US Army Corps
of Engineers
Philadelphia District

DELAWARE BAY OYSTER RESTORATION PROJECT
DELAWARE AND NEW JERSEY

FINAL Environmental Assessment

April 2006

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 did not reopen until 2001. Since 2001, the condition of the oyster resource has deteriorated 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 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. 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, in addition to direct shell planting, previous planted shell with spat will be transplanted upbay; spatted shell on privately leased grounds will be purchased and transplanted upbay; and broodstock oysters from marginal areas will be transplanted to waters where a better growth potential occurs. As in 2005, roughly 25-acre plots will be planted in Bay waters of both states. The first substrate placed will be oyster shell, if available, but if not available in sufficient quantities, clamshell will be used. 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 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.

______________________________ _________________________

Robert J. Ruch
Lieutenant Colonel, Corps of Engineers
District Commander

Date

Delaware Bay Oyster Restoration Project
Delaware and New Jersey

Final ENVIRONMENTAL ASSESSMENT
Table of Contents

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 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), Delaware Bay Section Shellfisheries Council (NJ), Governor's Council on Shellfisheries (DE), the Delaware River Basin Commission (DRBC), the Delaware River Basin Authority (DRBA), the National Marine Fisheries Service (NMFS), 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 built 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. The following list provides a summary of the proposed project's relationship with 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. 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 (*Parkinus 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 the parasites significantly affected the oyster population dynamics or caused significant mortality. 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%) 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 in Delaware did not reopen until 2001. 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 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.

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 2005, Delaware Bay was in its sixth year of well below average recruitment (less than 0.5 spat per oyster per year). Five such consecutive years is unprecedented from the perspective of the 53-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.

During the 1997-2005 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 has significantly endangered the stock.

Aside from the decline of 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. Since 2000, oyster abundance has neared the lowest level recorded for the 1952-2005 record and is expected to reach a record low in 2006 without shellplanting. However, the U.S. Army Corps initiated the first year of shell planting, in collaboration with the non-Federal sponsor, the DRBA, DRBC, NJDEP, DNREC, and HSRL. This 2005 planting added significantly to bay recruitment in 2005.

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, 1992 (a). 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.

Further demonstration of high success rates of the shell planting program shows in the monitoring results of the initial 2005 shell planting conducted by the U.S. Army Corps of Engineers. The approach taken in the first year of shell planting (2005) in the two states differed somewhat to maximize use of local conditions. Planted areas were approximately 25 acres in size (a 0.2" latitude x 0.2" longitude rectangle) to 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.

In 2005, the total number of bushels of shell planted in New Jersey sites was 169, 437 (105,489 oyster shell, 33,448 ocean quahog shell, and 30,500 surf clam shell) at Shellrock, Bennies Sand, Reeds Beach, and East Point (MRC) covering approximately 87 acres. In Delaware two sites were planted with shell cultch in 2005: Lower Middle Bed (17,778 bushels of quahog shell and 46,382 bushels of oyster shell on 22 acres) and on Jigger Hill, part of the Ridge Bed complex (54,650 bushels of oyster shell on 20 acres) for a Delaware state total of 118,810 bushels. Combined total of shell planted in both states in 2005: 288,247 bushels. 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 recycles a waste product into a useful commodity, thereby alleviating present storage and disposal issues.

Although there are differences in the two fisheries, the history of the oyster industry in Connecticut provides an example of an industry that declined to near zero production in the late 1960s and subsequently recovered to become one of the leading suppliers of oysters in the United States using natural set techniques and intensive bed management. The Oyster Industry Revitalization Task Force began addressing this 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). Thus, a recruitment enhancement program is important for three reasons: 1) recruitment enhancement is needed immediately to stabilize stock abundance imperiled by six consecutive years of recruitment failure; 2) recruitment enhancement is needed to permit continuation and expansion of the oyster industry; and 3) 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.

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 7th SAW (Stock Assessment Workshop), organized by the Haskin Shellfish Research Laboratory in February 2005, indicate that oyster broodstock abundance will continue to decline over the next three years without this project, reaching the lowest levels recorded in the 53-year survey time series. For 2005, industry allocations were cut by 50% (DE) and 64% (NJ). Population dynamics modeling of abundances so 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, 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%. As oyster abundance and thus, oyster shell inputs decline to historical lows. Oyster beds are sustained, as the high diversity and complexity of this habitat, by continued addition of shell; without an active abundant oyster population, the quality of the Essential Fish Habitat (EFH) will assuredly also decline. The oyster populations and their habitat are expected to continue to decline unless efforts to improve abundance and 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 are 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, 1992 b). 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. Therefore, emphasis during the early stages of the oyster revitalization program should focus on the enhancement of natural seed production. 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 (Table 3-1). 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 necessary very good setting areas. 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 (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 (see Table 3-1). The expansion of the oyster industry in Connecticut (from 161,000 bushels in 1985 to 1.3 million bushels in 1994) is due largely to the timely planting of clean shell in high setting areas followed by its transplantation to nurseries and then to final growout grounds. In Connecticut, as well as in Louisiana and Maryland, which also plant shells, several million bushels of shells are put down each year (DRBA, 1999).

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

Table 3-1 inserted here

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. Surf clams and ocean quahogs are shucked in large quantity in southern New Jersey and are presently considered a waste product of clam processing. The shell planting program will generate a beneficial use of a "waste product" both environmentally and economically.

The 2005 shell planting program raised bay-wide recruitment by an impressive 54% in areas planted (<150 acres of bed planted with 286,000 bushels of shell) (E. Powell, pers. comm.). The proposed 2006 project proposes to more than double the scale of last year's planting program. Preliminary monitoring results show a long-term (> 4 years) reduction in native cultch on most beds due to low abundances, and as a consequence, low addition rates of native shell will result in the destruction of the 3-dimensional footprint of the beds essential for habitat complexity in the bay. In essence, 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 merrely a concentration, of finfish and decapod crustaceans.

The shell-planting project is proposed to continue annually for multiple 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 based on bottom surveys to be carried out at the inception of the project. Criteria will include condition of the bottom 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, Quahog, and surf clam shell will be purchased from several private sources, as it becomes available in 2006. Planting areas will be approximately 25 acres in size although local bottom conditions will dictate actual size of each planted area. Twenty-five acres 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 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. Oyster shell will be used when available. 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 and surf clam 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, if possible, 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.

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**: Both oyster and clam shell totaling approximately 700,000 bushels will be purchased in 2006 and most of it placed on existing natural oyster beds within Delaware Bay in both Delaware and New Jersey. In addition, oyster shell is available on some downbay natural oyster beds that regularly support very low oyster abundances due to Dermo disease. Should additional oyster shell for planting be required and should

clam shell availability not meet this requirement, oyster shell may be recovered from these downbay natural beds by suction dredge, stored on shore in designated areas for a month or more, and then planted in designated existing natural oyster beds. Shell is planted on downbay inshore sites and leased grounds south and east of Egg Island Point to establish good sets by oyster spat. The cultch is then relocated in 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. 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. A small portion of the purchased shell may be stockpiled on New Jersey state property within the Bevans Wildlife Management Area, Cumberland County.

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 exist 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. In the current program, oysters available for transplant may be identified by DNREC for possible transplant (quantity will be estimated with reference to stock assessment data) and transplanted downbay using dry or suction dredge. However, in the current year, it is unlikely that sufficient quantities of broodstock oysters will be available for transplant this year.

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 (Figure 4-1).

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

Figure 4-1 inserted here

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, Inc. 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 selected for monitoring (Figure 4-2). The nine study sites were centered 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. Selected portions of these beds were targeted by the present shell planting program for the initial shell planting that occurred in 2005. The New Jersey oyster beds are annually sampled in October by the Haskin Shellfish Research Laboratory. Two of the nine sites were located in known Delaware oyster seedbeds (Over the Bar and Lower Middle). The coordinates for the sampling sites are shown in Table 4-1. All sites were located on natural beds except for one leased oyster ground in New Jersey (554D).

Sediment grain size ranged from pebbles on the surface of medium-sand (L0) to medium-coarse sand (A0) to stiff clayey sediments. Versar, Inc. conducted a sediment profile study in 2001 using imagery at 50 stations (Table 4-2). The predominant sediment type throughout the study area was fine-sand and occurred at 38% of the sampling stations.

Figure 4-2 inserted here

Table 4-1 inserted here

Table 4-2 inserted here

Table 4-2 second page inserted here

Six of these possessed very-fine-sand. Fine-medium-sand also occurred at three stations. Medium-sand occurred at six stations and medium-coarse-sand at one station. Fifteen stations (30%) had a fine sediment component (silts or clays) with silty-clay occurring at six (12%) stations. Oyster shell, whole shell to coarse shell hash, was the only substrate observed at eight (16%) stations. Shell was a significant component of the sediments at 17 stations that were not classified as oyster or mussel shell beds.

At most stations sediments were homogeneous with depth from the sediment surface, but layered sediments occurred at ten stations (20%). Sandy sediments overlaid finer sediments at eight stations (16%) with thin layers of finer sediments over sandier sediments at two stations. Medium to fine-medium-sands overlaid silty-clay sediments at four stations, all of which were in the Arnold's Range. Fine to very-fine-sands overlaid fine-sand-silt-clay sediments at four stations (all in the lower bay).

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. Turbidity was consistently higher at several stations (DLM and DOB in Delaware, and Station NAN in New Jersey). 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 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 of the oyster bed monitoring stations (554D, NEW, SJN, and ARN) (Table 4-3). 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, ARN and SJN, 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. The turbidity maximum zone is that area within an estuary where salt water 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 at Station ARN 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 ARN during mid-summer and ranged to 3.5 mg/L. This data is 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

Table 4-3 inserted here

Table 4-3 second page inserted here

during late summer when reproduction taxes adult oysters and when oyster larvae require high food concentrations for success.

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).

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. The horseshoe crab also supports a limited commercial industry for fish bait, eel bait, and biomedical research.

4.7.1. *Oysters*. Oyster habitat quality of the nine sites evaluated by Versar, Inc. (2001) is described as follows (see Figure 4-2):

4.7.1.1. The following sites were selected to be evaluated because they are representative of the range of oyster beds occurring in Delaware Bay.

Lease 554D is located southeast of Egg Island Point. As is typical with most leased grounds in Delaware Bay, oyster abundance is naturally low on lease 554D due to disease and mortality. Oysters were transplanted to Lease 554D from Shell Rock in 1999. Lease 554D is plagued with an influx of sediment and is not unique to sedimentation. The phenomenon is widespread on leased grounds.

Egg Island is one of the lowermost natural oyster beds in Delaware Bay and representative of the Egg Island/Ledge bed system. Historically, this bed has rarely been productive, due in early years to high predation rates on new recruits and later on by the addition of disease mortality. In recent years, spat set has been very low.

New Beds and Bennies lie within the region of the bay that has supported the majority of the 1990s oyster harvest. These beds are representative of Bennies Sand, Vexton, Strawberry, Hog Shoal, and Hawk's Nest. In the last decade, mortality rates have been relatively high and spat recruitment rates relatively low on these beds. Area management of oyster industry fishing effort was introduced in 2001 to prevent over-fishing on these beds.

Nantuxent Point, Beadons and Ship John are representative of Cohansey, Sea Breeze, Middle, and Upper Middle beds. These are characterized as having relatively high levels of spat recruitment in the 1990s. Mortality rates are higher at Nantuxent Point. Total oyster abundance is near the 1990s-record levels on Ship John. However, like most areas in the bay, six years of low recruitment is resulting in significant abundance declines.

Arnolds is representative of Upper Arnolds and Round Island. These are low salinity beds near the upper bay limit for oyster growth in Delaware Bay. Mortality rates are low and growth rates slow. The beds are therefore characterized with a high abundance of small oysters. Fishing has been limited on this bed in the 1990s.

Ridge and Silver are beds representative of Delaware natural oyster beds. The Ridge was not harvested for 15 years prior to opening in 2001. There has been some limited harvesting on other beds during the period between 1991 and 1995 but all beds were closed during the period 1996 through 2000**.** Recruitment has been consistently low on these beds since 2000.

Fouling organisms present on Delaware Bay oysters include bryozoans (e.g. *Electra, Membranipora*) and boring polychaetes (*Polydora*), encrusting polychaetes and barnacles. Encrusting sponges (*Microciona*) were present at higher salinity sites. Hydroids were present in greater abundance on the New Jersey side of the bay and a few anemones and tunicates were also present (Versar, 2001). An oyster population study conducted by Powell *et al.* (2001) covered measurements of abundance, condition, health, and the enumeration of associated predators and fouling organisms. The study is presented in its entirety in the Appendix A.

4.7.1.2. 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). In 2000, prevalence of *P. marinus* reached 100% at all sites except Arnolds and Over-the-Bar (see Appendix A; Figure 20). Prevalences and infection typically increase to peak levels in late summer and early fall. 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 (Appendix A; Figures 21-22). 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 (Appendix A Figure 24). 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 (Appendix A; Figure 25). Large ciliates were found in the gut, gill, mantle and digestive gland. These ciliates were observed through the year on all oyster beds (Appendix A; Figure 25). Small oysters had a disproportionate infection intensity, indicating that infections lessen with age. None of these minor parasites substantially impacts oyster population dynamics.

4.7.1.3. Predators

Predation accounts for a significant fraction of total mortality (mostly spat and juveniles) (Appendix A; Figure 28). 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 (Appendix A, Figure 30). 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 (Appendix A, Figure 30).

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 (Appendix A, Figure 31). *E. depressus* was more widespread in abundance across the salinity gradient (Appendix A; Figure 31). Mud crab abundance increased with increasing salinity. Seasonal cycles in abundance were not dramatic or consistent among sites.

4.7.1.4. 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 (Appendix A; Figure 34). 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, with the exception of Arnolds, where coverage was unusually high (Appendix A, Figure 36).

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 (Appendix A; Figure 37). *G. demissa* was also commonly found on New Beds and Bennies. The time series showed distinctively lower coverages during the summer months (Appendix A; Figure 38). 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 by encrusting polychaetes was highest at the two Delaware sites, Over-the-Bar and Lower Middle, and on Lease 554D (Appendix A; Figure 37). Coverage was highest in spring and declined during the summer months. Mudtubes increased in abundance with increasing salinity in a nearly monotonic fashion (Appendix A; Figure 39). Sabellariid polychaetes were most common at the two Delaware sites and Lease 554D. However no time-dependent trends were present (Appendix A; Figure 39). Serpulid tubes were much more common on Lease 554D 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 (Appendix A; Figure 40). 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 (Appendix A; Figure 41). 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 (Appendix A; Figure 40).

Hydroids were present in greatest abundance on the New Jersey side of the bay. Abundance was high at five of seven New Jersey sites (Appendix A; Figure 40). Coverage peaked in April 2000 and again in March 2001.

A few anemones and tunicates were present. The organisms were present in highest abundance on Lease 554D (Appendix A; Figure 42). Abundances peaked in fall 2000 and remained relatively high in March 2001.

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.

4.7.1.5. 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. Figure 4-3 illustrates New Jersey natural seed oyster beds 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 (Figure 4-4). However, upper bed oysters are thin-shelled, slow growing, and of marginal market quality. 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 (and comprises the two middle zones illustrated in Figure 4-3). This zone includes all the beds from New Beds to Upper Middle. Survival, growth, and market quality can very widely within this region but are best within these beds (New Beds, Bennies, Bennies Sand, and several small inshore 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.

Figure 4-3 inserted here

Figure 4-4 inserted here

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 seasgrass meadows (luckenback and Coen). 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 sixth year of well below average recruitment (less than 0.5 spat per oyster per year). Six such consecutive years is unprecedented for the 53-year record for which detailed survey data are available (1952-2005).

The primary objective of this project is to continue the shell-planting program that was initiated in 2005. 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. These beds offer excellent opportunities for enhancement. Thus, the primary goal on the New Jersey beds will be directed at increasing recruitment rather than reestablishing productive bottom. Nearshore sites for cultch plantings will be chosen from beds distributed along the nearshore areas from Ben Davis Point to Beadons Point, such as Beadons and Nantuxent Point beds. Shell will be planted at the time of maximum setting potential. New Jersey Department of Environmental Protection (Division of Fish and Wildlife) staff will run a subsequent program to monitor spat number. When a desired number is present, some of these spatted cultch may be recovered by dry dredge or suction dredge and moved to upbay nursery areas, which typically undergo both lower disease and predation rates. However, if conditions merit, the spat will remain *in-situ* to grow. Transplant of spat upbay will significantly increase the survival of these young oysters in low flow years. The purpose of the transplant is to put more oysters in regions where fecundity is high to enhance the reproductive potential of the natural broodstock.

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. 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 2005 shell plants demonstrate that recruitment can be enhanced by a factor of 3 to 10 by direct addition of shell to existing oyster beds. Direct plants in 2005 on Shell Rock and Bennies Sand recovered 200-500 spat per bushel during a year when set on native cultch yielded less than 50 spat per bushel. 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 contrast to New Jersey, 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 will occur on all six sites before a determination can be made which sites will receive shell in the 2006 planting. 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. In general the 2005 recruitment in Delaware can only be characterized as poor. However, the shell planting site on Jigger Hill (Northern Ridge) in 2005 had a five fold spat increase relative to the remainder of the bed (R. Cole, pers. comm.). These findings are currently being analyzed in comparison to similar findings on New Jersey oyster beds as well as data collected on these beds by the Haskin Shellfish Research Laboratory.

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. The only exception will be thicker shell plants in Delaware for the purpose of reef revitalization. Hence the oyster beds have already been partially or completely silted over, thus there will not be an impact on the oyster reef community.

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 severe 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 25 tons per year for each pollutant. 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 Severe Nonattainment Area (25 tons of each pollutant 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 for the Delaware River Main Channel Project (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 HABITAT FOR THE DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT (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.

* Spawning adults present in mixing zone.

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 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**
	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

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**
	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 (Pratt, 1999).

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 pilot-scale 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 (Luckenbach and Coen).

A 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 degree of success. Each state will conduct stock assessment surveys. In year one of any shell plant, the number of spat present and the comparison with the average spat count on natural beds in the area will be evaluated. In future years, the total number of oysters supported by the shell planting, including market-sized individuals 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 and the oyster shell produced by the shell plant will also increment available settlement space in future years. The usable life span of a shell plant is likely to exceed 10 years. 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.

The monitoring program will include three sampling programs: (1) Downbay transplants of oysters taken off upbay beds in preparation for shell planting must be monitored. These transplants provide part of the economic benefit of the proposed shell-planting program. (2) Quantitative samples must be taken in coordination with the stock assessment programs of both states to estimate the gain in abundance and increase in permissible harvest provided by the program. Additional data are required to evaluate the cost/benefit ratio in terms of gain in abundance or increase in bushel of quota per dollar invested. (3) Monthly sampling supporting the evaluation of the merits of selected planting approaches will be carried out with the aim of optimizing the gain in abundance per dollar invested. This program will include monitoring of disease prevalence and infection intensity.

***Evaluation of Broodstock/Seed Transplants*:** This program is designed to increase reproductive capacity using oysters already available in the Delaware Bay system but located in marginal habitats or areas where survivorship is low due to disease. This program will be evaluated by: (1) Documenting the total number of oysters and their size composition as transplanted and (2) Evaluating the production of these transplants in terms of growth and yield to the fishery. Yield encompasses an evaluation of survivorship of the transplants, as well as growth in length and weight subsequent to the transplant. The annual quota setting process incorporates expected production from transplants. Hence, the technical infrastructure necessary for assessing the worth of the downbay transplant is also institutionalized within the stock assessment program.

Quantitative Assessment: Each state conducts a stock assessment survey in October. In coordination with this survey, all permanent shell plants and broodstock/seed transplants will be quantitatively sampled to provide data for estimating total abundance and the quantity of clam and oyster cultch material present. Both states use oyster dredges for surveying. In New Jersey, a dredge calibration program permits quantification of dredge samples on a per area swept basis. Dredge efficiency is evaluated using diver quadrat sampling. However, the dredge efficiency for shell plants is unknown and the quantity of clam shell present cannot be easily estimated from dredge samples because the depth of penetration of the dredge is unknown. As a consequence, divers must be used for this component of the sampling program. However, many diver samples would be needed to fully sample a large shell plant. Accordingly, the sampling approach will emphasize dredge hauls quantitated using diver samples. Sample analysis will follow protocols established for the states stock assessment programs so compatibility to conditions on the non-enhanced beds can be monitored and compared.

Two biological sampling programs will be conducted. The first is a quantitative assessment that will occur in October. This program will be field intensive and provide a quantitative measure of abundance for comparison to the total abundance as determined by the stock assessment programs of both states. Each shell plant and broodstock/seed transplant will be sampled at this time as previously described. The second program is a monthly monitoring program piggy-backed on the present Dermo monitoring program designed to provide information on growth and mortality, as previously described. Shell-plant and transplant sites added to the Dermo monitoring program will be sampled five times per year, in April, June, August, September, and October.

A secondary benefit 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% 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.

. 5.7. Cultural Resources

The planting of additional oyster shell should have no effect to 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 to risk a statistical decline in both the natural environment and ecological value of the Delaware Estuary to the regional economic environment as well. Decimated by disease and also excessive siltation and in some areas 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. 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 to initiate 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 local 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.

7.0. LITERATURE CITED

Canzonier, W.J. 1992 (a). *New Jersey oyster production: Thirty-five years of observation from deck and dockside.* Mid-Atlantic States Seafood Associatioon. Seafood Seminars. Pleasantville, New Jersey Oct 27-29, 1992.

Canzonier, W.J. 1992 (b). *Remote setting of disease resistant oysters in Delaware Bay.* Final Project Report to USEPA, Region III. 45 pp.

Delaware River and Bay Authority, 1999. *Oyster Industry Revitalization Task Force: Report to the governor and legislature of the state of New Jersey.*

Ford, S.E. 1997. *History and present status of molluscan shellfisheries from Barnegat Bay to Delaware Bay.* In: The History, Present Condition, and Future of the molluscan fisheries of North and Central America and Europe. Vol. 1: North America (Mackenzie, C.L., Jr., V.G. Burrell, Jr., A. Rosenfield, and W.L. Hobart, Eds.) pp. 119-140. U.S. Department of Commerce, NOAA Technical Report NMFS, Seattle, Washington.

Ford, S., E. Powell, J. Klincke, and E. Hoffman. 1999. *Modeling the MSX parasite in eastern oysters (Crassostrea virginica) populations. 1. Model development, implementation, and verification.* J. Shellfish Res. 18: 475-500.

Haskin, H.H., R.A. Lutz, and C.E. Epifanio. 1983. *Benthos (Shellfish)* Chapter 13. In: The Delaware Estuary: Research as background for estuarine management and development (Sharp, J.H., Ed.) pp. 183-207.

Haskin Shellfish Research Laboratory, 2005. pers. comm. Dr. E. Powell.

Hofmann, E.E., E.N. Powell, J.M. Klinck, and G. Saunders. 1995. *Modeling diseased oyster populations. I. Modeling Perkinsus marinus infections in oysters.* J. Shellfish Res. 14: 121-151.

Howe, S. and W. Leathem, 1984. *Secondary production of benthic macrofauna at three stations in Delaware Bay and coastal Delaware.* NOAA Tech Memo. NMFS-NEFC-32.

Howe, S.D., D. Maurer, and W. Leathem. 1988. *Secondary production of benthic mollusks from the Delaware Bay and coastal area.* Estuarine, Coastal, and Shelf Science, Vol 26: 81-94.

Kinner, P., D. Maurer, and W. Leathem. 1974. *Benthic invertebrates in Delaware Bay: animal-sediment associations of the dominant species.* Int. Revue ges. Hydrobiol. 59: 685-701.

Leathem, W. and D.Maurer. 1980. *Decapod crustaceans of the Delaware Bay area.* J. of Nat. Hist. Vol 14.

Maurer, D. L. Watling, P. Kinner, W. Leathem, and C. Wethe. 1978. *Benthic invertebrate assemblages of Delaware Bay.* Mar. Biol. Vol 45: 65-78.

Powell, E.N., S.E. Ford, M. Cummings, R.D. Barber, and B.M. Brewster, 2001. *Army Corps of Engineers Delaware River Main Channel Deepening project monitoring study-oyster component.* In: Pre-construction oyster, water quality and sediment monitoring study for the Delaware River Main Channel Deepening project.

Powell, E.N., K.A. Ashton-Alcox, S. Banta, and A.J. Bonner. 2001. *Impact of repeated dredging on a Delaware Bay Oyster Reef*. J. of Shellfish Res. Vol. 20: No. 3 961-975.

Powell, E.N. and K. Ashton-Alcox. 2004. *A comparison between a suction dredge and a traditional oyster dredge in the transplantation of oysters in Delaware Bay*. J. of Shellfish Res. Vol. 23: No. 3 803-823.

Versar, Inc. 2001. Powell, E.N., F. Kelley, and R. Diaz. *Pre-construction oyster, water quality, and sediment monitoring study for the Delaware River Main Channel Deepening project.* Prepared for the U.S. Army Corps of Engineers, Philadelphia District.

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 up to 510,000 bushels of shell and stockpile approximately 200,000 bushels of shell for subsequent planting. Planting areas will be 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. The first substrate placed will be oyster shell if available, but if not available in significant quantities, clamshell will be used.

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 sixth year of well below average recruitment (less than 0.5 spat per oyster per year). Six such consecutive years is unprecedented from the perspective of the 53-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 on Delaware sites will provide needed shell cultch on state-owned natural oyster beds. The Delaware 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 oyster shell or clam 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. Available oyster shell will be used first. If oyster shell is not available in sufficient quantities, clamshell will be used. 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

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

5. 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 somewhat 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. 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).

3. 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.

4. 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.

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

6. 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.

7. 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.

8. Actions to minimize impacts - Impacts to benthic resources will be minimal at the placement site considering the anticipated recolonization. No dredging will take place. 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. <u>Finding of Compliance or Non-Compliance with the Restrictions on Discharge</u>

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.