehensive dredge efficiency measurements were conducted on Hawk's Nest and Nantuxent Point. Values for the efficiency of capture of native shell were representative of previous experiments. Live oyster catchability coefficients[♭], q, averaged 3.93 versus the 3.11 value obtained in 2003[⊗]. Boxes averaged 6.01 versus

[♭] The catchability coefficient q as used herein is defined as the inverse of dredge efficiency e: $q = \frac{1}{e}$.

[⊗] 2003 and 2000 values are taken from: Powell, E.N., K.A. Ashton-Alcox, J.A. Dobarro, M. Cummings, and S.E. Banta. 2002. The inherent efficiency of oyster dredges in survey mode. *J. Shellfish Res.* 21:691-695 and Powell, E.N., K.A. Ashton-Alcox, J.N. Kraeuter.

4.64. Cultch averaged 9.05 versus 8.14. These additional measurements suggest that dredge efficiency has changed little since 2003.

In 2005, extensive dredge efficiency assessments revealed that the survey dredges had a low efficiency of capture of surf clam and ocean quahog cultch. Additional information obtained in 2006 confirms this trend (Table 11). In general, surf clam cultch is caught with greater efficiency, albeit still low, than ocean quahog cultch. This is likely a result of the somewhat larger size of the surf clam material. In either case, the data suggest that diver sampling is the most advantageous approach to quantitative assessment of shell plants.

Table 11. Catchability coefficients, calculated as the reciprocal of dredge efficiency, for spat on planted cultch and for planted cultch.

Type of Shell Planted	Spat	Cultch
2005 efficiency values		
Ocean quahog	98.30	197.59
Surf clam	150.25	123.73
2006 efficiency values		
Ocean quahog	238.15	333.09
Surf clam	131.91	112.01

As diver sampling is inherently logistically complex and costly, we evaluated the performance of an oyster dredge with reduced ring size. A standard survey dredge has a bag composed of 50.8 mm rings. A dredge of this type was outfitted with a chain bag lined with a flexible stainless steel mesh of approximately 1/8″ ID to catch the smallest pieces of quahog shell. The the sides were left un-lined to provide sufficient water flow while dredging. Side-by-side measured tows were taken with the standard survey dredge and the closed survey dredge. The closed dredge was normally a factor of 2 to 10 more efficient than the standard dredge (Table 12). In comparison, divers were normally more efficient by a factor of 100 or more. Thus, the closed dredge, although providing an improved sample relative to the standard dredge, did not offer sufficient improvement to obviate the need for divers as a primary sampling tool.

Table 12. Catchability coefficients calculated as the reciprocal of dredge efficiency for the standard survey dredge relative to the closed dredge. –, insufficient data.

in press, Re-evaluation of Eastern oyster dredge efficiency in survey mode: Application in stock assessment. *N. Am. J. Fish. Manage.*

Bed or Bed Group	Year	Shell Type	q for Spat	q for Cultch
Delaware				
Lower Middle	2005	ocean quahog	–	1.76
Drum, Silver, Pleasanton Rock	2006	ocean quahog	–	16.58
		surf clam	5.14	46.89
New Jersey				
Bennies Sand 11	2005	ocean quahog	5.61	3.52
Shell Rock 12,43	2005	surf clam	1.15	0.11
Bennies Sand 6,7,12	2006	ocean quahog	4.25	9.69
Shell Rock 20,24,32, Hawk's Nest, Nantuxent Point	2006	surf clam	2.55	9.99

APPENDIX B

General Conformity Review and Emission Inventory
Delaware Bay Oyster Restoration Project
April 2007

The 1990 Clean Air Act Amendments include the provision of Federal Conformity, which is a regulation that ensures that Federal Actions conform to a nonattainment area's State Implementation Plan (SIP) thus not adversely impacting the area's progress toward attaining the National Ambient Air Quality Standards (NAAQS). In the case of the Delaware Bay Oyster Restoration Project, the Federal Action is to plant shell on existing oyster beds at several locations in Delaware Bay (States of Delaware and New Jersey). Another component of the project is to transplant adult oysters and oyster spat to areas in the bay more conducive to oyster success. The U.S. Army Corps of Engineers, Philadelphia District would be responsible for construction. Delaware Bay, New Jersey and Delaware within which the Federal Action will take place is classified as moderate nonattainment for ozone (oxides of nitrogen [NOx] and volatile organic compounds [VOCs]). Delaware Bay, New Jersey and Delaware is within the Philadelphia-Wilmington-Trenton Nonattainment Area (PA-NJ-DE-MD).

There are two types of Federal Conformity: Transportation Conformity and General Conformity (GC). Transportation Conformity does not apply to this project because the project would not be funded with Federal Highway Administration money and it does not impact the on-road transportation system. GC however is applicable. Therefore, the total direct and indirect emissions associated with the Delaware Bay Oyster Restoration Project must be compared to the GC trigger levels presented below.

Pollutant	**General Conformity Trigger Levels (tons per year)**
NOx	100
VOCs	50

To conduct a general conformity review and emission inventory for the Delaware Bay Oyster Restoration Project, a list of equipment necessary for construction was identified. Pertinent pieces of equipment include: tug boats, pump engines to power water cannons and a suction dredge. Table 1 lists these pieces of equipment along with the number of engines, engine size (hp), and duration of operation. A Load Factor (LF) was also selected for each engine, which represents the average percentage of rated horsepower used during a source's operational profile. Load factors were taken from the General Conformity Review and Emission Inventory for the Delaware River Main Channel Deepening Project.

Table 1 shows the estimated hp-hr required for each equipment/engine category. Hp-hr was calculated using the following equation:

hp-hr = # of engines*hp*LF*hrs/day*days of operation

The second calculation is to derive the total amount of emissions generated from each equipment/engine category by multiplying the power demand (hp-hr) by an emission factor (g/hp-hr). The following equations were used:

emissions (g) = power demand (hp-hr) * emission factor (g/hp-hr)

emissions (tons) = emissions (g) * (1 ton/907200 g)

Conservative values for the NOx and VOC emission factors were selected for the equipment/engine categories. These factors were taken from the General Conformity Review and Emission Inventory for the Delaware River Main Channel Deepening Project. Tables 2 and 3 present the emission estimates for NOx and VOCs, respectively. The tables present the emissions from each individual equipment/engine category and the combined total. Table 4 estimates emissions associated with workers driving to and from the work site each day over the course of the construction period.

The total estimated emissions that would result from construction of the Delaware Bay Oyster Restoration Project are 1.85 tons of NOx and 0.29 tons of VOCs. These emissions are below the General Conformity trigger levels of 100 tons per year for NOx and 50 tons per year for VOCs. General Conformity under the Clean Air Act, Section 176 has been evaluated for the project according to the requirements of 40 CFR 93, Subpart B. The requirements of this rule are not applicable to this project because the total direct and indirect emissions from the project are below the conformity threshold values established at 40 CFR 93.153 (b) for ozone (NOx and VOCs) in a Moderate Nonattainment Area (100 tons NOx and 50 tons VOCs per year). The project is not considered regionally significant under 40 CFR 93.153 (i).

General Conformity Review and Emission Inventory for the Delaware Bay Oyster Restoration Project

Table 1. Project Emission Sources and Estimated Power

hp-hr = # of engines*hp*LF*hrs of operation

Load Factor (LF) represents the average percentage of rated horsepower used during a source's operational profile.

Equipment/Engine Category	**# of engines**	**hp**	**LF**	**hrs of operation**	**hp-hr**
Tug Boat Prime Engine	1	1000	0.40	96	38400
Tug Boat Prime Engine	1	1000	0.40	96	38400
Tug Boat Auxiliary Engine	1	175	0.20	96	3360
Tug Boat Auxiliary Engine	1	175	0.20	96	3360
Water Cannon Pump Engine	1	400	0.50	96	19200
Water Cannon Pump Engine	1	400	0.62	96	23808
Suction Dredge for Delineation	1	320	0.50	96	15360
Suction Dredge for Planting	1	320	0.62	112	22221
Suction Dredge for Reharvesting	1	320	0.43	112	15411

Load Factors taken from the General Conformity Review and Emission Inventory for the Delaware River Main Channel Deepening Project. (May 2003). Prepared for the U.S. Army Corps of Engineers, Philadelphia District by Moffatt & Nichol Engineers.

General Conformity Review and Emission Inventory for the Delaware Bay Oyster Restoration Project

Table 2. Emission Estimates (NOx)

Emissions (g) = Power Demand (hp-hr) * Emission Factor (g/hp-hr)

Emissions (tons) = Emissions (g) * (1 ton/907200 g)

NOx Emissions Factor for Off-Road Construction Equipment is 9.20 g/hp-hr

Equipment/Engine Category	**hp-hr**	**EF (g/hp-hr)**	**Emissions (tons)**
Tug Boat Prime Engine	38400	9.20	0.39
Tug Boat Prime Engine	38400	9.20	0.39
Tug Boat Auxiliary Engine	3360	9.20	0.03
Tug Boat Auxiliary Engine	3360	9.20	0.03
Water Cannon Pump Engine	19200	9.20	0.19
Water Cannon Pump Engine	23808	9.20	0.24
Suction Dredge for Delineation	15360	9.20	0.16
Suction Dredge for Planting	22221	9.20	0.23
Suction Dredge for Reharvesting	15411	9.20	0.16
	Total NOx Project Emissions (tons) =		1.82

Table 3. Emission Estimates (VOCs)

Emissions (g) = Power Demand (hp-hr) * Emission Factor (g/hp-hr)

Emissions (tons) = Emissions (g) * (1 ton/907200 g)

VOC Emissions Factor for Off-Road Construction Equipment is 1.30 g/hp-hr

Equipment/Engine Category	**hp-hr**	**EF (g/hp-hr)**	**Emissions (tons)**
Tug Boat Prime Engine	38400	1.30	0.06
Tug Boat Prime Engine	38400	1.30	0.06
Tug Boat Auxiliary Engine	3360	1.30	0.005
Tug Boat Auxiliary Engine	3360	1.30	0.005
Water Cannon Pump Engine	19200	1.30	0.03
Water Cannon Pump Engine	23808	1.30	0.0341
Suction Dredge for Delineation	15360	1.30	0.02
Suction Dredge for Planting	22221	1.30	0.03
Suction Dredge for Reharvesting	15411	1.30	0.02
	Total VOCs Project Emissions (tons) =		0.26

Table 4. Pollutant Emissions from Employee Vehicles

Assumptions:

Average trip distance (1 way) is 25 miles.
Average NOx vehicle emission factor is 0.96 g/mile.
Average VOC vehicle emission factor is 0.84 g/mile.
Work crew comprised of 12 people
Every member of the work crew drives their own vehicle.
Project construction period is 46 days..

Actual work days = 46 days

NOx Calculation: 12 workers * 2 trips/work day * 46 work days * 25 miles/trip * 0.96 g of NOx/mile

Total NOx resulting from employee vehicles = 0.03 tons.

VOC Calculation: 12 workers * 2 trips/work day * 46 work days * 25 miles/trip * 0.84 g of VOC/mile

Total VOCs resulting from employee vehicles = 0.03 tons.

Pollutant emissions associated with employee vehicles derived from data found in: Marine and Land-Based Mobile Source Emission Estimates for 50-Foot Deepening Project. January 2002. Prepared for The Port Authority of New York and New Jersey by Killam Associates and Starcrest Consulting Group, LLC.