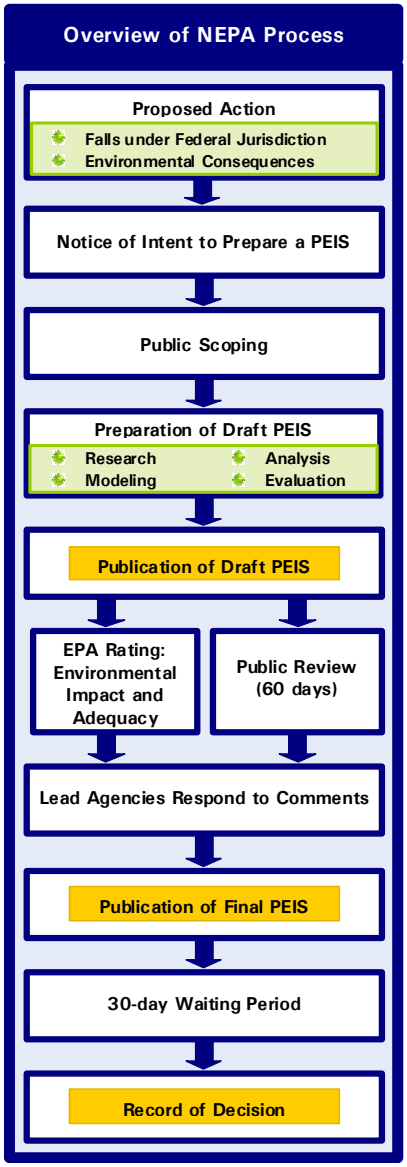
1 Purpose and Need For Action

1.1 STUDY AUTHORITY, SCOPE, AND STATEMENT OF PURPOSE

1.1.1 Authority and Scope for a Programmatic Environmental Impact Statement

Oysters once contributed significantly to maintaining water quality and habitats in the Chesapeake Bay ecosystem, supported an economically important fishery, and were of great cultural value to many residents of the Bay area. The population of the native Eastern oyster (*Crassostrea virginica*) has declined to a small fraction of its historical abundance, and restoration efforts undertaken to date have failed to reverse the decline (Sections 1.2 and 1.3). Recognizing this failure, the States of Maryland and Virginia have begun to consider nontraditional approaches for attempting to rebuild the oyster stock, including introducing the nonnative Suminoe oyster (Section 1.4).



The proposal to introduce the Suminoe oyster into Chesapeake Bay is very controversial and has attracted many opponents as well as proponents. All parties concerned about the status of the Bay's oyster stock agreed that the proposal merited a high level of review by agencies responsible for managing natural resources and the environment because of its potentially significant benefits and adverse effects throughout Chesapeake Bay and possibly within other coastal estuaries. Given the need for a rigorous formal evaluation of the potential risks and benefits of the proposed action, the States of Maryland and Virginia requested assistance from the U.S. Army Corps of Engineers (USACE), Norfolk District (CENAO), to develop a Programmatic Environmental Impact Statement (PEIS) to evaluate the proposed introduction of the Suminoe oyster and reasonable alternative strategies for restoring the ecological and economic functions of oysters in Chesapeake Bay. In 2003, Congress authorized CENAO to coordinate the preparation of this PEIS pursuant to the National Environmental Policy Act (NEPA) Section 102. A Notice of Intent to prepare a PEIS was published in the Federal Register in 2004 (FR Vol. 69 No. 2, January 5, 2004). USACE's Baltimore District (CENAB) provided technical

support, and the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (FWS), and the National Oceanic and Atmospheric Administration (NOAA) are cooperating Federal agencies. The proposal to introduce a reproducing population of Suminoe oysters into Chesapeake Bay is addressed throughout this PEIS as the "proposed action" because that is the NEPA term for the issue that triggers a NEPA evaluation. NEPA requires an environmental impact statement to identify and evaluate reasonable alternatives that are designed to meet the same need that prompted the proposed action and the stated objective of that action. The alternatives are intended to provide a rational context for evaluating the pros and cons of the proposed action and identifying the most appropriate strategy for meeting the stated objective. Details of the proposed action and all alternatives evaluated in this PEIS are presented in Section 2. The USACE and the States of Maryland and Virginia did not establish a preferred alternative in the Draft PEIS but have done so in this Final PEIS. The preferred alternative and the manner in which the lead agencies selected it are described in Section 2.

A Programmatic EIS, as described in the Council on Environmental Quality's (CEQ) *Forty Most Asked Questions* (CEQ 1981), is used when subsequent NEPA analyses and documents may be prepared in tiers (40 C.F.R. § 1508.28) as narrower, more site-specific plans for implementing the proposed action or an alternative are defined. A PEIS considers multiple related Federal actions that encompass a large geographic scale or that constitute a suite of similar programs, both of which are characteristics of the joint State and Federal effort to restore the size and functions of the oyster population throughout Chesapeake Bay. This PEIS is intended to be used as guidance for subsequent NEPA analyses and decisions that may be needed when more site-specific plans for implementing the preferred alternative are defined. The role of the PEIS is to address broad issues so that the large-scale analyses can be incorporated into subsequent site-specific assessments. A PEIS should support program-level decisions regarding which specific projects will be considered in the future.

The scope of this PEIS is to evaluate the potential effects of the proposed action and each alternative on the resources and ecosystem of the Bay in as much detail as is possible given uncertainties about how the actions, which are described very generally (Section 2), might be implemented. Representative plans for implementing the proposed action and alternatives were developed to provide a basis for predicting and assessing the potential consequences of those actions. Specific implementation plans for actions undertaken following completion of this PEIS process will almost certainly vary from those assessment scenarios and may require further NEPA analyses and regulatory compliance, as defined in Section 1.1.3. The programmatic analyses presented in this Draft PEIS are based on the best information available at the time the analyses were completed. If new data or information becomes available in the future, that information will be incorporated into later tiers of NEPA analyses to modify the programmatic conclusions as needed. This PEIS has served the important purpose of facilitating collaboration among Federal, State, and local agencies that will be involved in oyster restoration efforts. The interactions among agencies and with the public established by this programmatic NEPA process will be maintained through the tiered NEPA analyses to ensure comprehensive stakeholder involvement (as recommended by NEPA Task Force 2003).

CENAO is the lead Federal agency for preparing this PEIS. Virginia Marine Resources Commission (VMRC), on behalf of the Commonwealth of Virginia, and Maryland Department

of Natural Resources (DNR), on behalf of the State of Maryland, are the lead State agencies. These three entities are referred to throughout this PEIS collectively as the "lead agencies." Representatives of the senior management of the three lead agencies together constituted the Executive Committee (EC) for this PEIS. Those representatives included the CENAO District Engineer (Colonel Dionysios Anninos), Maryland's Secretary of Natural Resources (Mr. John Griffin) and Virginia's Secretary of Natural Resources (Mr. L. Preston Bryant, Jr.). EPA, FWS, and NOAA are cooperating Federal agencies. Additional review and assistance in preparation of the PEIS was provided by CENAB, the Potomac River Fisheries Commission (PRFC), and the Atlantic States Marine Fisheries Commission (ASMFC). The lead agencies established a project delivery team (PDT) to coordinate with State, Federal and regional agencies whose goals, objectives, policies, and regulations are implicated in or would be affected by the outcome of the project. The PDT includes representatives of CENAO, CENAB, DNR, VMRC, EPA, NOAA, FWS, and PRFC. This document was prepared in accordance with Code of Federal Regulations 40, parts 1500 – 1508, CEQ regulation 1502, and Army Regulation 200-2.

1.1.2 Purpose and Need for Action

NEPA requires the preparers of an EIS to develop specific definitions of the need and purpose for action so that reasonable alternatives can be formulated for analysis and evaluation. The lead agencies, working closely with the cooperating agencies via the PDT and with the public via NEPA's scoping process (Section 5), established the following statement of need for the actions being evaluated in this PEIS:

> ***A need exists to restore the ecological role of oysters in the Bay and the economic benefits of a commercial fishery through native oyster restoration and/or an ecologically compatible nonnative oyster species that would restore these lost functions.***

NEPA requires detailed specification of the purpose (i.e., goal) of actions evaluated in an EIS to ensure objective and consistent evaluation of the proposed action in comparison to all alternatives. In its *Chesapeake 2000* agreement, the Chesapeake Bay Program (CBP) established a relatively short-term goal to increase oyster abundance by a factor of 10 above the 1994 level by the year 2010 (Section 1.3). The PDT chose to establish a more expansive goal for the actions being evaluated in this PEIS to reflect the large-scale, programmatic context of the decisions to be based on these analyses. Upon considering the history of oyster harvest in the Bay (Figure 1-1), the PDT observed that harvests remained fairly stable between 1920 and 1970, during a time of significant environmental change within the Bay. The average annual harvest over that period was on the order of 35 million pounds, which is roughly equivalent to five million bushels of market-size oysters (Section 2.1.1). The PDT reasoned that consistent harvests over five decades suggested that the oyster population at that time was large enough and healthy enough to sustain an annual harvest of that volume despite environmental stresses on the Bay's ecosystem; consequently, a population of that size probably provided substantial ecological services in the Bay and would be an appropriate, albeit ambitious, goal for restored oyster abundance.

The PDT, in cooperation with the public, therefore, defined the following statement of purpose for the actions being evaluated in this PEIS:

> ***The purpose of this proposal is to establish an oyster population that reaches a level of abundance in Chesapeake Bay that would support sustainable harvests comparable to harvest levels during the period 1920–1970.***

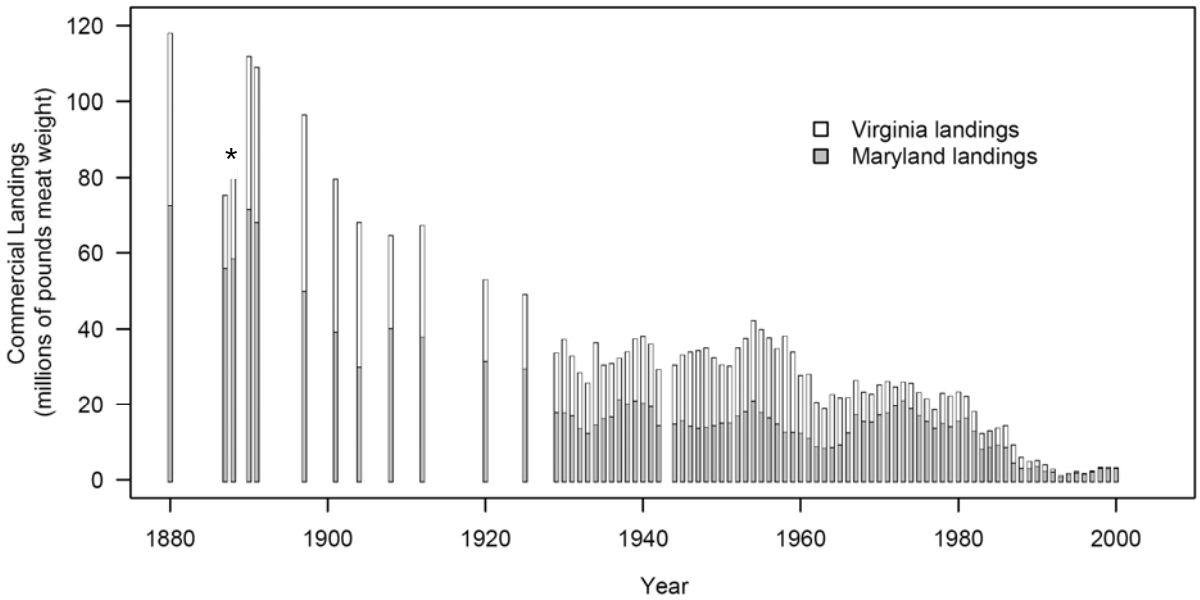


Figure 1-1. Commercial landings of oysters in Chesapeake Bay from 1880 to 2000. Adapted from NRC (2004) with data provided by NOAA. No data are available for years with no bars. The year 1887 (indicated by "*" on the graph) excludes catch from the James and Potomac rivers.[1]

The views of many stakeholders and agencies differ regarding the relative importance of the ecological functions of oysters and the socioeconomic contributions of an oyster fishery in Chesapeake Bay. The PDT intends the statement of purpose to address both of these important considerations, as specified in the statement of need. The PDT intends the term "sustainable harvests" to comprise both harvests of wild oysters and landings of cultivated oysters from leased bottom and other forms of aquaculture throughout the Bay. The stated purpose addresses the need for action to restore the abundance of oysters Bay-wide, without differentiating between Maryland and Virginia. The PDT did not consider the feasibility of achieving a population of the size implied by the statement of purpose when they developed it. They intended the analyses for the PEIS to determine the extent to which the proposed action and the alternatives might be capable of reaching the implied goal. Section 2 provides more information about how this statement of purpose was interpreted to evaluate the proposed action and alternatives.

[1] Commercial landings of oysters are reported in pounds of oyster meat after the oysters are shucked; 7 pounds of oyster meat is considered the equivalent of 1 bushel of market-size (more than 3 inches long) oysters.

1.2 HISTORY OF OYSTERS IN CHESAPEAKE BAY

The Eastern oyster *(Crassostrea virginica*) was once so abundant in Chesapeake Bay that it inspired the Algonquin to name the bay *Chesepiook*, meaning "great shellfish bay." The abundant oyster was a keystone species that provided a variety of ecological services within the Chesapeake Bay ecosystem. It was a primary component of the Bay's filtration system and provided rich habitat for many other species (Newell 1988). Oysters filter water to feed on small plankton, removing sediment and other particles from the water column, clearing the water, and increasing light penetration. Improved water clarity promotes the growth of underwater grasses, which benefit blue crabs and many other aquatic organisms. Oyster reefs also provide a unique kind of habitat for fish and other species in the Bay. In addition to its ecological functions, the Eastern oyster was as an important food resource for Native Americans and early European settlers, and the Bay's oyster fishery developed into a large export industry during the 1800s. The Chesapeake oyster fishery became the largest in the world during the 1880s (NRC 2004). Towns such as Crisfield on Maryland's Eastern Shore were established and prospered solely on the basis of the abundance of oysters in local waters. The oyster became widely recognized as an important cultural symbol of the Chesapeake Bay region.

Commercial landings of oysters in Chesapeake Bay declined steadily during the late 19th and early 20th centuries (Figure 1-1).[2] Harvest yields declined by half in the 50 years between the late 1880s and about 1930. Major factors believed to have contributed to that decline include intense fishing pressure, mechanical destruction of habitat, siltation of optimal substrate, and stock overfishing[3] (Rothschild et al. 1994). The rate of harvest of oysters increased rapidly during the 1800s as watermen began to fish more efficiently by using sailboats (the iconic "skipjack") to dredge oyster reefs instead of the traditional hand-tong method. The use of increasingly destructive harvesting methods increased after 1865, when the use of large mechanized dredges was legalized (Stevenson 1894). Dredging for oysters began to degrade the physical integrity of centuries-old reefs (DeAlteris 1988) by breaking off shell and oysters that were too small to harvest, thereby reducing the population and the habitat available for future production and harvest. By the late 1800s, the historic reefs were severely degraded. One hundred years of increasingly intensive and mechanized fishing contributed to leveling the profile of the oyster bars in Chesapeake Bay (Rothschild et al. 1994). Declining water quality also contributed to reducing the oyster population. Clearing of forests and development of land within the Bay's watershed caused increased agricultural runoff, sedimentation, nutrient input, and environmental pollution that killed oysters or created conditions that were less favorable for them (Kemp et al. 2005; Boynton et al. 1995).

During the mid-20th century, oyster harvests remained comparatively stable for several decades (through the late 1970s) before beginning a further decline through the 1990s (Figure

[2] The size of the oyster population in the Bay has never been monitored regularly. In the absence of reliable estimates of the population, changes in the size of the oyster harvest over time have been considered to be indicative of changes in the abundance of oysters in the Bay. Changes in harvest, however, provide only a gross indication of changing abundance because harvest varies with the level of fishing activity as well as with the population of oysters.

[3] The term "stock overfishing" refers to a level of fishing intensity at which the magnitude of harvest results in a reduction in the reproductive capacity of the stock.

1-1). Figure 1-2 illustrates the very small oyster harvests in recent years; note that the scale of this figure is one fifth the scale of Figure 1-1. The Bay's oyster population is now estimated to be less than 1% of its size during the 1800s (Newell 1988). The more recent decline in the population has been attributed primarily to the introduction of two foreign diseases to which the Eastern oyster initially appeared to have no resistance, given the large increase in disease-related mortality that began to be evident. The diseases Dermo and MSX are harmless to humans but usually are fatal to Eastern oysters. The diseases are caused by protozoan parasites that were first found in the Bay in 1949 (Dermo) and 1959 (MSX).

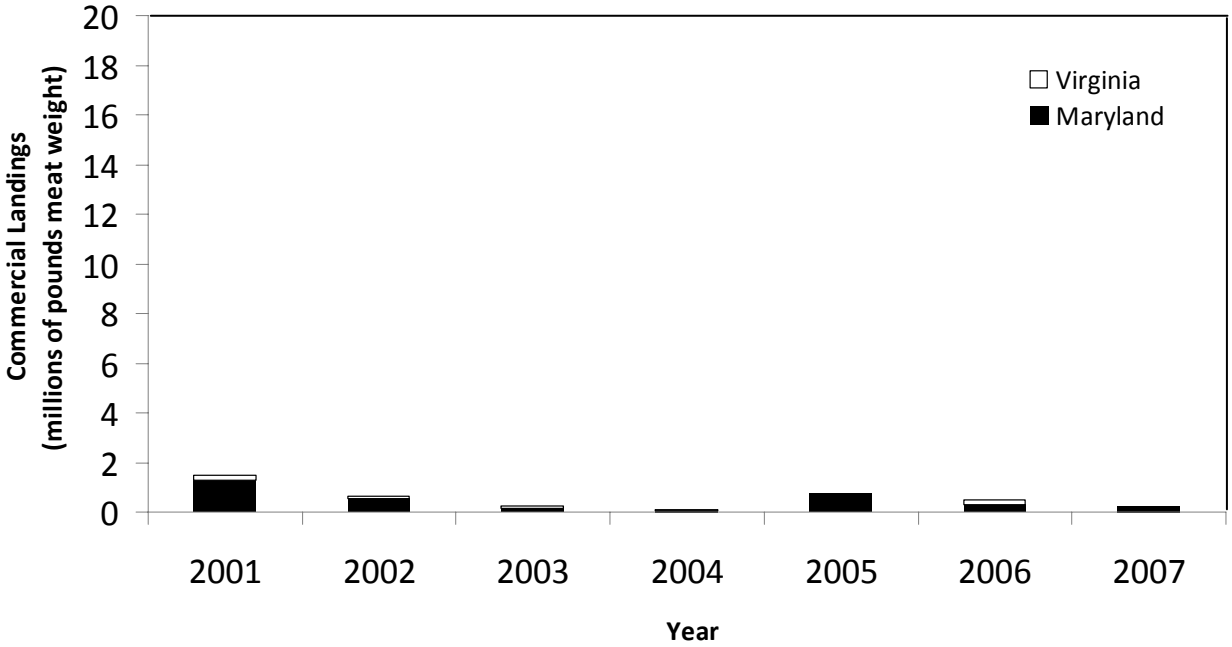


Figure 1-2. Commercial landings of oysters in Chesapeake Bay from 2001 to 2007.

Dermo is caused by a parasitic, single-celled organism called *Perkinsus marinus*, which is found along the Atlantic and Gulf coasts of the Unites States (Ford and Tripp 1996) and is distributed throughout the water column. Oysters contract Dermo as they filter the water for food. Infected Eastern oysters may transmit the parasite directly to nearby oysters or spread the infection by releasing parasites into the water after death (NRC 2004). Dermo weakens the muscle that opens and closes the shell when oysters feed (Mackin 1962; Gauthier et al. 1990); consequently, infected oysters eventually die from starvation (Choi et al. 1989; Ford and Tripp 1996). Most mortality occurs two to three years after oysters become infected with Dermo. Older, larger oysters generally have the greatest levels of infection because their greater rates of filtration increase their uptake of the parasite from the water column (Andrews and Hewatt 1957).

Water temperature and salinity determine the spread of Dermo. The parasite is active during the warmer months (at temperatures above 20°C) but can survive much colder

temperatures (Andrews 1996; Chu and La Peyre 1993). Cool water temperatures during winter and early spring suppress Dermo infections (Andrews 1996; Ragone-Calvo and Burreson 1994). A recent trend toward warmer winters has allowed Dermo to flourish in the Bay (NRC 2004). Dermo is relatively inactive at salinities less than 8 parts per thousand (ppt; Mackin 1956; Ragone and Burreson 1993; Chu et al. 1993), and infection rates decrease during wet years, when a larger-than-average volume of freshwater runoff reduces salinity in the Bay. During the 1980s, several particularly dry years caused salinity to increase in upstream areas of the Bay, where freshwater runoff typically keeps salinity low. These conditions allowed Dermo to spread to many upstream oyster bars that previously had been unaffected (NRC 2004). Transplanting large quantities of diseased seed oysters also is thought to have carried parasites into regions they might not have reached via natural vectors of transmission (Paynter 1999; Wesson et al.1999). "Seed oyster" refers to juvenile oysters or spat from hatcheries or natural sources that are planted on bars where they are expected to grow to market size and, ultimately, to be harvested. Spat generally are most abundant in high-salinity areas where oyster spawning is most successful; therefore, high-salinity areas serve as the primary wild sources of seed oysters. Dermo and MSX, however, are most prevalent in those high-salinity areas. Burreson and Ragone-Calvo (1996) documented the transfer of seed oysters infected with Dermo from an area in the James River, which the parasite had reached naturally, to tributaries of the Potomac River (i.e., Coan and Yeocomico rivers and Machodoc Creek), where Dermo had not occurred previously.

Surveys conducted throughout the Bay from 1990 through 2004 revealed that the prevalence of Dermo ranged from 50% to 95% each year; most years with prevalence greater than 85% were classified as dry (Carnegie and Burreson 2005; Tarnowski 2003; M. Tarnowski, DNR, pers. comm.). The mean annual mortality rates of market-size oysters throughout the Bay from 1991 through 2004 have been estimated to range from 5% to 90% depending on salinity and the prevalence and intensity of disease (Vølstad et al. 2008). These mortalities, however, could have resulted from the effects of both Dermo and MSX.

Oyster Disease Terms

Prevalence – A measure of the frequency of occurrence of infection; the percent of examined oysters that contain at least one disease-causing parasite.

Intensity – A measure of the concentration of parasites within an oyster; high disease intensity generally results in mortality.

Resistance – An oyster either is not susceptible to disease or is subject to only limited infection.

MSX is believed to have been introduced into the Bay through an illegal planting of the nonnative Pacific oyster, *C. gigas* (Burreson and Ragone-Calvo 1996). MSX is caused by a single-celled, infectious parasite called *Haplosporidium nelsoni*, which is now found along the entire Atlantic coast of the United States (Ford and Tripp 1996). Infections of MSX start in an oyster's gill and enter its bloodstream, causing tissue damage and difficulty with respiration and feeding. A large concentration of parasites develops in infected oyster tissue and disrupts the oyster's physical functions, eventually causing death (Ford and Tripp 1996). Eastern oysters infected with MSX produce fewer eggs and sperm than uninfected oysters (Ford and Figueras 1988). The parasite forms spores that are transmitted to new host oysters, but the method of transmission is unknown, and new infections are unrelated to the proximity of infected oysters (NRC 2004).

The prevalence of MSX is controlled by water temperature and salinity, similarly to Dermo. Initial MSX infection generally occurs at water temperatures greater than 20°C and salinities greater than 10 ppt (Ford and Haskin 1982). Oysters may be able to expel MSX parasites if the oysters are exposed to lower salinities for extended periods (Ford and Haskin 1988). Infections generally occur from mid-May to October and kill the host oysters more quickly than Dermo. Oysters infected early in the season generally die between July and October, but oysters infected later in the summer may survive through the winter and die during the following spring (Ford and Tripp 1996). Climatic conditions that cause high salinity and warmer water temperatures during the winter favor the spread of MSX, as they do for Dermo. Infection with MSX was less prevalent than Dermo infection in the Chesapeake Bay between 1990 and 2004. Surveys conducted throughout the Bay revealed that about 1% to 30% of sampled oysters were infected with MSX each year (Carnegie and Burreson 2005; Tarnowski 2003; M. Tarnowski, DNR, pers. comm.). High rates of MSX infection were correlated with dry years, although the statistical relationship was less strong than that observed for Dermo. Both Dermo and MSX became more widespread in Maryland portions of the Bay and in upstream tributaries in Virginia in recent decades, in part because several dry years caused salinity to increase in areas where it previously had been low (Burreson and Andrews 1988; Andrews 1996) and also because of the seed transplanting programs described earlier.

These two diseases have been particularly detrimental to the oyster fishery because they kill many oysters before they reach market size. In the absence of MSX and Dermo, the average lifespan of the Eastern oyster is 6 to 8 years, and the maximum is probably 25 years (NRC 2004). Eastern oysters are marketed in the United States when they reach three inches or more, typically after three to four years in Chesapeake Bay (NRC 2004). Oysters infected with Dermo, however, generally live only two or three years, and oysters infected with MSX generally die within one year. High mortality rates caused by these diseases not only remove oysters potentially available for harvest, but also reduce the number of large, highly reproductive oysters that are left to propagate. Overall, oyster populations in the Bay are now strongly affected by disease (Ford and Tripp 1996) in addition to being negatively affected by harvest, degraded oyster habitat, poor water quality, and complex interactions among these factors (Hargis 1994; NRC 2004).

1.3 HISTORY OF MANAGEMENT AND RESTORATION EFFORTS

Maryland and Virginia historically have managed oysters in their respective portions of the Bay separately, using a combination of harvest restrictions, size limits, habitat enhancement, and planting of seed oysters to support the oyster fishery. Management efforts during the period from 1930 to 1960 are believed to have helped maintain oyster harvests in the range of 30 to 40 million pounds per year (equivalent to 4.3 to 5.7 million bushels per year) over that time period. These and other management strategies resulted in relatively stable annual oyster harvests in Maryland from the mid 1960s through the early 1980s, while landings in Virginia decreased gradually over the same period (Figure 1-1). Virginia's oyster fishery was affected disproportionately by MSX and Dermo because both diseases are more active in the salty water of the southern portion of the Bay (NRC 2004). About two-thirds of Virginia's oyster harvest over the past several decades was supported by private investment on leased grounds. These investors gradually stopped maintaining their grounds and moving seed because it was not

profitable; nevertheless, the State continued its original level of habitat enhancement (J. Wesson, VMRC, pers. comm.). Nearly all the management programs during this time period were aimed at maintaining oyster fisheries, with limited focus on restoring the ecological role of oysters and oyster reefs in the Bay.

The importance of the ecological role of the Eastern oyster within the Bay's ecosystem (i.e., maintaining and improving water quality and creating habitat) gained increased attention as a result of the precipitous decline of the oyster population during the 1980s. State and Federal agencies increasingly began working together to restore oysters. The CBP began in 1983 with the goal of restoring the Bay to its former health and productivity using an ecosystem management strategy. The signatory members of the program were Maryland, Pennsylvania, Virginia, the District of Columbia, and EPA, but many other agencies and stakeholders have joined the effort (http://www.chesapeakebay.net/). The Bay Program identified oyster restoration as a key component for improving the health of the Bay and established specific management goals in its 1987, 1994, and 2000 agreements. The most recent agreement, known as *Chesapeake 2000*, established the goal of attaining a standing oyster population that is 10 times greater than the 1994 baseline by the year 2010. The Chesapeake Bay Executive Council adopted the Chesapeake Bay Oyster Management Plan (OMP) in January 2005 to provide a general framework and specific guidance for restoring and managing the Bay's native oyster resource.

The following sections of this document provide overviews of the most recent major management programs.

1.3.1 Repletion Programs

Repletion programs are designed to take advantage of the life history characteristics of oysters. Oysters have two primary life stages: a planktonic larval stage that is present in the water column and an immobile stage that encompasses the juvenile and adult forms. Oysters reproduce by simultaneously releasing sperm and eggs into the water, where fertilization takes place. Fertilized eggs develop larval characteristics within about 24 hours and are dispersed through the water by currents and, to a lesser extent, by their own swimming ability. Larvae must adhere (set) to a clean hard substrate after two to three weeks in the water column or they will die. Larvae prefer to set on oyster shell (Luckenbach et al. 2005a) but will set on other materials such as concrete and stone. Settled larvae quickly metamorphose into the young-oyster growth stage (spat) and remain immobile for the rest of their lives. Oysters produce very large numbers of gametes (eggs and sperm), and large females can produce many millions of eggs. Because of their great reproductive potential, even small numbers of oysters can quickly increase into large populations when conditions favor settlement and survival of newly set oysters. This trait allows oysters to persist in dynamic environments such as Chesapeake Bay by occasionally producing very large year classes. Such large year classes can compensate for poor year classes that result from unfavorable environmental conditions during other years. Many species of oysters, including Eastern oysters, tend to settle on existing groups of shells called reefs, bars, or beds. The term "repletion" describes two approaches for encouraging settlement, growth, and survival of oysters by planting shell: (1) permanent plantings, in which shell is planted in areas where large spat sets occur naturally, and the resulting spat are left in place until they are large enough to be harvested; and (2) seed-area plantings, in which shell is planted in areas of high

salinity where large spat sets are most likely, and the resulting spat are moved to areas of lower salinity to attempt to protect them from disease.

In Maryland, shell for permanent planting historically was obtained by dredging deposits of old, buried shell. The oyster-shell dredging and planting program in Maryland began in 1960. Using an industrial-scale hydraulic dredge, shells were recovered from deposits buried as much as 40 feet deep in the bottom at locations primarily in the upper Bay. Dredged shells were washed and transported to productive oyster bars, where they were planted to create a layer of shell 3 to 6 inches thick. About five million bushels per year were planted until 1990. Beginning in 1991, the program was reduced to about 1.5 to 2.8 million bushels per year. About 350 acres were planted with shell per year (depending on the volume of shell dredged) while the program was in full operation. Some stakeholders have opposed shell dredging because it alters the bottom substrate, may adversely affect other fisheries, and creates a sediment plume. The shell-dredging program ceased in 2006 when the dredging permit issued by USACE and the Maryland Department of Environment expired (DNR 2006). At that time, DNR decided not to reapply for the permit required to continue the program.

DNR has investigated alternative means of enhancing substrates suitable for oysters. One alternative is shell reclamation. This involves retrieving previously planted shell that has been reburied due to siltation. The program, which is currently in the developmental design phase, is expected to consist of dredging silted shell plantings to a depth of approximately one foot, stockpiling the shells on a barge or other vessel, and replanting the cleaned shells on a more viable bar nearby. No estimate of the cost of implementing this program for rehabilitating oyster habitat is available currently, but the cost is expected to be comparable with that of the previous shell-dredging program in the upper Bay, which ranged from $5,000 to $8,000 per acre depending on the volume of shell obtained. If implemented, this program could facilitate the rehabilitation of significant amounts of oyster-bar habitat (DNR 2006). DNR also has experimented with using other substrates to create artificial reefs for oysters. Since 2002, DNR has planted approximately 71 acres with the equivalent of 985,000 bushels of alternative habitat materials at a cost of $1.7 million, or $24,000 per acre. The use of non-shell substrates has several limitations. Most of the materials acquire low spat sets and are expensive; furthermore, the available volume of some materials is too small to support a large-scale program for rehabilitating oyster habitat. DNR will evaluate the continued use of alternative materials for restoring oyster habitat in the context of its costs and benefits compared to those of other methods for restoring habitat, such as reclaiming previously planted shell.

In Virginia, oyster shell was dredged for substrate consistently until sometime during the 1980s. The State used only dredged shell at that time because no fresh shell (from shucking houses) was available from the oyster processing industry. After the 1980s, additions of dredged or fresh shell became more sporadic, but more fresh shell was deployed. Between 2000 and 2005, the amount of shell habitat created in Virginia ranged from 35 acres to 142 acres for sanctuaries and from 154 acres to 478 acres for harvest areas (Section 1.3.2). Before 2000, nearly all the shell was placed in harvest areas (J. Wesson, VMRC, pers. comm.).

The concept for seed-area plantings, the second and most common kind of repletion program in Maryland, arose from observations that spat set is greatest on clean oyster shell in

highly saline waters and that mortality due to disease is lowest in less salty waters. Each year, clean shell is planted in areas of high salinity, where large spat sets are most likely. Drifting and swimming larval oysters settle on the clean shell and grow into spat. The shell, now covered with tiny oyster spat called seed, is then moved (if seed numbers are large enough) to areas of low salinity to protect the oysters from disease as they grow to harvestable size (C. Judy, DNR, pers. comm.). Shell with seed-counts of less than about 500 spat per bushel generally is not moved because the costs of production and transportation reduce the cost effectiveness of the effort to grow market-size oysters from low seed counts. Much of Virginia's oyster harvest is from natural spat set on privately leased bottom. Although Virginia also has an active repletion program, very few areas in Virginia waters have salinity low enough to protect seed oysters from disease, and many seed-planting efforts have failed because of disease (J. Wesson, VMRC, pers. comm.).

Survival in repletion areas is strongly influenced by the amount of freshwater inflow to the Bay each year. Seed-area plantings produce more market-size oysters during periods when salinity declines due to heavy rainfall than when salinity increases due to drought. Although repletion programs enhance oyster production under some circumstances, they have neither altered disease effects nor contributed significantly to increasing the size of the Bay-wide stock of Eastern oysters because planted seed oysters and any wild larvae that settle on planted shell are subject to harvest when they reach legal size and because the reproductive success of the remaining oysters is low in low-salinity waters. Transplanted seed can carry Dermo or MSX if it is obtained from areas where the disease-causing organisms are prevalent; consequently, repletion programs are believed to have contributed to spreading the diseases (Section 1.2). Maryland's oyster repletion program has supported a large portion of the commercial harvest in the state during the past 10 years. An estimated 80% of the oyster harvest from public grounds in recent years was taken from areas that DNR planted with clean shell or seeded shell (NRC 2004). Shell-planting and seed-planting sites are rotated so that new acreage can be rehabilitated cyclically, and year classes sometimes can be separated. DNR consults with oyster committees for each county annually in March to coordinate shell-planting sites and seed-planting sites with local oystermen. DNR and the committees concur on the selections of bars and sites within bars. The rapidly declining availability of clean shell (Section 1.3.4) is a significant issue that has constrained the extent of Maryland's repletion program in recent years (C. Judy, DNR, pers. comm.).

An additional approach for increasing the amount of suitable habitat for oyster settlement and growth that is not currently a major element of either State's repletion programs is to build structures intended to mimic the three-dimensional characteristics of historical oyster reefs. Federal and State agencies and non-profit groups (e.g., Chesapeake Bay Foundation) are funding projects to construct three-dimensional artificial reefs at several locations in the Bay. In contrast to standard habitat rehabilitation that involves placing relatively thin layers of clean shell on existing hard bottom (i.e., repletion), constructing three-dimensional reefs involves placing thick layers or piles of shell to create bars that are elevated from the bottom of the Bay or installing other hard structures that create elevated surfaces (e.g., large concrete construction debris, specialized artificial-reef structures such as reef balls). Constructed reefs of this nature are designed to counteract the adverse effects of habitat loss due to sedimentation and can elevate oysters above the sediment surface to a height at which the availability of dissolved oxygen (DO)

and food may be greater than it is nearer the bottom. VMRC and partners have placed more than 70, three-dimensional reef structures in the Bay since 1993. VMRC has attempted to create new habitat in both subtidal and intertidal areas (intertidal reefs may protrude above the surface of the water at low tide). Although oysters grew rapidly on the structures, most were overcome by disease within two to four years (Mann et al. 2001).

Virginia deployed a prototype, concrete, modular, subtidal reef in the lower Rappahannock River in 2000. Sampling after four and a half years showed four year classes of Eastern oysters on the structure. Approximately half of the oysters were more than two years old (i.e., were old enough to reproduce; Lipcius and Burke 2006), thus creating the potential for increased oyster reproduction, at least locally on that reef. Fifteen oyster reefs established in the Elizabeth River have been reported to be supporting multiple generations of oysters; however, no stock assessment data for those reefs are available (Elizabeth River Project 2008).

The USACE created the largest network of sanctuary reefs in the Bay in the Great Wicomico River in 2004. Low-relief reef (LRR) totals 54.8 acres; medium-relief reef (MRR), on which the shell surface is elevated above the bottom, totals 29.8 acres. Sampling of the constructed reefs has shown positive results, including an increase in the local oyster population by a factor of 62, multiple age classes of oysters, strong recruitment over multiple years, and both vertical and cohesive growth of the reefs. Oysters on the MRR are growing significantly faster than those on the LRR, and this more rapid growth is contributing to an increase of total shell on the MRR. The MRR is accreting shell faster than it is being lost and is supporting oysters at a density of 1,027/m^2 (± 51.5 SE) whose average size is 47.3 mm (± 1.2 SE). The LRR is supporting oysters at a density of 250/m^2 whose average size is 41.0 mm (± 1.1 SE). The total population on these constructed reefs is estimated to be 184.5 million oysters (Schulte et al. 2009). No oysters were found during a pre-construction survey of the areas in which these reefs were built; therefore, this new population is a direct augmentation of the wild oyster population in the Great Wicomico River. Although significant mortality due to disease is expected in the future, recent research has suggested that this subpopulation exhibits resistance to disease akin to that of a hatchery-produced strain of disease-resistant Eastern oysters (R. Carnegie, VIMS, pers. comm. to C. Seltzer, USACE). Oysters larger than 70 mm, and some larger than 100 mm, are present on the constructed reefs even though they are located in waters in which oyster diseases are endemic. Recruitment to the constructed reefs during 2009 was strong for the fourth consecutive year (C. Seltzer, pers. comm.).

Overall, the results at the project in the Great Wicomico River differ from results at locations of prior restoration efforts in several ways: (1) recruitment has been strong and steady for several years; (2) a significant proportion of the constructed reefs is achieving positive shell balance; and (3) oysters are growing at greater densities than on any other subtidal reefs in Chesapeake Bay. Private leaseholders are reporting a return to productivity on leases in the Great Wicomico above Sandy Point, where USACE's project is located (K. Smith, pers. comm. to D. Schulte, USACE), suggesting that a key benefit of the sanctuary network is being achieved. The constructed sanctuary reefs appear to be supplying recruits to fished areas within the area of hydrodynamic influence of the restoration project.

The Lynnhaven River is another area in which "non-traditional" methods of restoring native oysters are being employed (USACE 2006). This river is a highly saline (14-23 ppt) trap estuary where larvae produced by oysters in the river remain in the area to settle. The Lynnhaven River has been closed to a public oyster fishery for about 30 years due to contamination with fecal coliform bacteria, chemicals, and metals (Burke 2008); however, in 2008 about 1,450 acres of the river were opened to harvest (Bay Journal 2008). The Norfolk District of USACE began a major program to construct oyster reefs in the Lynnhaven River in 2007. About 50 acres of permanent-sanctuary oyster reefs have been established to date (C. Seltzer, USACE, pers. comm.). USACE is planning to restore a total of 111 acres of oyster reef habitat using a combination of mostly LRR (6-18 inches high) and MRR (2-4 feet high) and about 5 acres of high-relief reef (USACE 2006). These reefs will be stocked with a combination of disease-resistant seed (DEBY strain, see Section 4.1.3) and wild seed from Lynnhaven River for five years. The wild seed is being produced from large (> 4 inches) oysters collected from the Lynnhaven River because those oysters are believed to have inherited disease resistance naturally (Burke 2008). Two-thousand bushels of spat-on-shell have been planted to date (Burke 2008).

Restoration programs appear to have positively influenced spat set in the Lynnhaven River. Prior to any restoration, spat fall was estimated at 10 spat per square meter, but a reef constructed in 1998 showed 180 spat per square meter (USACE 2006). Sampling in August 2008 indicated a natural spat set on the constructed reefs (Burke 2008). A 2006 survey of 7.5 acres of reefs in the Lynnhaven basin showed an average of 744 oysters per square meter (CBOPE 2006), which represents a nearly 100-fold increase in the abundance of oysters in the river since 1997 ($8/m^2$; CBOPE 1997). Brumbaugh et al (2000) described the apparent success of restoration efforts in the Lynnhaven and Elizabeth rivers. Hatchery-produced oysters grown by school students were planted on strategically located sanctuary reefs in those rivers. Order-of-magnitude increases in the abundance of juvenile oysters on both reefs and high rates of spat settlement on oyster grounds surrounding the reefs were observed subsequently.

In contrast to the promising results of recent restoration projects such as those in the Great Wicomico and Lynnhaven rivers, the results of three-dimensional reef projects implemented in earlier years were less than encouraging. Southworth et al. (2008) evaluated the performance of 24 constructed, three-dimensional reefs (typically of oyster shell) from the time of their construction in Virginia portions of Chesapeake Bay through 2007, focusing primarily on the intensity of recruitment after construction. Their major findings were as follows:

- An exponential-decay model[4] described spat abundance over time for each reef; none of the reefs examined showed an increase in oyster population (density) over time (longest period was 13 years).
- The largest recruitment tended to occur within the first few years after construction.
- One year-class can dominate reef demographics (regardless of reef age), but this scenario rarely occurs (1/13 yrs), is not sustained, and tends to occur in large watersheds.

[4] An exponential decay model is a mathematical formula that characterizes data that show a rapid decline over time.

- Adding brood stock to reefs does not alter these patterns significantly.

Cost is a major consideration in construction of "non-traditional" three-dimensional reefs. Estimated costs for standard habitat rehabilitation range from about $6,436 per acre in Maryland to about $2,249 per acre in Virginia and Potomac River (D. Lipton, UMD, pers. comm.). Those figures served as the basis for estimating the costs of the proposed action and the alternatives evaluated in this PEIS (see Section 4.6.2). In contrast, the cost per acre for three-dimensional reefs constructed in Virginia has ranged from about $100,000 to $150,000 per acre (J. Wesson, VMRC, pers. comm.). The USACE, Norfolk District, has abandoned the three-dimensional reef design used by VMRC and is now building reefs in various configurations that result in more height off the bottom than standard replenishment programs, presumably at lower cost (D. Shulte, USACE, pers. comm.). The estimated total cost to construct, seed, and monitor the restoration project in the Lynnhaven River described above is approximately $6.5 million for the full 111 acres, or approximately $59,000 an acre (USACE 2006).

The most common methods of harvesting oysters (e.g., hand tongs, patent tongs, dredging) all would damage constructed three-dimensional reefs; therefore, such reefs would be most useful for restoring oysters to provide ecological services. If constructed, three-dimensional reefs were to result in the establishment of local populations of oysters that reach sexual maturity, they might serve as sources of oyster larvae that would disperse more widely in the Bay and support harvest on exploitable bars. Individual bars, however, can serve either as sources of larvae that are exported to other bars, or as "sinks" that attract larvae produced at other bars but do not produce larvae that are exported (Mann and Powell 2007). Research conducted to date has not been sufficient to categorize the Bay's oyster bars as sources of, or sinks for, larval production. Such information is essential for identifying bars or locations that would be the best candidates for producing large, regional increases in oyster populations.

The extent to which the local increases in oyster abundance reported on the constructed reefs in the Lynnhaven, Great Wicomico, Elizabeth and other rivers may be contributing to significant net increases in oyster populations on a larger, regional scale is not known, and the possibility that sustaining such increases might require further intervention (e.g., additional reef construction, seeding) is an additional uncertainty. Most of the recent three-dimensional reef projects have been underway for relatively short periods; consequently, the likelihood that they will result in long-term, sustained enhancement, even of local stocks of oysters, has not yet been established conclusively. Mann and Powell (2007) suggested that the local benefits of such constructed reefs are not likely to be sufficient to counteract the effect of the loss of hard-bottom habitat throughout the Bay. At the high-relief reefs in the Great Wicomico River, however, 20 liters of new shell material per square meter of constructed reef have accumulated naturally since the reefs were installed in 2004 (Schulte et al. 2009). Outcomes such as that, if widespread and consistent over time, could significantly counteract habitat loss. The scale of reef construction that would be required to achieve the PEIS goal, even assuming successes such as those reported to date, has not been estimated, and neither Maryland nor Virginia has implemented a large-scale program to construct three-dimensional reefs as a major element of its oyster restoration program to date.

1.3.2 Sanctuary and Harvest Reserve Programs

Maryland's and Virginia's most recent management efforts have focused on restoring the ecological benefits of oysters by establishing areas where harvest is prohibited or delayed. Virginia's oyster management plans have included designating oyster sanctuaries where harvest is prohibited, creating artificial reefs to increase habitat available for oysters, and imposing harvest limits. Virginia historically relied on natural spat set in highly saline waters to populate its sanctuaries. Recently, Virginia also has planted hatchery-raised oysters bred for disease resistance in its management programs.

Areas in Maryland set aside for restoration include both sanctuaries and harvest reserves. Sanctuaries are closed to harvest indefinitely by law and regulation. Reserves are stocked and closed to harvest long enough to allow a predetermined percentage of the oysters to grow to market size. Once this objective is achieved, reserves are opened to harvest. Reserves are designed to allow the reefs to provide ecosystem services for some period of time before the surviving oysters are harvested. Sanctuaries and reserves in Maryland are usually seeded with disease-free oyster spat-on-shell[5] produced in oyster hatcheries rather than using natural seed transplanted from seed-areas in the lower Bay, which typically are infected. Sanctuary reefs in Maryland are constructed in subtidal areas by planting shell or alternative materials (i.e., concrete, stone, slag) at a thickness of four to eight inches. Smith et al. (2005) showed that oyster substrate created as part of restoration programs becomes covered with sediment after an average of five and a half years, limiting its long-term benefit. In general, sanctuary programs have established some successful reefs but have contributed a relatively small number of oysters to the total population of the Bay. Their contribution also appears to have been limited by illegal harvesting in some areas that are supposed to be closed to harvest by regulation.

1.3.3 Funding for Oyster Restoration

Funds contributed by the States and the Federal government to support in-water restoration of the native oyster population and recovery of the fishery throughout Chesapeake Bay totaled approximately $17 million for sanctuaries and $41 million for harvest areas from 1994 through 2006 (Figure 1-3). Section 5021 of the Water Resources Development Act of 2007 increased USACE's authorization limit for native oyster restoration activities in Chesapeake Bay from $30 million to $50 million, although funding has to date not be made to that limit..

The annual production of hatchery-raised oyster seed increased from 38 million in 2000, to 350 million in 2006. The hatchery-raised seed oysters have been distributed to managed reserves, harvest grounds, and sanctuaries to "jumpstart" recovery efforts in Chesapeake Bay. Oyster restoration partners prepared and/or seeded nearly 600 acres of suitable bottom habitat in Chesapeake Bay. In 2006, the USACE planted shell on approximately 51 acres in the Chester, Choptank, and Severn rivers and continued seeding reefs in the Great Wicomico River (DNR 2007).

[5] "Spat-on-shell" refers to hatchery-reared oyster larvae that are allowed to settle in groups on pieces of shell in the hatchery. The oyster-covered shell is then transplanted to the areas for planting.

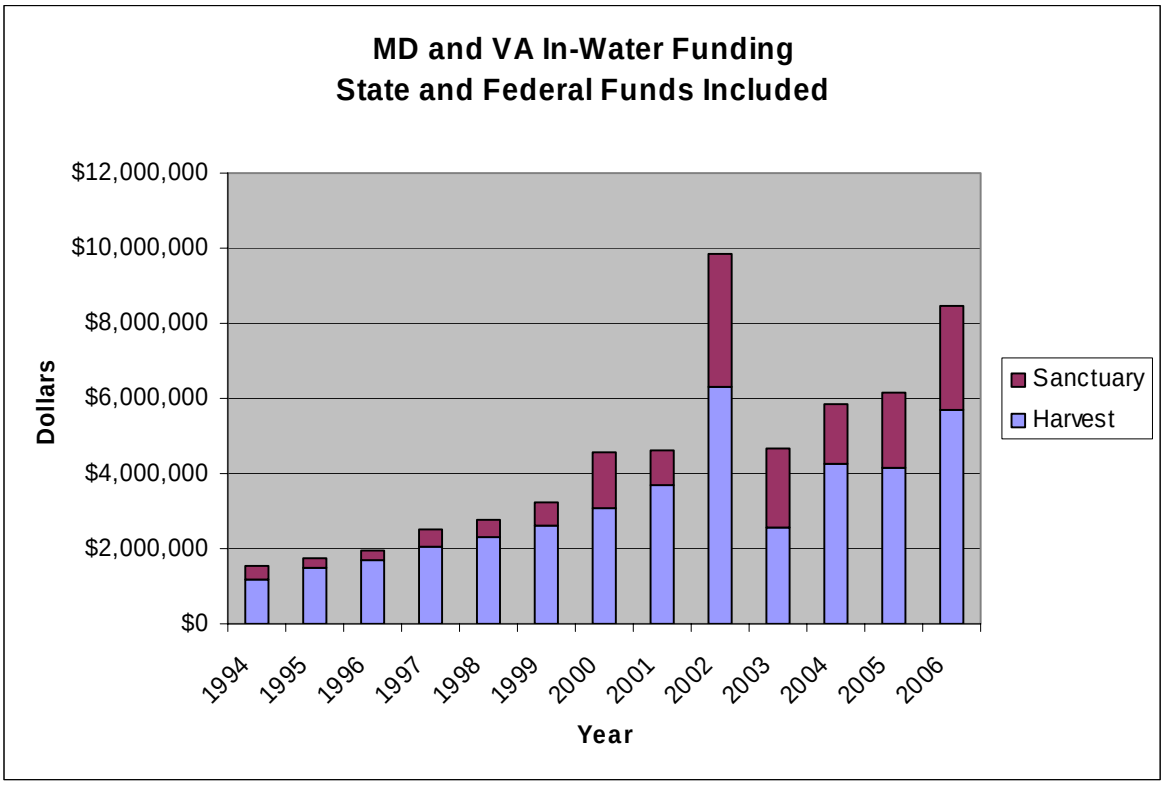


Figure 1-3. State and Federal funding for oyster sanctuary and harvest programs in Maryland and Virginia from 1994 through 2006; figures include the States' expenditures as well as Federal funds from the USACE, EPA, and NOAA; data compiled by DNR.

1.3.4 Constraints on Restoration Programs

Funding clearly is a potential constraint on the continuation or expansion of oyster restoration programs. As shown in Figure 1-3, concern about the status of the oyster in Chesapeake Bay at both local and national levels resulted in a nearly five-fold increase in funding between 1994 and 2006. Regardless of funding, limited availability of hatchery capacity for producing seed oysters and lack of sufficient substrate material for increasing oyster habitat could both limit the future scope of restoration programs. Existing hatchery capacity in the Bay was considered in defining the restoration strategies evaluated in this Draft PEIS (Section 2). Expanding existing hatcheries or constructing new ones to supply enhanced restoration efforts would require increased funding. One alternative to increasing hatchery capacity would be to purchase Eastern oyster spat from hatcheries outside the Bay area. Meeting the demand for habitat enhancement material is more problematic.

The current high rate of loss of oyster habitat combined with the disappearance of sources of shell for enhancing habitat are generally recognized as major obstacles to all oyster restoration efforts. A sampling of 18 oyster bars considered to be representative of oyster habitat in Maryland's portion of the Bay revealed a 70% loss of suitable oyster habitat on those bars between about 1980 and 2000, suggesting a 3.5% loss of oyster habitat each year (Smith et al. 2005; Attachment 1 of Appendix A). Sedimentation and the deterioration of existing shell both contribute to this loss. Mann (2007a) found that that 20% or more of the shell stock in the James

River is lost each year as a result of natural processes. The high rate of habitat loss is a critical issue for the future of oyster populations because larval oysters require hard substrate on which to settle. A healthy, growing oyster population creates its own habitat through production of new shell. At their current low level of abundance in the Bay, oysters are not creating adequate amounts of new shell to support a significant increase in the population. The two sources of shell available for habitat restoration in the past were shucking houses and buried shell deposits dredged from the bottom of the Bay. These sources have waned or ceased to exist completely, resulting in a significant shortage of new shell for oyster restoration programs. Continuing habitat degradation throughout the Bay decreases whatever potential may exist for reproductive success of the existing remnant oyster stock (Mann and Powell 2008). The limited ability to increase and maintain new areas of clean substrate for larval settlement, therefore, is a major constraint on restoration programs in both states.

> The current high rate of loss of oyster habitat combined with the disappearance of sources of shell for enhancing habitat are generally recognized as major obstacles to all oyster restoration efforts.

1.3.5 Outcomes of Management Programs

As implemented to date, the management programs described above have produced no substantial increase in oyster harvests over the past decade. The 10-year average harvest from 1997 to 2006 was 1.3 million pounds (approximately 186,700 bushels) with a standard deviation of 1.1 million. The average from 2002 to 2006 was 0.4 million pounds (approximately 57,100 bushels) with a standard deviation of 0.3 million pounds (D. Lipton, U. of MD, pers. comm.). The decreasing average harvest for the most recent five years clearly illustrates that management efforts have not enhanced harvests. Decreasing oyster harvests generally indicate a decreasing population of market-size oysters (more than 3 inches long). Other factors, however, can contribute to a decrease in harvest (e.g., establishment of oyster reserves and sanctuaries where harvest is limited or prohibited), and harvest figures provide no information about the abundance of young oysters that have not yet reached market size.

> As implemented to date, management programs have produced no substantial increase in oyster harvests over the past decade.

Neither Maryland nor Virginia conducts surveys to estimate the size of the oyster populations in their respective portions of the Bay; however, data from several fishery-independent surveys conducted for management purposes provide a means of developing such estimates. These estimates are available at a Web site entitled "Chesapeake Bay Oyster Population Estimates" (http://www.vims.edu/mollusc/cbope/basin.htm). A more recent recalculation of population estimates for Maryland waters is documented in Attachment 7 of Appendix A to this Draft PEIS. Figure 1-4 presents estimates of Bay-wide oyster biomass for the years 1994 to 2006; data for Virginia are from the Web site noted above, and data for Maryland are from Attachment 7 of Appendix A. The size of the population is estimated in terms of biomass because that measurement allows all ages and sizes of oysters to be counted together and because biomass is a useful measure of the magnitude of ecological services that the population may be contributing.

Confidence limits on estimates for Maryland are presented in Attachment 7 of Appendix A; no confidence limits are available for the estimates for Virginia. All of these population estimates have a high degree of uncertainty. Only the Maryland data were sufficient to support trend analysis. The annual estimates vary considerably, but there is no statistically significant trend in oyster abundance in Maryland over the indicated period. The 2006 total is about 88% of the total for 1994, and the likelihood of attaining the *Chesapeake 2000* goal of a standing oyster population that is 10 times greater than the 1994 baseline by the year 2010 appears small. These data and the harvest data suggest that recent oyster management programs have not increased the Bay-wide population of oysters and have not enhanced the oyster fishery in the Bay. It is not clear whether the local increases in oyster abundance reported from some of the successful restoration projects described in Section 1.3 are included in the population estimates presented in Figure 1-4.

The likelihood of attaining the *Chesapeake 2000* goal of a standing oyster population that is 10 times greater than the 1994 baseline by the year 2010 appears small.

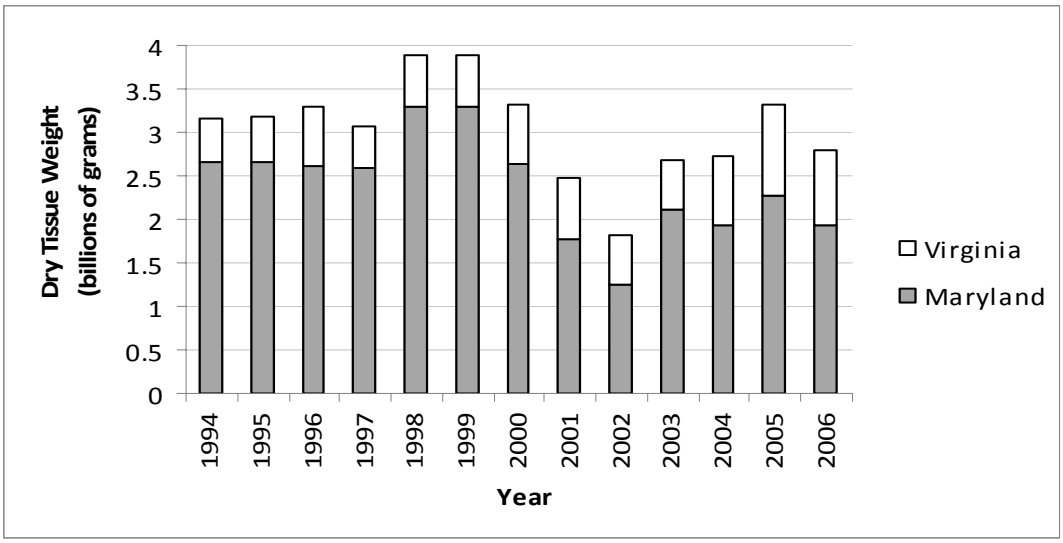


Figure 1-4. Estimated biomass of oysters present in the Maryland and Virginia portions of Chesapeake Bay from 1994 to 2006. Estimates are based on fishery-independent surveys conducted by DNR and the Virginia Institute of Marine Science.

A group called the Oyster Restoration Evaluation Team (ORET), comprised of oyster researchers from the University of Maryland and VIMS, has initiated a study to examine the results of oyster restoration efforts since 1990 throughout Chesapeake Bay. The ORET's objective is to synthesize the lessons learned regarding specific scientific and management goals that have driven restoration efforts and, in particular, the success to date in reaching those goals. The first step in the evaluation process, consolidating available data, was completed in 2008 and is summarized in a preliminary report entitled *Meta Data Analysis of Restoration and Monitoring Activity Database (*ORET 2008). No specific conclusions can be drawn yet; nevertheless, the ORET made a number of preliminary observations. The database documents a wide array of activities, goals, and objectives drawn primarily from programs funded by Maryland and Virginia. The data are mostly qualitative and do not afford the opportunity to quantify changes in the size of the oyster population over time, even on a site specific basis. The

ORET identified the need for quantitative data collected from both restored and un-restored reefs following well-conceived restoration designs and monitoring plans to facilitate definitive analyses of the results of restoration activities.

1.4 CONSIDERING THE INTRODUCTION OF A NONNATIVE OYSTER

Recognizing the failure of current management programs to reverse the long-term decline of the Bay-wide oyster population, Maryland and Virginia began to consider nontraditional approaches to rebuilding the oyster stock. Oyster diseases appear to be a significant factor inhibiting the recovery of the stock; therefore, one approach being considered is to introduce a nonnative oyster that has environmental requirements similar to those of the Eastern oyster and might provide similar ecological services but is resistant to MSX and Dermo. Initial investigations during the 1990s focused on the Pacific oyster (*C. gigas*) which is native to Asia and has been cultivated in many estuaries throughout the world (Mann et al. 1991). Pacific oysters can acquire Dermo but tend not to suffer appreciable mortality or growth effects (Barber and Mann 1994; Calvo et al. 2001). Although the Pacific oyster demonstrated resistance to MSX and Dermo in tests in Chesapeake Bay, it was subject to severe mud blistering caused by a native, shell-boring worm called *Polydora*. The effects of *Polydora* rendered most Pacific oysters grown in Chesapeake Bay waters unmarketable and increased their vulnerability to predation by weakening their shells (Calvo et al. 1999).

The Suminoe oyster (*C. ariakensis*), another nonnative oyster from Asia currently being considered for introduction, was first imported to the West Coast of the United States in 1957 to be evaluated for use in aquaculture. No stocks descended from those early imports exist today. The "Oregon stock" of Suminoe oysters originated from a shipment of seed imported from Ariake Bay, Japan, between 1969 and 1971 (Bohn et al. 2004). These seed oysters were grown in a bed with other oysters in Yaquina Bay, Oregon, where a shellfish grower noticed that a few oysters grew unusually quickly. Analyses conducted by what is now the Hatfield Marine Science Center of Oregon State University (OSU) identified the fast-growing specimens to be Suminoe oysters. Researchers from OSU recovered 12 to 15 adult Suminoe oysters from the bed in Yaquina Bay and spawned them in hatcheries. OSU conducted field trials to examine growth rates in Tomales Bay, California (in bags on racks); Mud Bay, Washington (on bottom); Yaquina Bay, Oregon (in rafts); and Coos Bay, Oregon (bottom culture) between 1990 and 1993. The University of Washington conducted field studies on reproduction and gonad maturation in Oakland Bay, Washington (Perdue and Erickson 1984). OSU later transferred the brood stock to commercial hatcheries that frequently held oysters to produce seed for private growers. OSU has tracked the progeny of these founding Suminoe oysters for more than 30 years (Perdue and Erickson 1984; Langdon and Robinson 1996).

Hatchery production of the Suminoe oyster by commercial growers on the West Coast was sporadic and brief due to difficulties with rearing the species and competition with the numerous varieties of oysters available for the niche markets at which growers were targeting the Suminoe oyster. Although several growers obtained Suminoe seed through OSU, the most experienced was Louis Wachsmuth, the founder of the Oregon Oyster Company (OOC) and the grower on whose beds the initial Suminoe oysters were discovered. Mr. Wachsmuth experimented with cultivating the Suminoe oyster on the bottom and in floating cages. The OOC

maintained 80 to 100 acres of commercial Suminoe oyster beds for an extended period of time. In a presentation to the Pacific Coast Oyster Grower's Association in 1979, Mr. Wachsmuth ranked the Suminoe oyster the highest among seven species for several commercial traits. Other growers that produced Suminoe seed included the Bay Center Oyster Company in Bay Center, Washington; the Lummi Indian Nation in Bellingham, Washington; and the Whisky Creek Shellfish Hatchery in Netarts, Oregon. The brood stock maintained by the Lummi Indian Nation eventually was transferred to North Carolina through the Virginia Institute of Marine Science (VIMS).

The brood stock held by Taylor Shellfish Farms at Totten Bay, Oregon, and North Bay, Washington, are the only remaining descendents of the Oregon stock being held on the West Coast. The stock has spawned 5 times in 15 years. The several generations of this stock are free of pathogens and have not experienced any unusual mortality (Bohn et al. 2004). Seed or progeny from the seed of this stock have been used in field and lab studies in Chesapeake Bay and in North Carolina (e.g., Calvo et al. 1999, 2000, 2001; NRC 2004). The founding population of the Chesapeake Bay brood stock of Suminoe oysters being maintained at VIMS and at the Horn Point laboratory in Maryland consisted of 9 males and 7 females that were progeny of the original Oregon stock of 12 to 15 Suminoe oysters whose descendents are now being maintained by the Taylor Shellfish Company (S. Allen, VIMS, pers. comm.). The Oregon stock also provided a source of seed for research projects in France (NRC 2004).

Studies to assess the extent to which the Suminoe oyster might be suited to estuarine environments along the East Coast began in North Carolina in 1996 and in the Chesapeake Bay region in 1998 (Attachment A of Appendix B). Biosecurity measures are employed to avoid unintentionally introducing the species into East Coast estuaries during these studies. Special containment facilities were established at the hatcheries in Maryland and Virginia where the species is housed and propagated. The Suminoe oysters to be deployed for studies in Bay waters are altered to render them almost completely sterile[6] and contained in bags or cages during the studies. These studies have shown that MSX and Dermo typically do not kill Suminoe oysters and that Suminoe oysters generally grow faster than Eastern oysters (details of study findings are presented in Section 4.1.1 and in Appendix B, Section 4.2). These biological attributes have lead proponents of an introduction to believe that the species could become established and prosper in Chesapeake Bay and enhance both the oyster fishery and the ecological services provided by oysters.

Planned and accidental introductions of nonnative species, however, often have had unexpected negative effects on the ecosystems that receive them (Kolar and Lodge 2001); moreover, the introduction of a naturally reproducing nonnative shellfish species into an open aquatic environment is almost certainly irreversible (NRC 2004; McKindsey et al. 2007). In response to such concerns, the Chesapeake Bay Commission, the Chesapeake Bay Foundation, EPA, and the U.S. Senate Committee on Appropriations asked the NRC of the National Academy of Sciences to describe the state of knowledge about the Suminoe oyster in order to

[6] A normal, fertile oyster has two sets of chromosomes (i.e., diploid or 2n), but an altered "triploid" oyster has three sets (3n). The presence of a third set of chromosomes generally reduces the likelihood that an oyster can spawn successfully even though it develops gonadal tissue and produces some gametes. See Section 4.1.6 for more information about how triploids are produced.

assess the risks involved with introducing the species into Chesapeake Bay. The NRC's report, *Nonnative Oysters in the Chesapeake Bay* (NRC 2004), identified gaps in the state of knowledge about the Suminoe oyster and recommended research needed to support an adequate risk assessment. An additional review by the Scientific and Technical Advisory Committee (STAC) of the CBP also identified research needs and ranked them according to priority (Breitburg et al. 2004). In 2004, Maryland, Virginia, and the PRFC funded some of the needed research, and NOAA initiated a three-year research program to fill the gaps in research that the NRC and STAC identified has having the highest priority. This Final PEIS incorporates the results, to date, of those studies and others that have been or are being conducted to address research needs related to the proposed action to introduce the Suminoe oyster in Chesapeake Bay.

Section 2 describes the proposed action and alternatives in detail, provides justification for dismissing two alternatives from further consideration in PEIS analyses, presents a summary comparison of the alternatives, and identifies the preferred alternative and the basis for selecting it. Section 3 describes the potentially affected natural and human environments defined for this PEIS, and Section 4 describes and evaluates the predicted environmental consequences of the proposed action and six alternatives. Section 5 describes the public scoping and consultation components of the NEPA process for this PEIS and presents a summary of comments that were received on the Draft PEIS.

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