4 Environmental Consequences

This section of the Draft PEIS presents the evaluation of the potential environmental consequences of the proposed action and six alternatives. Eastern oysters in Chesapeake Bay have been studied for decades, as documented in numerous state and Federal management reports and many scientific publications. Management programs and scientific studies devoted to the Eastern oyster have been diverse, but most were conducted for purposes very different than addressing the kinds of issues being evaluated in this PEIS. Basic information, such as the size of the Bay-wide oyster population, the percentage of oysters that are harvested each year, and the rate of growth of oyster populations at different locations in the Bay and in different years, is only poorly defined. Despite such limitations, the data and results from those programs and studies were the only resources available for use in conducting assessments and served as the primary basis for the assessments of the Eastern oyster presented here. Descriptions of those assessments acknowledge the uncertainties resulting from data limitations.

In response to the interest in and concerns about introducing the Suminoe oyster into Chesapeake Bay, State and Federal agencies funded an extensive research program to investigate the species (Attachment A of Appendix B). Much of that research has been completed, but some studies are still in progress. All available information from these studies, whether completed and peer-reviewed or continuing and documented only in progress reports, was used to assess the potential effects of the proposed action and alternatives that involve the Suminoe oyster. The assessments acknowledge and, to the extent possible, account for the uncertainties associated with using preliminary findings of incomplete research. Additional information comes from field trials with sterile, triploid Suminoe oysters undertaken by the Virginia Seafood Council (VSC). These trials were a cooperative effort between commercial oyster growers in Virginia and State and Federal agencies to obtain information about the growth and behavior of the species in Chesapeake Bay and evaluate its market potential. Triploid Suminoe oysters were deployed at locations representing various salinity regimes within the Virginia portion of the Bay. Table 4-1 summarizes the VSC trials to date. All growers involved in the trials received permits from the Army Corps of Engineers, and deployed oysters were contained using a variety of methods including on-bottom and off-bottom cages, floats, and rack systems. Throughout the trials, oysters were monitored for genetic patterns, growth, condition, and disease. As noted by the NRC (2004), the commercial field trials also provided “an opportunity to research the potential effects of extensive triploid-based aquaculture or introduction of reproductive non-native oysters on the ecology of the bay.”

Table 4-1. Numbers of growers and triploid Suminoe oysters involved in VSC trials.

Year	**2000**	**2001**	**2003**	**2005**	**2006**	**2007**	**2008**
Number of growers	6	13	9	10	13	10	10
Total number of Suminoe oysters deployed	6,000	60,000	800,000	1 M	1.3 M	700,000	1 M

A major objective for the analysis of the proposed action and alternatives was to assess the extent to which each might contribute to attaining the goal suggested in the statement of purpose for this PEIS (i.e. an estimated 12 billion market-size oysters; Section 2.1). The assessment of the environmental consequences of the proposed action and the alternatives described in this section, therefore, begins with an evaluation of each action's potential for attaining the oyster population goal.[1] Next, the effects of the proposed action and each alternative on other biological components of the ecosystem of Chesapeake Bay (Section 4.2) and water quality are described (Section 4.3). The assessments for ecosystem components are drawn primarily from the ERA for Oyster Restoration Alternatives (Section 4.4 of Appendix B). Potential effects of the proposed action and the alternatives on rare, threatened, and endangered species (RTE; Section 4.4) and essential fish habitat (EFH; Section 4.5) are presented next. The assessments of effects on RTE and EFH also are based on the results of the ERA, and the discussion of effects on those groups reiterates the discussion of effects on ecosystem components to some extent. These categories of potential effects are included to meet NEPA regulatory requirements. Effects of the proposed action and the alternatives on all remaining elements of the affected environment are then described in the order presented in Section 3.

4.1 OYSTERS

4.1.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

Many issues of concern to stakeholders regarding the proposed action have to do with the potential for adverse ecological consequences if the Suminoe oyster were to become established in Chesapeake Bay. Those issues are addressed in Section 4.2.1. The only issues addressed in this section are the likelihood that a population of Suminoe oysters would become established (i.e., the feasibility of the proposed introduction) and the potential magnitude of an established population.

ICES protocols for introducing a new oyster species require producing spat in a hatchery and placing them at a limited number of locations in a receiving body of water. DNR, VMRC, and PRFC developed what they consider to be a feasible representative plan for implementing an introduction program according to ICES protocols (Table 4-2). Their assumption of feasibility was based on the capacity of existing hatcheries, the size of the available spawning stocks, and realistic expectations of future increases in funding. The representative plan calls for introducing Suminoe spat over a decade beginning with 400 million in year 1 and increasing to 2.3 billion each in years 7 through 10. Maryland's hatchery was assumed to produce between 75 million and slightly more than 2 billion spat each year; 25 million of these would be allocated to the Potomac River annually. Virginia's hatchery was assumed to produce 50 to 200 million spat annually. Suminoe oyster spat from those hatcheries would be planted first on designated sanctuaries in Maryland and Virginia, separate from native oyster restoration projects, where harvesting would be prohibited permanently. In Maryland, spat would be planted on harvest-reserve and special-management areas later in the 10-year introduction period; only selective harvesting would be allowed in those areas. In the mainstem of the Potomac River, all spat

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[1] The baseline Bay-wide population of market-size Eastern oysters in 2004 was estimated to be 809 million (Attachments 3 (addendum) and 7 of Appendix A).

would be planted on open-harvest areas. Spat would be planted at concentrations ranging from one million to five million per acre. Differences in the number of spat to be planted per acre are based on salinity-dependent differences in the natural mortality of hatchery-reared spat and different management objectives for sanctuaries and open-harvest areas. In each management region, seed would be planted on a given bar several times over the 10-year period. As a result, the total number of acres to be planted with spat at some bars would exceed the current total size of the bars. The representative implementation plan calls for planting Suminoe oyster seed on bars with existing suitable habitat and, therefore, does not include habitat rehabilitation for those bars. Effort to restore the native oyster, which includes effort to rehabilitate oyster habitat, would continue at current levels, as described in Section 4.1.2, and current regulations on harvest would apply. Suminoe oysters planted on open-harvest bars in the Potomac River would become available for harvest when they reached market size, and those planted on harvest-reserve and special-management bars would become available when those locations were opened to harvesting. Suminoe oysters would become more generally available for harvest after spat planted on sanctuary bars reached sexual maturity and produced progeny that settled on harvestable bars and grew to market size.

Table 4-2. Representative plan for introducing Suminoe oysters in Chesapeake Bay; figures represent number of spat placed in the three salinity zones(a) within each state, each year, over a 10-year period.

Year	**Maryland**			**Virginia**			**Total Spat**
	Low	**Medium**	**High(b)**	**Low**	**Medium**	**High**	
1	303,000,000	0	0	5,000,000	25,000,000	70,000,000	403,000,000
2	453,000,000	0	0	5,000,000	35,000,000	110,000,000	603,000,000
3	693,000,000	60,000,000	0	40,000,000	65,000,000	145,000,000	1,003,000,000
4	873,000,000	130,000,000	0	40,000,000	65,000,000	145,000,000	1,253,000,000
5	1,053,000,000	200,000,000	0	40,000,000	65,000,000	145,000,000	1,503,000,000
6	1,493,000,000	260,000,000	0	40,000,000	65,000,000	145,000,000	2,003,000,000
7	1,779,000,000	274,000,000	0	40,000,000	65,000,000	145,000,000	2,303,000,000
8	1,779,000,000	274,000,000	0	40,000,000	65,000,000	145,000,000	2,303,000,000
9	1,779,000,000	274,000,000	0	40,000,000	65,000,000	145,000,000	2,303,000,000
10	1,779,000,000	274,000,000	0	40,000,000	65,000,000	145,000,000	2,303,000,000

(a) The low, medium, and high salinity zones correspond generally to oligohaline (0.5 to 5 ppt), mesohaline (5 to 18 ppt), and polyhaline (18 to 30 ppt) zones used in the Ecological Risk Assessment (Section 3.4 of Appendix B).

(b) No spat allotted to high-salinity areas in Maryland because there are no sanctuary, harvest-reserve, or special-management bars in those areas.

The Suminoe oyster spat to be used in the introduction would be produced using the existing brood stock being maintained at hatcheries in Maryland and Virginia, whose origin was described in detail in Section 1.4. The stock is more than three generations removed from the original Oregon stock. The VIMS Department of Environmental and Aquatic Animal Health has certified that spat produced from the brood stock after the first generation are free of any exotic pathogens (S. Allen, VIMS, pers. comm.); therefore, the Chesapeake Bay brood stock meets the requirements of the ICES protocol specified in the proposed action.

> The Chesapeake Bay brood stock of Suminoe oysters is certified to be free of exotic pathogens.

Despite the availability of a suitable stock, lack of sufficient hatchery production capacity could constrain the States' ability to implement the introduction plan as described. Producing the 400 million spat proposed in year 1 of the introduction plan would require producing about 4 billion eyed larvae and 40 billion eggs, which would require about 4,000 females and, thus, a minimum of about 8,000 diploids. Increasing production to 2 billion spat to supply the introduction plan in year 6 would require a brood stock about 5 times larger than the current stock (S. Allen, VIMS, pers. comm.). A sufficient number of diploids might be available between the stocks being maintained in Maryland and Virginia; however, producing 2.3 billion spat would require about 23 billion eyed larvae, which is about the maximum production capacity of the University of Maryland's soon-to-be-expanded hatchery at Horn Point (Section 4.0 of Appendix C). Unless all of the existing hatchery capacity were to be devoted to producing Suminoe oysters, implementing the proposed action as suggested in the introduction plan might require expanding existing hatcheries or constructing additional oyster hatcheries in the Bay watershed. No biosecurity would be required at such new hatcheries because the proposed action is to introduce diploid, reproductively viable oysters. Another potentially less expensive possibility would be to purchase Suminoe oyster spat from hatcheries outside of the Bay area (i.e., from Taylor Shellfish). Any imported spat would have to meet ICES protocols for introducing a nonnative species.

Lack of sufficient hatchery capacity could constrain the States' ability to implement the proposed action as currently planned.

The likelihood that an introduction would result in expansion and growth of a population of Suminoe oysters throughout the Bay would depend on the relative importance of positive factors (primarily disease resistance and higher growth rate) and negative factors (primarily susceptibility to predation, competition with the Eastern oyster, continuing loss of hard-bottom habitat, and vulnerability to infection by *Bonamia*) that could influence the species in Chesapeake Bay. Details concerning all the factors that could influence the outcome of the proposed action provide some basis for informed judgment about the likelihood of successfully establishing a self-sustaining population of Suminoe oysters in Chesapeake Bay.

4.1.1.1 Factors that Favor a Successful Introduction

Tolerance to Disease – The most important of the Suminoe oyster's characteristics considered to favor a successful introduction is the species' ability to survive when exposed to Dermo and MSX. Information on this trait is available from a wide range of studies, some of which were designed specifically to consider disease issues and many others in which observations about disease were ancillary to the primary objective of the study.

Salinity is a major factor in determining whether oysters become infected with Dermo or MSX and the level of intensity of disease (Section 1.2). Both diseases are more virulent at higher salinities. The likelihood that disease will kill an oyster is influenced by many factors besides disease intensity. An oyster living in ideal conditions (i.e., with adequate dissolved oxygen and abundant food) may be able to survive despite a substantial infection, whereas an oyster with a less intense infection might succumb quickly if exposed to an environmental stressor such as prolonged hypoxia. Disease can also affect other biological characteristics of an oyster. For example, diseased oysters generally exhibit slower growth rates than healthy oysters.

Such effects and interactions are evident in results of the studies summarized here and must be considered in interpreting those results.

Calvo et al. (2000) conducted a field study in which triploid Suminoe oysters were placed together with diploid Eastern oysters in waters with salinities ranging from less than 15 ppt to greater than 25 ppt. They found that although 100% of the diploid Eastern oysters harbored Dermo across all the salinities, only about 33% of the triploid Suminoe oysters were infected. The intensity of Dermo infection within an individual oyster also was greater among the diploid Eastern oysters than among the triploid Suminoe oysters. Seventeen percent of the Eastern oysters (97 of 567) experienced heavy infections, but none of the Suminoe oysters (0 of 708) had heavy infections. Eastern oysters had a much greater rate of mortality at low-salinity sites (81%) than Suminoe oysters (14%). At sites ranked as medium and high salinity, cumulative mortality was 16% for Suminoe oysters and 100% for Eastern oysters at the end of the experiment (Calvo et al. 2000). The results of these studies may have been compromised by the fact that the Suminoe oysters were obtained directly from a disease-free hatchery, but the Eastern oysters had been maintained in ambient waters where they may have been exposed to Dermo prior to the study. In studies in the Rhode River (salinity 6 to 12 ppt) in Maryland, Breitburg and Hines (2007) found that triploid Suminoe oysters could acquire Dermo infections from infected Eastern oysters and that disease intensity was greater among Eastern oysters than among Suminoe oysters placed in the same environment. Paynter (2007) found the prevalence of Dermo to be similar among Suminoe and Eastern oysters at three of four sites he studied. The York River site had the highest mean salinity (13.7 ppt) compared to sites on the Severn (6.1 ppt), Choptank (7.9 ppt), and Patuxent rivers (8.5 ppt). Only at the York River site did Eastern oysters experience more than three times the prevalence of Dermo observed among Suminoe oysters.

In their native waters of China and Japan, Suminoe oysters harbor infections of the parasite that causes Dermo and another parasite of the same genus at levels of prevalence up to 100% (Moss et al. 2007). Neither parasite has been specifically identified to cause mortality among any oysters in Asian waters. A group of triploid Suminoe oysters that apparently were infected at low prevalence during a very brief exposure in Virginia waters, however, developed fatal Dermo infections when subsequently maintained under experimental laboratory conditions (Moss et al. 2006). The authors concluded that the stress of being held in an unnatural aquarium environment for 5 months combined with experimental manipulation may have promoted the development of the intense Dermo infections that killed the oysters. Dungan et al. (2007) reported that diploid Suminoe oysters acquired Dermo infections when reared in water from the Chesapeake Bay in Maryland. The findings of most studies suggest that although the Suminoe oyster is susceptible to infection by Dermo, the disease does not cause significant mortality among Suminoe oysters under most conditions, including in high-salinity waters where the disease is most virulent for the Eastern oyster. The Suminoe oyster can generally be characterized as being relatively resistant to Dermo (C. Dungan, DNR, pers. comm.).

In the study reported by Calvo et al. (2000), MSX was absent in Suminoe oysters at all salinities studied (mean salinity ranged from 6.1 ppt to 13.7 ppt). The maximum prevalence of MSX at any field site in one study was 25% for Eastern oysters and 0% for Suminoe oysters. Vasta et al. (2006) found similar patterns in Chesapeake Bay. MSX was not detected in Suminoe oysters from Asia (Moss et al. submitted 2007). Suminoe oysters appear to be highly resistant to MSX at all salinities studied (C. Dungan, DNR, pers. comm.).

The preponderance of findings to date (i.e., the last 6 years) suggests that neither MSX nor Dermo kills Suminoe oysters under most conditions (http://chesapeakebay.noaa.gov/docs/AriakensisQuarterlyReviewSpring2005.pdf). Many of the tests that provided data were field tests of triploids in confined deployments (typically not on-bottom) or diploids grown in laboratory conditions; therefore, no information is available to determine if Suminoe oysters growing on the bottom of the Bay in a potentially stressful environment might experience greater rates of infection or mortality.

Studies to date confirm that the Suminoe oyster is generally resistant to MSX and Dermo over a wide range of salinities.

Faster Growth Rates – A second favorable attribute of the Suminoe oyster is its rapid growth. The Suminoe oyster's rapid accumulation of biomass may contribute to reproductive development that is earlier and results in greater fecundity than the reproductive development of the Eastern oyster (Section 4.2.2.2 of Appendix B), which could hasten the growth of a population. Information on growth rates of Suminoe oysters is available from trials with sterile triploids in the Bay and from studies of diploids in the laboratory. During indoor mesocosm studies that used ambient water from the Choptank River in Maryland (Newell 2005), diploid Suminoe oysters and diploid Eastern oysters held in single-species treatments grew (i.e., the length of their shells increased) at similar rates during the summer, within 3 months after settlement; however, at 3 to 6 months and 6 to 9 months after settling, Suminoe oysters grew up to 9 times faster (1.8 mm^2/day and 0.85 mm^2/day) than Eastern oysters (0.2 mm^2/day and 0.1 mm^2/day). Diploid Suminoe oysters also appear to reach reproductive maturity earlier. After one year of growth in a mesocosm, 67% (16 of 24) of the Suminoe oysters sampled had numerous male follicles containing sperm; however, no gametogenesis was observed among Eastern oysters of similar age (Newell et al. 2008).

Preliminary data indicate that diploid Suminoe oysters grew nearly twice as fast and reached sexual maturity earlier than Eastern oysters in a mesocosm study.

Triploid forms of both oyster species grow faster than diploids because energy that would be allocated toward gonad development in diploids is shunted to growth in triploids. Harding (2007) studied the growth of triploid Suminoe and Eastern oysters in a flume fed with unfiltered water from the York River. Triploid Suminoe oysters grew faster, attaining the Virginia market size of 76 mm in 1.1 years compared to 1.2 years for triploid Eastern oysters. Similar patterns were found in field trials in Chesapeake Bay to evaluate the commercial potential of each oyster; triploid Suminoe oysters outgrew triploid Eastern oysters at all sites (Allen and Hudson 2007; Allen 2008). This pattern was most notable on the York River, where Suminoe oysters measured 180 to 190 cm in shell height[2] after 2.5 years, and Eastern oysters were 110 to 120 cm long (Paynter et al. 2008). In studies comparing the growth rates of disease-resistant triploid Eastern oysters and triploid Suminoe oysters from 10 farms in the VSC, triploid Suminoe oysters experienced cumulative growth similar to that of Eastern oysters (40-60 mm v. 40-45 mm) despite having been deployed 2 to 3 months after the Eastern oysters (Allen and Hudson 2007; Allen 2008). Those studies also showed that triploid Suminoe oysters (55 mm) outgrew triploid (38 mm) and diploid (30 mm) Eastern oysters during a period of 8 to 10 months (averaged across 9 sites).

The Suminoe oyster grows over a greater portion of the year than the Eastern oyster.

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[2] The term "shell height" is used to refer to the length of the oyster shell from hinge to front edge.

Growth of the two species also differed seasonally. For Eastern oysters, 50% of growth occurred during the summer. The growth of Suminoe oysters was distributed more evenly across seasons (Allen and Hudson 2007; Allen 2008).

VSC trials with Suminoe oysters provided a substantial amount of additional growth data. The VSC distributed 100,000 triploid Suminoe oysters and 10,000 triploid Eastern oysters to each of 8 participants in the fall of 2003. Salinity varied among the locations, and growth tended to increase with salinity (Woodworth et al. 2005). After 18 months at low salinity, the average shell height of Suminoe oysters was between 83 and 89 mm, and triploid Eastern oysters measured from 51 to 75 mm. Average shell height at medium salinity was 88 to 125 mm for Suminoe oysters and 70 to 75 mm for Eastern oysters. At the highest salinity, Suminoe oysters measured 140 to 161 mm, and Eastern oysters measured 78 to 88 mm. The Eastern oysters grew most during the summer, but the Suminoe oysters grew consistently throughout the fall, spring, and summer. The greatest meat weight was observed at the highest-salinity sites, where meat weight ranged from 4 to 14 g for Eastern oysters and from 20 to 72 g for Suminoe oysters.

Triploid Suminoe oysters grow faster than diploid and triploid Eastern oysters across a gradient of salinity; the greatest difference in growth rate is apparent at higher salinities.

Luckenbach et al. (2008) studied on-bottom growth of caged triploid Eastern and Suminoe oysters in four Chesapeake Bay tributaries with varying salinities: the Machipongo and York rivers in Virginia and the Patuxent and Severn rivers in Maryland. Growth rates among the Eastern oysters were similar in the York, Patuxent, and Severn rivers (40-50 mm shell height after 8 months) but lower at the intertidal site in the Machipongo River (20-30 mm). The rate of growth among Suminoe oysters increased with increasing salinity (again with the exception of the intertidal site), and the fastest growth was observed at the site with the highest salinity (i.e., York River, 70-80 mm after 8 months). Although Suminoe oysters grew faster than Eastern oysters at most sites (e.g., Patuxent River, 90-100 mm for Eastern oysters and 100-110 mm for Suminoe oysters after nearly 2 years), the growth rates of the two species were most similar at the site with the lowest salinity (i.e., Severn River, 100 mm for both after nearly 2 years). Field studies in North Carolina estuaries showed that Suminoe oysters do not grow at salinities of less 10 ppt (Grabowski et al. 2004; Peterson 2005). At intermediate salinities ranging from 15 to 25 ppt, Suminoe oysters grew 24.5% faster than Eastern oysters, but the two species had similar survivorship rates (Grabowski et al. 2004). In contrast to the results of the studies in the Chesapeake Bay, Scarpa et al. (2008) showed that, in a subtropical environment, 1- to 2-year old diploid Suminoe oysters of the 2004 cohort had an instantaneous growth rate similar to that of Eastern oysters of the same cohort, except in December, when instantaneous growth of Eastern oysters was greater.

Growth rates of both species decline with increasing densities of settlement.

Relative growth patterns of Eastern and Suminoe oysters differ when space is limited, as illustrated in a series of studies conducted near Belle Island, Virginia (Luckenbach 2006). Oysters were grown in outdoor, flow-through aquaria at constant densities (1, 10, 20, and 50 spat per 100 cm^2) but varying proportions of each species. Growth was measured as increasing biomass (i.e., milligrams of ash-free, dry weight of tissue), and the superior competitor for space was defined as the species that grew faster during the 6-month study. In single-species assemblages, the growth rates of both species declined as density increased, but diploid Suminoe oysters (0.39 mg/day) grew even more slowly than diploid Eastern oysters (0.51 mg/day). Growth rates of both species declined even further when they were grown together. This pattern was particularly strong at high densities. For example, when 25 oysters of each species were grown together on a 100-cm^2 tile, Suminoe oysters grew at the rate of approximately 0.22 mg/day and Eastern oysters at 0.28 mg/day (Luckenbach 2006).

The preponderance of studies confirm that the Suminoe oyster grows faster than the Eastern oyster in high-salinity waters and that the faster growth rate is attributable, in part, to continuing to grow over a longer portion of the year. The Suminoe oyster's growth rate "advantage" is not as apparent at lower salinities. Disease affects growth rates, and the disease resistance of the Suminoe oyster could have contributed to the growth patterns observed in some comparative studies. If their faster rate of growth causes Suminoe oysters to reach sexual maturity earlier than Eastern oysters, as suggested in the mesocosm studies, the Suminoe oyster could have a shorter generation time that would contribute to more rapid population growth than is typical for the Eastern oyster.

Relative Settlement Success – The mortality of Suminoe oyster larvae after settlement appears to be lower than for Eastern oyster larvae. Newell et al. (2008) found that mortality during the period following settlement was lower among Suminoe oysters (55%) than among Eastern oysters (80%) in a mesocosm setting, even though predation pressure (from flatworms, but in the absence of crabs) was about the same. Greater survival of Suminoe spat would favor the success of a population of Suminoe oysters in the Bay.

Tolerance to Salinity – Preliminary evidence indicates that the Suminoe oyster is capable of growing and reproducing over the same wide range of salinities as the Eastern oyster (5 to 35 ppt; NRC 2004). The species would be capable of becoming established at all existing oyster habitat in the Chesapeake Bay, which would favor the success of an introduction. In experiments in hatcheries in Maryland and Virginia, Suminoe oysters spawned at salinities from 5 ppt (only a single male) to 20 ppt. No spawning occurred at 27 ppt, and no tests were done at salinities between 20 and 27 ppt (Merritt et al. 2007). Breese and Malouf (1977) studied growth of spat at salinities ranging from 10 to 30 ppt. They found that the growth rate at 20 ppt was twice the growth rate at 10 and 30 ppt. Laboratory studies by Langdon and Robinson (1996) showed that salinities of 15 and 20 ppt resulted in the highest number of larvae setting on substrate. Larval setting was lower at 25 to 30 ppt set, and no larvae set at 35 ppt. They did not test setting at salinities less than 15 ppt.

4.1.1.2 Factors that Could Constrain the Success of an Introduction

Habitat Availability – Sediment that is washed into the Chesapeake Bay can cover reefs or other hard-bottom substrates, thereby reducing the amount of available habitat upon which oyster larvae can settle (Smith et al. 2005). Another significant factor contributing to habitat loss is deterioration of old oyster shell. In preliminary analysis of data from the James River, Mann (2007a) found that the annual rate of shell loss from 1999 to 2006 was on the order of 20%; rates during some years were as high as 30% to 50%. Old shell deteriorates as a result of disarticulation, bioerosion, breakage, and dissolution (Powell et al. 2006). Sedimentation and deterioration of shell together are reducing existing hard-bottom habitat in Chesapeake Bay faster than the remaining population of Eastern oysters can produce new shell. The result is a severe and continuing decline in the area of suitable habitat for settlement of oyster larvae.

Oyster grounds in Chesapeake Bay once encompassed more than 450,000 acres. The Yates Survey (1911) and the Maryland Bay Bottom Survey (1985) charted about 215,000 acres of historic oyster grounds in Maryland. The Baylor Survey (1894) charted 243,000 acres of historic oyster grounds in Virginia. Only about half of those historic oyster grounds are believed to have been productive oyster habitat because the original reefs were interlaced with patches of mud and sand. New acoustic techniques for surveying the bottom of the Bay suggest that less than 1% of Maryland's historic oyster grounds can be classified as clean or lightly sedimented shell. Most of the substrate that is suitable for settlement of oyster larvae is within areas where the State has planted shell recently. The recent rate of decrease in the area of oyster habitat in the Bay and the methods for deriving that estimate are described in Attachment 1 of Appendix A. Between the Maryland Bay Bottom Survey (1978 to 1983) and recent surveys (1999 to 2000; Smith et al. 2005), the amount of habitat on sampled bars had declined by nearly 70%, or about 3.5% per year. The current (2004) area of oyster habitat in the Bay is estimated to be 76,030 acres (Attachment 1 of Appendix A). Assuming that the rate of loss on the 18 bars sampled between 1999 and 2001 is representative of the rate of loss of habitat throughout the Bay, approximately 2,661 acres are lost each year. There is no reason to believe that this rate of decrease has slowed.

Sedimentation and deterioration of old shell are reducing oyster habitat in Chesapeake Bay faster than the remaining population of Eastern oysters can produce new shell. Oyster habitat in the Bay is decreasing at an estimated rate of 3.5% (about 2,700 acres) per year.

Oyster larvae settle on clean shell at much greater rates than on shell that has deteriorated or been covered with silt. Smith et al. (2005) demonstrated that the effectiveness of replenishing shell (i.e., habitat rehabilitation) for increasing oyster recruitment declines over time. They found that the spaces between shell deployed on the bottom were covered with sediment after only 5.5 years, and conditions in replenished areas were nearly identical to those on adjacent, untreated bars. This pattern could limit the effectiveness of effort to rehabilitate habitat unless the new shell is colonized by spat and a growing oyster population produces new shell faster than the local rate of sedimentation.

The benefits of planting shell to rehabilitate habitat are temporary and short-lived unless the new shell is colonized by spat, and oyster growth is substantial.

The continuing loss of oyster habitat in the Bay will decrease the area of settlement substrate available to the progeny of introduced Suminoe oysters, which could limit the magnitude and geographical extent of expansion of an introduced population.

The continuing loss of hard-bottom habitat is an overarching constraint on the likelihood of increasing the oyster population in Chesapeake Bay, whether by introducing the Suminoe oyster or by implementing any of the other alternatives evaluated in this Draft PEIS. The consequence of the continuing loss of habitat for the success of the proposed action is that progeny of introduced Suminoe oysters would have decreasing amounts of hard substrate on which to settle, which could limit the magnitude and geographical extent of any expansion of the introduced population. Once established, a population of Suminoe oysters might enhance the availability of shell substrate for both species of oyster because of its potentially greater survival and faster growth rate. Mann and Powell (2007) noted, however, that the longevity of Suminoe oyster shell in the Chesapeake Bay is not known; furthermore, the time required for the rate of shell production by an introduced population of Suminoe oysters to exceed the rate of habitat loss cannot be estimated.

Genetic Bottleneck – The reduced genetic diversity of the Chesapeake Bay stock of Suminoe oysters (Section 2.3.1) could adversely affect the species' ability to survive and prosper over the long term in the variable environment of Chesapeake Bay. Wild populations generally contain individuals with a wide range of genetic traits that are the product of many generations of natural selection in a dynamic environment. Such genetic diversity allows some individuals to survive changes in environmental conditions or exposure to pathogens, even if those events cause large-scale mortality. Lack of genetic diversity can negatively affect the viability of a population because the small founder population may not carry all of the traits needed to survive extreme changes in environmental conditions over the long term. Insufficient genetic diversity could reduce the ability of the Suminoe oyster population to adapt to novel conditions after the species has become established; that is, the small size of the founder population could cause an introduced population to fail many years after an apparently successful introduction. The stock of Suminoe oysters held at VIMS hatchery, which is descended from the Oregon stock, showed some reduction in genetic variation and diversity in comparison to wild specimens, which is consistent with the concept of a genetic bottleneck (Section 2.3.1). Loss of genetic variability among stocks of aquaculture species that have been isolated from natural populations can occur even in the first hatchery generation (Verspoor 1988). This is probably due to the relatively small number of parents used for spawning in hatcheries (Reese and Allen 2004). Similar results were reported by Zhang et al. (2005).

The reduced genetic diversity of Suminoe oysters descended from the Oregon stock may make an introduced population vulnerable to environmental fluctuations in Chesapeake Bay and decrease the probability of success of the proposed action.

No data are available to support or refute this concern; however, if a genetic bottleneck exists, it could decrease the probability of success of an introduction effort. Additional individuals could be imported from China to resolve this issue, if the imported oysters could meet the requirements of ICES protocol as specified in the proposed action. Zhang et al (2005) suggested that results of their studies of the genetics of the Suminoe oyster reinforce the need to supplement hatchery stocks regularly with new stock from wild populations to maintain genetically healthy hatchery stocks and avoid inbreeding depression and the loss of genetic variability. The number of additional oysters required to reduce the potential of a genetic bottleneck and the origin of those oysters has not been determined.

Response to Low Dissolved Oxygen – Dissolved oxygen in the water column is essential for respiration, and estuarine species exhibit a range of vulnerability to decreasing concentrations of dissolved oxygen (i.e., hypoxia). Juvenile Suminoe oysters are much more vulnerable than juvenile Eastern oysters to hypoxic and anoxic conditions. Prolonged exposure (144 hours) to anoxic water caused 100% mortality of Suminoe oysters but only 51% mortality of Eastern oysters (Matsche and Barker 2007). Similar patterns were observed after 192 hours of exposure

The Suminoe oyster's relative inability to tolerate hypoxia suggests that the species might not be able to colonize some areas of available substrate in deeper waters of the Bay.

to decreasing levels of dissolved oxygen. These studies were conducted in warm water (30°C), which holds less oxygen in solution; therefore, the studies represent worst-case scenarios. A study by Harlan and Paynter (2007) found similar differences in hypoxic mortality between Eastern and Suminoe oysters at temperatures of 10°C and 20°C. In another study, Suminoe oysters exhibited greater mortality than Eastern oysters at oxygen saturations of 0%, and in treatments in which oxygen saturation decreased from 20% to 13%, and from 10% to 6% (Matsche and Barker 2007). The researchers attributed species-specific differences in tolerance for hypoxia to the tendency of Suminoe oysters to gape (i.e., allow their shells to remain open) during hypoxic or anoxic conditions. Eastern oysters were able to keep their shells closed under those conditions. This difference between the two species suggests that the Suminoe oyster might not successfully colonize some areas of suitable substrate located in deeper waters in the Bay, where intermittent hypoxia is common.

Response to Exposure at Low Tide – Sessile organisms living at the margin of the land-sea interface are faced with a unique set of challenges. There, in the intertidal zone, organisms spend part of the day under water and part of the day exposed to air in an alternating cycle that is determined primarily by the gravitational pull of the moon. The duration and amplitude of this diurnal cycle varies throughout the month. During high tide, submersion in water provides access to food for suspension-feeding bivalves such as oysters but also increases susceptibility to aquatic predators, such as blue crabs and oyster drills. Exposure to the air during low tide means separation from their only food source and exposure to the heat and desiccation of the sun and to non-aquatic predators, such as birds.

The Suminoe oyster's vulnerability to stress in intertidal conditions could limit its success in colonizing the limited portion of the Bay's oyster habitat that is in the intertidal zone.

A series of experiments examined relative rates of survival and growth of Suminoe oyster spat and Eastern oyster spat under simulated intertidal conditions during the spring (Luckenbach and Kingsley-Smith 2006). Suminoe oysters grew about 17% faster than Eastern oysters at subtidal elevations and survived well only in the subtidal during the 5-week experiment. This is consistent with natural patterns of distribution in the native habitat of the Suminoe oyster in China, where it is limited to subtidal habitats (Guo et al. 2007). Overall, Eastern oysters exhibited greater rates of survival than Suminoe oysters in both the intertidal and subtidal zones (Luckenbach and Kingsley-Smith 2006). A field experiment conducted by Bishop and Peterson (2006) found that faster growth in a subtidal environment was evident, but only during the winter. During the spring, triploid Suminoe oysters grew 34% faster (initial size = 29.9 mm) in the intertidal zone than in the subtidal zone. Bishop and Peterson concluded that the difference was due to the lower incidence of fouling in the intertidal (21%-38% of shells fouled) than in the subtidal (94% of shells fouled). Fouling by other suspension feeders evidently reduced the growth of Suminoe oysters in the subtidal zone through localized competition and increased energetic costs, illustrating that factors beyond simply presence in intertidal or subtidal areas can affect how Suminoe oysters may respond.

Luckenbach et al. (2008) compared the survival of caged spat on shell of both species deployed on the bottom at an intertidal site. The starting density of both species was approximately 400 oysters/m^2. After 10 months, they found that the density of live oysters ranged from 0 to 50/m^2 for triploid Suminoe oysters and from 50 to 100/m^2 for triploid Eastern oysters at the intertidal site. Survival of both species was greater at the subtidal sites (100-250 survivors/m^2 and 150-300 survivors/m^2 for Suminoe and Eastern oysters, respectively). The authors attributed mortality at all sites for both species to early post-settlement predation and handling stress. Growth was reduced at the intertidal site, where mean shell height was 80 to 90 mm for triploid Suminoe oysters and 50 to 60 mm for triploid Eastern oysters after 10 months. This reflects slower growth than at the subtidal sites, where mean shell height ranged between 90 and 110 mm for Suminoe oysters and between 90 and 100 mm for Eastern oysters. The authors attributed growth differences to reduced opportunity for feeding and physiological stress associated with living in the intertidal zone. Although the total area of oyster habitat in intertidal portions of Chesapeake Bay is very limited, the Suminoe oyster's vulnerability to stress in those areas could limit the species' success in that proportion of the Bay's oyster habitat.

Reproductive Interference due to Gamete Competition with the Eastern Oyster – Spawning interactions between Suminoe and Eastern oysters could adversely affect the growth and dispersal of an introduced population of the Suminoe oyster. The time of spawning of the two oyster species overlaps, and each species appears to be able to induce the other to spawn. Oysters are broadcast spawners, and their gametes commingle and fuse in the water column. If two species from the same genus spawn synchronously in the same location, their gametes may fuse and develop into hybrid offspring. This creates a situation in which the gametes of one species compete with those of another species for its own opposite-sex gametes. About 10 times more sperm is needed to successfully fertilize a congeneric than a conspecific; consequently, the likelihood of cross-fertilization decreases as gametes are diluted. Although gametes of Suminoe and Eastern oysters can form hybrid offspring, they are not viable and die after 8 to 10 days (Allen et al. 1993; Meritt et al. 2006). The result is a net loss of functional gametes and a potential population-level reproductive loss called a "gamete sink."

If both species occur on a bar, reproductive interference could constrain the growth of an introduced population of Suminoe oysters.

Eastern oysters may have a small advantage over Suminoe oysters in gamete competition. In laboratory studies, Eastern oyster sperm were more likely to fertilize Suminoe oyster eggs than vice versa (Bushek et al. 2007). Yet for Eastern oysters, the gamete sink still reduced the rate of fertilization by conspecifics in this study by as much as 50% (Bushek et al. 2007). The population that is locally more abundant, which would be the Eastern oyster on all bars except those where Suminoe oysters were planted, would have a greater effect on the smaller population because of the greater number of gametes produced; therefore, Suminoe oysters would have an advantage on the bars where they are introduced and would be disproportionately negatively affected on bars to which the population dispersed during the initial stages of an introduction program. This situation would reverse only if the Suminoe oyster population were to become much larger than the Eastern oyster population. The faster growth rate of the Suminoe oyster could be important because fecundity increases with size among oysters. Gregarious setting behavior could increase the likelihood of reproductive interference between the species because young oysters that are likely to be male would be attached to older adults that are likely to be female. Given the many factors that could influence spawning success, it is not possible to predict how these interactions would affect the population of either species over time, or the extent to which this phenomenon could constrain the rate of growth of an introduced population of the Suminoe oyster (Section 4.2.2.3 of Appendix B).

Competition with the Eastern Oyster for Food – Oysters are suspension-feeding bivalves that filter organic particles, primarily phytoplankton, from the water column (Newell and Jordan 1983). Suspension-feeding bivalves possess the ability to sort captured particles and select which particles to ingest (Jorgensen et al. 1986). Rejected particles may be deposited as pseudofeces on the bottom. In-depth studies have examined the diet and particle-selection behavior of the Eastern oyster (Newell and Jordan 1983; Shumway et al. 1985); however, no similar field or laboratory studies have been conducted to identify the Suminoe oyster's preferred diet, the size or biovolume of phytoplankton it typically consumes, or its ability to take up other suspended solids (e.g., bacterioplankton). Laboratory studies conducted for aquaculture purposes have found that Eastern and Suminoe oysters consumed similar algal diets (diatoms and flagellates) provided in culture (Langdon and Robinson 1996).

The availability of food is unlikely to be a limiting factor for the growth of the Suminoe oyster population, except on a very local scale.

A whole host of factors can influence feeding rates, including oyster size, water temperature, salinity, dissolved oxygen concentration, algal concentration, and algal nutritional quality (Cerco and Noel 2005b and references therein). Preliminary laboratory experiments indicated that size-specific filtration rates are similar among Eastern and Suminoe oysters grown at ambient seston levels (8-12 mg/l) and 23ºC (NRC 2004, pers. comm. from Newell cited in Bean et al. 2006). This is consistent with previous reports that size-specific filtration rates are similar for most marine bivalves (Powell et al. 1992).

The amount of food available to oysters in the Bay as a whole is unlikely to limit populations in the near future because of nutrient enrichment (i.e., eutrophication) caused by development within the watershed; however, the concentration of phytoplankton in the Bay is spatially and temporally patchy, which could lead to different growth patterns for oysters located in different parts of a bar or basin. Suminoe oyster larvae that set on bars occupied by larger and more abundant Eastern oysters could experience some degree of competitive disadvantage in using available food resources, which might constrain their growth.

Relative Response to Harmful Algal Blooms – The two species appear to respond somewhat differently to harmful algal blooms (HABs); the Suminoe oyster appears to be adversely affected by some species of algae that do not adversely affect the Eastern oyster. Harmful algal blooms in Chesapeake Bay are composed of different species that proliferate under particular environmental conditions. Spawning of Eastern oysters in the Bay coincides with the time during which two species of "bloom algae," *Karlodinium veneficum* and *Prorocentrum minimum*, are most abundant. *K. veneficum* is most abundant at salinities between 7 and 17 ppt and at surface water temperatures greater than 13ºC, although it can occur over a salinity range of 3 to 29 ppt and a temperature range of 7ºC to 28ºC

Suminoe oysters appear to be more vulnerable than Eastern oysters to the adverse affects of some bloom algae in the Bay.

(Li et al. 2000). *P. minimum* can grow over wide gradients of temperature and salinity but is most abundant between 12ºC and 22 ºC and 5 to 10 ppt salinity (Tango et al. 2005). Gilbert et al. (2008) studied new shell growth of spat being fed different algal diets during a period of 96 hours. Eastern oyster spat grew 1.3 to 1.4 mm when feeding on *P. minimum* compared to Suminoe spat, which grew only 0.9 to 1.0 mm (Gilbert et al. 2008). Similarly, Brownlee (2006) showed significantly greater growth rates for Eastern oyster spat compared to Suminoe oyster spat exposed to either *P. minimum* or *K. veneficum*. Acute toxicity tests carried out by Gilbert et al. (2007) looked at mortality rates for new, naturally spawned larvae after 48 hours of exposure. Both Eastern and Suminoe oysters suffered greater mortality (60% to 80%) when exposed to either *P. minimum* or *K. veneficum* compared to controls. Both oysters also experienced structural deformation in the larval phase when exposed to *K. veneficum*. Gilbert et al. (2008) examined the swimming behavior of 2-week-old larvae grown on different species of bloom algae for 72 hours. They found that a diet of *P. minimum* caused 65.4% of 2-week-old Suminoe oyster larvae to stop swimming and settle to the bottom; the swimming behavior of Eastern oyster larvae did not appear to be affected. The viability of the larvae that ceased swimming was not determined. Neither species of oyster exhibited swimming behavior when exposed to *K. veneficum*.

Predation – Juvenile Suminoe oysters appear to be somewhat more susceptible to predators than juvenile Eastern oysters. Nonnative species will encounter an entirely new suite of predators in a new environment. Likely predators of Suminoe oysters in Chesapeake Bay include blue crabs, mud crabs, drills, flatworms, seastars, ctenophores, and some species of birds and fish, such as cownose rays (Newell et al. 2007a) and oyster toadfish (*Opsanus tau*). The greater susceptibility of the Suminoe oyster to predation by crabs is due to its weaker shell. The shell compression strength of Suminoe oyster shell is 64% less than that of Eastern oyster shell. The Suminoe oyster's weaker shell makes it more vulnerable to shell-penetrating predators (Bishop and Peterson 2005; Newell et al. 2007a), which could limit the growth of a population of Suminoe oysters. In laboratory assays, predation by blue crabs, which are found in all salinity zones throughout the Bay, caused 74% mortality among Suminoe oysters compared to 45.9% mortality among Eastern oysters (Newell et al. 2007a). Similar patterns were found for predation by 4 species of mud crab, which caused an average of 56.3% mortality among Suminoe oysters and 29.7% mortality among Eastern oysters (Newell et al. 2007a). Size selectivity by blue crabs affects rates of predation on the oyster species (Bishop and Peterson 2006). Blue crabs consumed 3 times as many Suminoe oysters as Eastern oysters in the 25-mm shell-height size class and 8 times as many in the 35-mm size class. Blue crabs preferred small Suminoe oysters over large ones, except when large Suminoe oysters (40 mm) were paired with small Eastern oysters (30 mm). In these trials, blue crabs consumed 7 times more large Suminoe oysters than small Eastern oysters (Bishop and Peterson 2006).

> Juvenile Suminoe oysters appear to be somewhat more susceptible to predators than juvenile Eastern oysters.

Mortality due to flatworm (*Stylochus ellipticus*) predation was similar among Suminoe and Eastern oysters, averaging 29.8% and 27.9%, respectively (Newell et al. 2007a). Predation by drills (*Urosalpinx cinerea*) was studied using Y-maze choice studies to determine if the chemical cues emitted by Eastern and Suminoe oysters attract predators differentially (Kennedy and Newell 2008). Drills were pre-conditioned by being fed a diet of either Eastern or Suminoe oysters. Drills were then allowed to choose to move toward water treated with effluent of either Eastern or Suminoe oysters. The study found that drills that were preconditioned with Eastern oysters subsequently tended to prefer water treated with Eastern oysters (Kennedy and Newell 2008). The authors interpreted these results to suggest that drills use chemical cues to track their prey, and that, if the species occur together, drills will be a more important predator of the native species. Similar Y-maze choice studies preconditioned seastars by exposing them to effluent of either Eastern or Suminoe oysters. The seastar *Asterias forbesii* preferentially selected Eastern oysters when offered a choice in laboratory assays, but in the Y-maze choice study, *A. forbesii* showed no significant preference for the effluent of either oyster species (Kennedy and Newell 2008).

Preliminary findings suggested that the ctenophore *Mnemiopsis leidyi* preys upon 10- to 13-day post-hatch larvae of the Suminoe oyster at a rate 50% greater than the rate at which it preys upon Eastern oyster larvae of the same age (Breitburg et al. 2007). The authors postulated that their results may not reflect selectivity by ctenophores, but rather the Eastern oyster's greater ability to evade predation or the similarities between Suminoe oysters and ctenophores in vertical distribution in the water column. Ctenophores have been estimated to consume an average of 10% to 25% of the oyster larvae available through the summer, and may be able to consume as much as 40% to 100% locally at peak ctenophore densities (Breitburg and Fulford 2006).

The faster growth rate of the Suminoe oyster could enable juveniles to reach larger sizes at which they are less susceptible to predation faster than Eastern oysters can. No studies to date, however, have investigated whether the positive effect of a higher growth rate would be sufficient to balance the negative influence of early susceptibility to predation. Suminoe oysters also would be susceptible to predation by cownose rays, but their relative vulnerability compared to Eastern oysters' vulnerability is not known.

Susceptibility to Diseases other than Dermo and MSX – Suminoe oysters growing in Chesapeake Bay could be susceptible to new pathogens that might invade Chesapeake Bay at some time in the future. One such example is *Bonamia*, a blood parasite known to infect and even decimate oyster populations in Australia, New Zealand, Europe, and North America. Recently, this parasite appeared in the mid-Atlantic of the United States, first around Cape Hatteras and subsequently expanding into other portions of North Carolina and southern Florida. Hatchery-reared Suminoe oysters transplanted to North Carolina for controlled field trials had both high rates of infection with *Bonamia* and high mortality rates among individuals of 40 to 50 mm in shell height (Burreson et al. 2004; Bishop et al. 2006; Carnegie et al. 2008). Forty-seven percent of Suminoe oysters deployed into Bogue Sound, North Carolina, became infected with *Bonamia*; however, no Eastern oysters from Bogue Sound were infected, suggesting that the native oyster is resistant to this disease (Burreson et al. 2005). Carnegie et al. (2008) noted that the effects of *Bonamia* on Suminoe oysters may be greatest at salinities of 25 ppt or more, and moderate to high at 22 to 25 ppt. Only at salinities of 18 ppt or less are researchers confident that the effects of *Bonamia*

Suminoe oysters are highly vulnerable to the disease organism *Bonamia*. If *Bonamia* becomes established in Chesapeake Bay, it could preclude Suminoe oysters from colonizing bars in high salinity areas or decimate established populations in those areas.

would be minimal. In general, infections occur at water temperatures greater than 20ºC to 25ºC and salinities greater than 25 ppt (Bishop et al. 2006; Burreson et al. 2005).

Vasta et al. (2007) reported detecting *Bonamia* in a small number of triploid Suminoe oysters in the York River; however, G. Burreson of VIMS indicated that his group has examined 1,930 triploid Suminoe oysters from VIMS' hatchery on the York River both by polymerase chain reaction (PCR) and by histology over the last seven years and has never seen *Bonamia*. Researchers at VIMS have examined many large triploid Suminoe oysters for the VSC field trials with similar negative results. Vasta's group used PCR only and did not confirm infections by histology; therefore, the findings are considered questionable (G. Burreson, VIMS, pers. comm.) If *Bonamia* were to become established in Chesapeake Bay, *Bonamia* infections could preclude Suminoe oysters from colonizing polyhaline waters (18 to 30 ppt salinity) in Virginia and Maryland. Only 3% of Maryland's oyster bars are in polyhaline waters, but about one third of Virginia's bars are in such salinities. The appearance of *Bonamia* in Chesapeake Bay, therefore, would have a disproportionate effect on Suminoe oysters in Virginia waters.

Studies along the coast of China revealed natural patterns of disease prevalence in habitats where the Suminoe oyster is native. Bushek et al. (2008) screened 1,295 oysters from this region using standard histology, immunologically enhanced histological methods, and PCR assays to identify a guild of parasites infecting the Suminoe oyster and other oyster species. No *Bonamia* parasites were detected, but species of *Perkinsus* and *Haplosporidium* were found. The haplosporidians generally were rare, reacted positively to the PCR primers for *Haplosporidium nelsoni*, and were detected across a broader latitudinal range than has been observed for this species in North America. *Perkinsus* spp. also were detected across a broad latitudinal range; prevalence generally was low but reached 40% at one site. Other diseases that might affect oysters in Chesapeake Bay if nonnative oysters were to be introduced without following ICES protocols included a herpes-like virus (OsHV) and fungal shell disease (NRC 2004; Reece et al. 2008). Although OsHV is prevalent in oysters collected from Asia, this disease was not present in any oysters sampled from hatcheries in the United States (Reece et al. 2008). The OsHV virus may remain latent and undetectable for up to 6 months (Reece et al. 2008). Another oyster species, *C. hongkonensis*, collected from southern China was able to transmit the OsHV virus to a prevalence of 3.3% (2/60) among diploid Suminoe oysters and 4.0% (1/25) among triploid Suminoe oysters; Eastern oysters were unaffected (Reece et al. 2008). A trial in Chesapeake Bay found that Suminoe oysters were much more susceptible to fungal shell disease than Eastern oysters; 90% of Suminoe oysters were infected compared to 20% of Eastern oysters (Fisher 2003).

The NRC did not consider the issue of whether a population of Suminoe oysters in Chesapeake Bay could lose its resistance to MSX and Dermo over time, possibly due to mutation of the disease-causing organisms. Such a phenomenon has never been reported in the literature and would appear to be unlikely; moreover, a host species is equally likely to mutate or experience selection that would lead the population to develop resistance to a new disease.

Another common condition called mud blisters occurs when the mud worm (*Polydora* spp*)* bores holes into oysters' shells. The holes fill with mud, and the infected oyster covers the mud-filled holes with new shell material, causing blisters. Mud worms are found along the Atlantic and Gulf coasts of the United States in subtidal areas and live in the shells of oysters and other mollusks (Haigler 1969). The two main species in this range are *Polydora websteri* and *P. ligni* (White and Wilson-Ormond 1996). Mud worms do not kill oysters directly; however, heavily infested oysters may expend more energy on repairing their shells than they spend on growth, reproduction, and feeding, resulting in poorer health, greater susceptibility to disease, and increased mortality among an infested oyster population (Owen 1957; Larsen 1978; Korringa 1952). At low rates of infection, mud blisters can reduce the marketability of oysters. At high rates of infection, mud blisters can diminish shell integrity, increase vulnerability to predation by crabs and gastropods (Skeel 1979), and increase the rate of mortality (Wargo and Ford 1993; Calvo et al. 2000). *Polydora* infections occur at low to intermediate salinities; however, the upper end of *Polydora*'s salinity range has not been determined. Both Suminoe and Eastern oysters can become infested with *Polydora* (Calvo et al. 2000; Grabowski et al. 2004; Bishop and Hooper 2005; Paynter 2007). Suminoe oysters' shells are thinner and less dense than those of Eastern oysters; consequently, Suminoe oysters tend to suffer greater damage as a result of *Polydora* infections, exhibiting more blisters and knobs. In studies of Suminoe and Eastern oysters in Chesapeake Bay, McLean and Abbe (2008) found higher rates of *Polydora* infection among Suminoe oysters than among Eastern oysters, although the rates were not quantified. Paynter (2007) found a significant difference between infected triploid Eastern and Suminoe oysters in the average percent of shell covered with mud blisters; the Suminoe oysters had higher infection rates. Diploid Eastern oysters at one study location, however, had significantly greater percent coverages than triploids of either species. Bishop and Hooper (2005) determined that *Polydora* infestations adversely affected the growth rates of Suminoe oysters to a greater degree than the growth rates of Eastern oysters.

Suminoe oysters appear to be highly vulnerable to the mud worm, *Polydora*, which is found throughout much of the Bay. Infections could increase Suminoe oysters' vulnerability to predation and decrease their market viability.

4.1.1.3 Overview

Evidence that Suminoe oysters are resistant to Dermo and MSX, grow faster than Eastern oysters, and grow fastest at higher salinities is fairly strong. Evidence that the high rate of loss of oyster habitat throughout the Bay is an obstacle to increasing the abundance of any species of oyster in the Bay is equally strong. The Suminoe oyster's vulnerability to predation (particularly by blue and mud crabs), to *Bonamia* in high-salinity waters, and to *Polydora* infestations are all factors that could further limit the potential for introduced Suminoe oysters to establish a self-sustaining population that could restore the ecological and economic functions of oysters in the Bay. The other potentially constraining factors discussed either appear to have lesser consequences or are more speculative. Although many studies of the Suminoe oyster have been conducted over the past five years, all studies done in the field were performed with non-reproductive triploids under

The success of an effort to establish a self-sustaining population of Suminoe oysters in Chesapeake Bay cannot be considered to be certain, and the rate at which an introduced population might grow and disperse throughout the Bay cannot be estimated.

confined conditions, and all studies with diploids were conducted in the laboratory. Neither of these experimental conditions effectively represents how reproductive Suminoe oysters would fare on natural oyster bars in Chesapeake Bay; therefore, available data do not provide a basis for definitively assessing the relative importance of the positive and negative factors. As a result, the probability of success of an implementation plan such as the one defined for this Draft PEIS (Table 4-2) for establishing a self-sustaining population of Suminoe oysters in Chesapeake Bay cannot be considered to be certain, and the rate at which an introduced population might grow and disperse throughout the Bay cannot be estimated. Although the proposed action appears to have potential for attaining the PEIS goal, the likelihood that such potential could be realized is uncertain. Continuing current efforts to restore the Eastern oyster under this alternative is likely to result in some increase in the abundance of Eastern oysters in low-salinity areas in Maryland, as described in Section 4.1.2, but would not contribute significantly to meeting the PEIS goal. Other effects of the proposed action on Eastern oysters are described in Section 4.2.1.

4.1.2 Alternative 1: No Action

Alternative 1 involves continuing Maryland's present oyster restoration and repletion programs, and Virginia's oyster restoration program at about 2004 levels under current program and resource management policies and available funding using the best available restoration strategies and stock assessment techniques (Section 1.3.1 and Attachment 5 of Appendix A). Under this alternative, existing oyster management programs in both states would continue for a period of at least 10 years. Current levels of funding for these programs were assumed to continue during that time. Tables 4-3 and 4-4 summarize spat planting and the amount of habitat rehabilitation, respectively, that would occur under Alternative 1. Existing hatcheries are producing the number of spat specified in this alternative; no new hatchery capacity would be required. Figure 4-1 shows the locations of spat planting and bar rehabilitation throughout the Bay. Since initiation of PEIS preparation, the dredged-shell planting component of Maryland’s repletion program has ceased (C. Judy, pers. comm.); however, DNR is planning to implement new programs that involve reusing previously planted shell. Although the methods of rehabilitating bars might be different than those used in the past, the amount of habitat affected would be similar. Under Alternative 1, harvest in both states would continue under current regulations and seasons.

Table 4-3. Total number of hatchery spat planted, allocation of spat within each management area, and number of acres to be planted annually under Alternative 1.

Region	Number of Hatchery Spat Planted Annually (Millions)	Allocation of Hatchery Spat (Millions)			Number of Acres Planted With Hatchery Spat Annually		
		Sanctuaries	Reserves	Harvest Areas	Sanctuaries	Reserves	Harvest Areas
Maryland	200	40	160		20	160	
Potomac	25			25			25
Virginia	50	50			10		
Bay wide	275	90	160	25	30	160	25

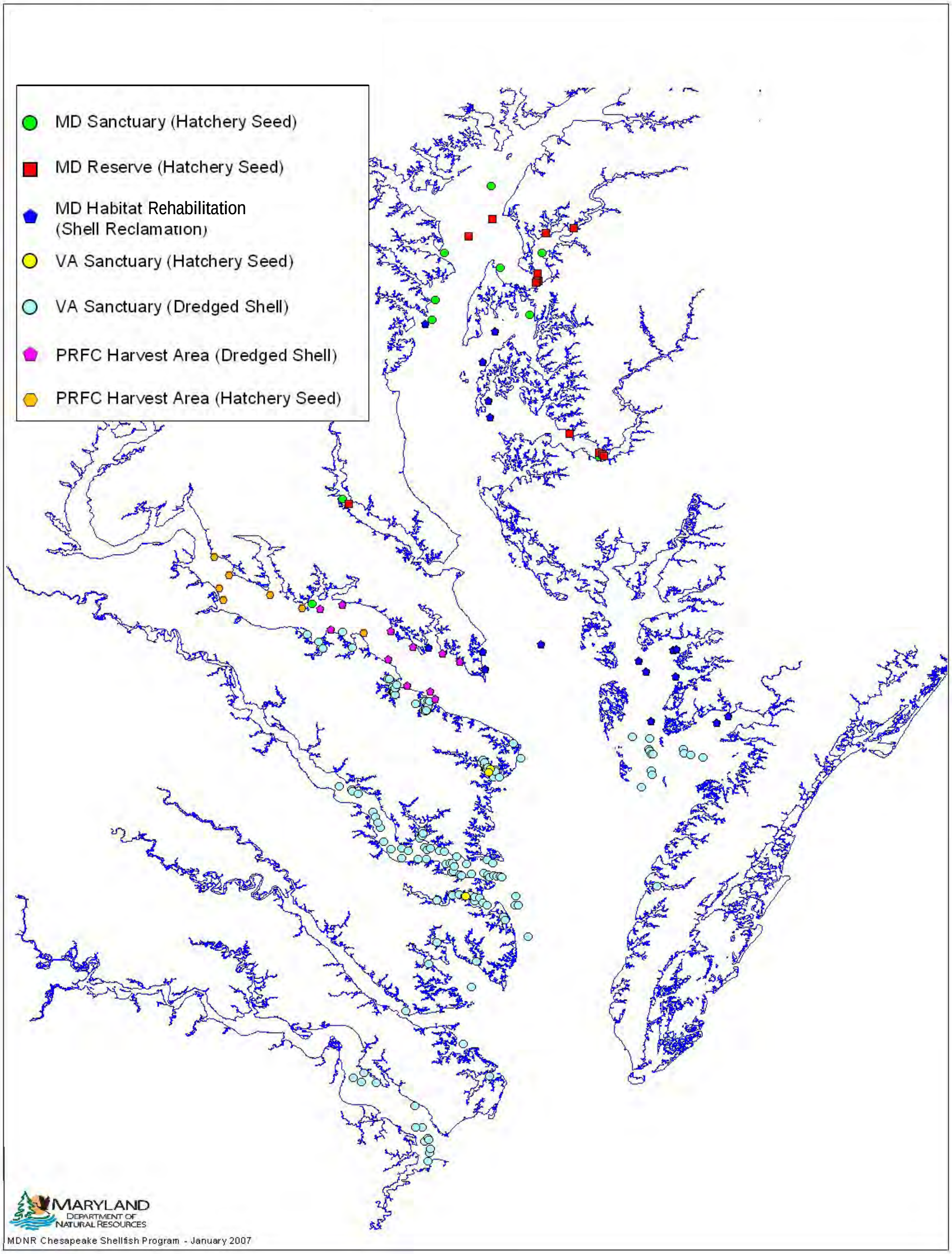

Figure 4-1. Location of plantings of hatchery-raised spat on sanctuaries, harvest reserves, and open-harvest areas, and location of oyster-bar rehabilitation activities for Alternative 1. These actions represent actual current programs, not anticipated programs.

Table 4-4. Acres of oyster bars rehabilitated within each management area and acres restored in sanctuaries, reserves, and open-harvest areas under Alternative 1.

Region	Total Number of Acres of Oyster Habitat Rehabilitated Annually	Number of Acres Rehabilitated Annually		
		Sanctuaries	Reserves	Harvest Areas
Maryland	200	40		160
Potomac	55			55
Virginia	223 to 1,484*	223 to 1,484		

* The area to be rehabilitated annually would vary within this range; a total of 9,500 acres would be rehabilitated in Virginia over 10 years.

The restoration activity assumed under this alternative is representative of restoration activity in recent years, including the period from 1994 to 2004. Figure 1-3 illustrates that restoration programs at that level did not result in an increase in the Bay-wide oyster population and that, in fact, the population decreased. As noted in Section 4.1.1.2, continuing loss of hard-bottom habitat at a rate of about 2,661 acres per year is a major contributing factor in the continuing decline in the oyster population under existing restoration programs. Under what might be considered natural rates of sedimentation and shell loss, healthy and growing oyster populations create their own habitat. Mann and Powell (2007) noted, however, that no accretion and accumulation of shell substrate has been documented in Chesapeake Bay recently. As the population of live oysters decreases, the total space available for settlement of oyster larvae decreases, but the rate of shell loss remains unchanged. Continued harvest under this alternative, although limited in magnitude, would remove additional shell and exacerbate the rate of habitat loss. Neither Maryland nor Virginia have mandatory shell-return policies that would require any oyster shell removed from the Bay to be returned to the water. The topic of shell loss due to harvest is addressed further in Section 4.1.4.

The current restoration programs almost certainly will not result in a Bay-wide increase in the oyster population. Continued harvest under Alternative 1 would remove additional shell and exacerbate the rate of habitat loss.

The current restoration programs almost certainly will not result in a Bay-wide increase in the oyster population; nevertheless, modeling exercises have suggested the possibility of some local increases in oyster abundance in areas of low salinity (i.e., oligohaline regions) in Maryland (Section 6 of Appendix A). This outcome of Alternative 1 could be anticipated for several reasons. First, under current programs, most spat are planted in Maryland on bars in the oligohaline zone. Second, nearly all spat planting in Maryland (excluding the Potomac) is on sanctuaries and reserves, which reduces removal via harvesting. Third, disease-related mortality rates are lowest in the low-salinity zones, so survival rates are higher there. Any such localized population increases would be driven by spat planting because reproduction of oysters is very limited in low-salinity areas; therefore, the increases would not be self-sustaining. Alternative 1 would not result in achievement of the PEIS restoration goal.

The development of resistance to disease within the population of Eastern oysters in Chesapeake Bay could contribute to a somewhat more optimistic assessment of future growth of the population under Alternative 1. Evidence for natural development of resistance to MSX disease among wild oysters is strong in Delaware Bay, where surviving brood stocks are substantially MSX-resistant. Mann and Powell (2007) reported that in Delaware Bay, MSX-susceptible oysters have been practically eliminated from the resident oyster population. Evidence for development of resistance to Dermo disease has been more elusive, even in Delaware Bay (Oyster Disease Workshop 2007). Several generations exhibiting enhanced resistance to Dermo have been demonstrated in artificial selection experiments in the laboratory (Calvo et al. 2003), and some recent data from the James, Lynnhaven, and Great Wicomico rivers have shown that the prevalence of Dermo and the proportion of more serious infections have stabilized or decreased among large, older oysters, suggesting that some level of disease resistance may have developed among those populations (Carnegie 2007 and pers. comm.). No estimates of the time or number of generations that would be required for resistance to Dermo to develop throughout the population of Eastern oysters in Chesapeake Bay are available.

The development of resistance to disease within the population of Eastern oysters in Chesapeake Bay could contribute to a somewhat more optimistic assessment of future growth of the population under Alternative 1.

Under Alternative 1, market-size oysters would be exposed to harvest in unprotected beds; consequently, older animals that survived due to disease resistance would have a high probability of being harvested. Documented events in recent years have raised general concern about illegal harvest of oysters in protected sanctuaries and reserves. Although the potential magnitude of such harvest cannot be estimated, any removal of oysters from protected grounds would further decrease the potential for development of disease resistance over time. Under current restoration programs, however, older oysters that might not be subject to harvest would be present predominately on protected bars in low-salinity waters, where both sustained disease pressure (which contributes to development of disease resistance) and reproductive success would be low; consequently, they would have a low probability of contributing to the geographical expansion of disease resistance to high-salinity areas.

4.1.3 Alternative 2: Enhance Restoration

Alternative 2 involves expanding, improving, and accelerating Maryland's oyster restoration and repletion programs and Virginia's oyster restoration program in collaboration with Federal and private partners. This alternative would include a substantial increase in habitat rehabilitation and originally called for the development, production, and deployment of large quantities of disease-resistant strains of the Eastern oyster for brood stock enhancement.

Some stakeholders have considered the use of disease-resistant hatchery strains as brood stock to produce spat for planting as a means of increasing the population. DEBY and CROSSBreed are two disease-resistant strains of Eastern oyster presently available from hatcheries in the Bay area. Evidence suggests that “domesticated” lines like DEBY and CROSSBreed have faster growth rates and greater tolerance to MSX than “wild” oysters in Chesapeake Bay. Allen and Hilbish (2000) suggested that spat produced from such selected strains of brood stock would have greater longevity on restoration reefs, perhaps “re-establishing overlapping year classes of adults.” Allen et al. (2003) suggested that a process called “genetic rehabilitation” involving supportive breeding using disease-resistant brood stock could amplify the presence of alleles that confer disease tolerance in the “wild” population. The potential benefit of using such disease-resistant strains in Alternative 2 is uncertain and controversial.

The consensus among participants at a workshop entitled "Revisiting Genetic Considerations for Hatchery-Based Restoration of Oyster Reefs" held in 2007 was that the absence of documented evidence that planting domesticated oysters has yielded improved survival or higher subsequent recruitment is a compelling argument against the use of domesticated oysters in ecological oyster restoration. The participants recommended a precautionary approach to any use of artificially selected strains of oysters (Hare 2007). Participants did not support continued pursuit of "genetic rehabilitation" of Chesapeake Bay oyster stocks using artificially selected oyster strains. They also concluded that the development of alternative strains of the Eastern oyster for use in restoration should not be pursued because selection is, by definition, a bottlenecking process; therefore, artificial selection for disease resistance would create strains with limited flexibility for coping with environmental change. They argued that preserving and enhancing local wild stocks that exhibit some level of natural disease resistance would be a preferred means of encouraging the development of disease resistance rather than to risk swamping the genetic diversity of the wild stock with domesticated hatchery spat.

No data are available to determine if domesticated strains of the Eastern oyster that are resistant to MSX and Dermo would be as resilient as wild populations to future environmental challenges or disease (viral, parasitic, etc.) or if planting an artificially selected strain could swamp the genetic diversity of the wild stock. In a study of the Olympic oyster, Camara (2008) showed a relationship between decreased survival and increased relatedness of the parents (inbreeding) that could be inferred to support the likelihood of a genetic bottleneck in populations subjected to artificial selection for disease resistance. Disease-resistant strains could become numerically dominant in locations where they are stocked and, thus, could maintain their genetic integrity over multiple generations. Progeny produced in those locations, however, would be dispersed throughout adjacent areas. If wild stock were present in high proportions in the areas where the progeny set, genetic dilution would be likely and would reduce disease-resistance characteristics. The genetic integrity of a disease-resistant strain would be easily compromised in any location if a large natural set of wild oysters occurred, such as in a drought year. Cross-breeding of the wild stock with the disease-resistant strain could result in rapid genetic dilution of disease resistance.

The preponderance of evidence suggests that using hatchery-produced, disease-resistant spat in Alternative 2 would not significantly enhance the potential outcome for the size of the population and might have a detrimental long-term effect on the genetic diversity of the Bay's oyster population. Furthermore, the existing disease-resistant brood stock is not likely to be large enough to produce the number of spat specified for this alternative, at least over the 10-year assessment period. Analyses for Alternative 2, therefore, assume the use of the general strain of Eastern oyster reared in hatcheries in Maryland and Virginia.

> The preponderance of evidence suggests that using hatchery-produced, disease-resistant spat in Alternative 2 would not significantly enhance the potential outcome for the size of the population and might have a detrimental long-term effect on the genetic diversity of the Bay's oyster population.

Complete details of all restoration activities included in Alternative 2 are presented in Attachment 5 of Appendix A and summarized here. As described in Section 2.2.2, when developing Alternative 2, the PDT determined that two different approaches for implementing this increased effort should be considered. Alternative 2a focuses enhanced restoration efforts in areas of low salinity, and Alternative 2b shifts a significant portion of effort into areas of moderate and high salinity. In Alternative 2a, all of the seed would be planted in low-salinity areas (<10 ppt); in Alternative 2b, only 55% of the sites to be seeded would be in low-salinity areas. The representative implementation program for this alternative includes habitat rehabilitation and seed planting of the type performed over the recent decade. As explained in Section 2.2.2, the PDT did not include large-scale construction of three-dimensional reefs in the representative implementation plan for Alternative 2 because of the significantly greater cost of that approach and its inconsistent performance.

The number of hatchery-raised spat planted to be planted over the 10-year assessment period would increase from 200 million to 2 billion annually in Maryland, from 25 million to 125 million annually in the Potomac River, and from 50 million to 200 million annually in Virginia. The production of 2.3 billion spat would require production of about 23 billion eyed larvae, which is somewhat greater than the production capacity of the University of Maryland’s hatchery at Horn Point after its currently planned expansion (Section 4.0 of Appendix C). Implementing this alternative might require expanding the Horn Point hatchery further, constructing at least one additional oyster hatchery somewhere in the Bay watershed,[3] or purchasing spat from hatcheries outside the Bay area. The number of spat stocked annually would increase through year 7, and then remain constant through year 10.

The number of acres of sanctuaries planted with hatchery spat annually would increase from 75 to 750 in Maryland and from 10 to 40 in Virginia over 10 years (Table 4-5). Plantings in harvest reserves would increase from 50 to 500 acres per year, and plantings in open-harvest areas in the Potomac River would increase from 25 to 125 acres annually over a 10-year period. In Alternative 2a, 32 sanctuaries, all located in low-salinity waters (5-12 ppt), would be planted with hatchery spat (Figure 4-2). In Alternative 2b, 39 sanctuary areas would receive spat; 26 of these would be in low-salinity waters and 13 in waters of moderate to high salinity (Figure 4-3). Table 4-6 shows the area of habitat that would be rehabilitated under Alternative 2. Over a 10-year assessment period, 3,200 acres of sanctuaries and 800 acres of open-harvest areas in Maryland and 1,100 acres in the Potomac River would be rehabilitated, and 16,899 acres in Virginia would receive shell.[4] Harvest would continue under current regulations.

The density of spat to be stocked (i.e., number per acre) each year would be the same as in Alternative 1: 2 million per acre in Maryland sanctuaries, 1 million per acre in Maryland harvest reserves and Potomac River open-harvest areas, and 5 million per acre in Virginia sanctuaries. These stocking densities are standard for existing restoration programs. The area stocked in Alternative 2, however, would be much greater than in Alternative 1 (Table 4-5): 23 times more sanctuary acreage in Maryland over 10 years, approximately 2 times more harvest

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[3] In the economics analysis (Section 4.6.2), hatchery costs are assumed to be included implicitly in the cost-per-spat figures provided by aquaculture experts in the Chesapeake Bay area; however, no specific cost analysis was conducted to substantiate those experts’ opinions (D. Lipton, UMD, pers. comm.).

[4] The management categories of oyster habitat, sanctuary, harvest reserve, etc., are described in Section 1.3.1 and 1.3.2.

reserve area in Maryland, 3.5 times more sanctuary acreage in Virginia, and approximately 4 times more harvest area in the Potomac River.

Table 4-5. Number of acres to be planted under Alternative 1 and Alternative 2a; the proportion of sanctuary acres would be about 6% higher under Alternative 2b.

Year	Maryland				Virginia		Potomac	
	Sanctuaries		**Reserves**		**Sanctuaries**		**Harvest Areas**	
	Alt 1	**Alt 2**	**Alt 1**	**Alt 2**	**Alt 1**	**Alt 2**	**Alt 1**	**Alt 2**
1	20	75	160	50	10	10	25	25
2	20	131	160	87	10	20	25	45
3	20	188	160	125	10	40	25	70
4	20	281	160	187	10	40	25	90
5	20	375	160	250	10	40	25	120
6	20	563	160	375	10	40	25	125
7	20	750	160	500	10	40	25	125
8	20	750	160	500	10	40	25	125
9	20	750	160	500	10	40	25	125
10	20	750	160	500	10	40	25	125
Total	200	4,613	1,600	3,074	100	350	250	975

Any increase in the Bay-wide oyster population under Alternative 2a probably would occur in low-salinity areas in Maryland because most spat would be planted in Maryland on bars in the oligohaline zone. Survival rates would be greater in low-salinity zones because 55% of the spat planted in Maryland (excluding the Potomac) would be on sanctuaries, which would eliminate removal by harvesting (except for any illegal harvest), and because disease-related mortality rates are lowest in oligohaline waters. Such localized population increases would be driven by spat planting because reproduction of oysters is very limited in oligohaline waters; therefore, planted populations probably would not be self-sustaining. Given that spat planting would peak at year 7 and then remain constant through year 10, further population increases beyond 10 years would be unlikely. Exploratory modeling suggested that the population of market-size oysters after a 10-year period might be about 5 times the starting population, and that the outcome under Alternative 2b would be about 10% less than under 2a (Section 6.0 of Appendix A). A lesser outcome under Alternative 2b would be expected if the rate of reproduction among oysters planted in mesohaline areas were insufficient to compensate for the effects of disease among those oysters. Placing a greater proportion of seed in mesohaline waters might enhance the rate of development of disease resistance by increasing the number of oysters that would be continually exposed to disease stressors; however, the length of time required for a population to develop disease resistance cannot be estimated (Section 4.1.2). Although an increase under this alternative might be greater than the potential increase under Alternative 1, neither Alternative 2a nor 2b would be likely to achieve the restoration goal.

> Any increase in the Bay-wide oyster population that might result from Alternative 2 would occur in oligohaline waters in Maryland and would not be self-sustaining. Neither form of Alternative 2 would be likely to achieve the restoration goal for this PEIS.

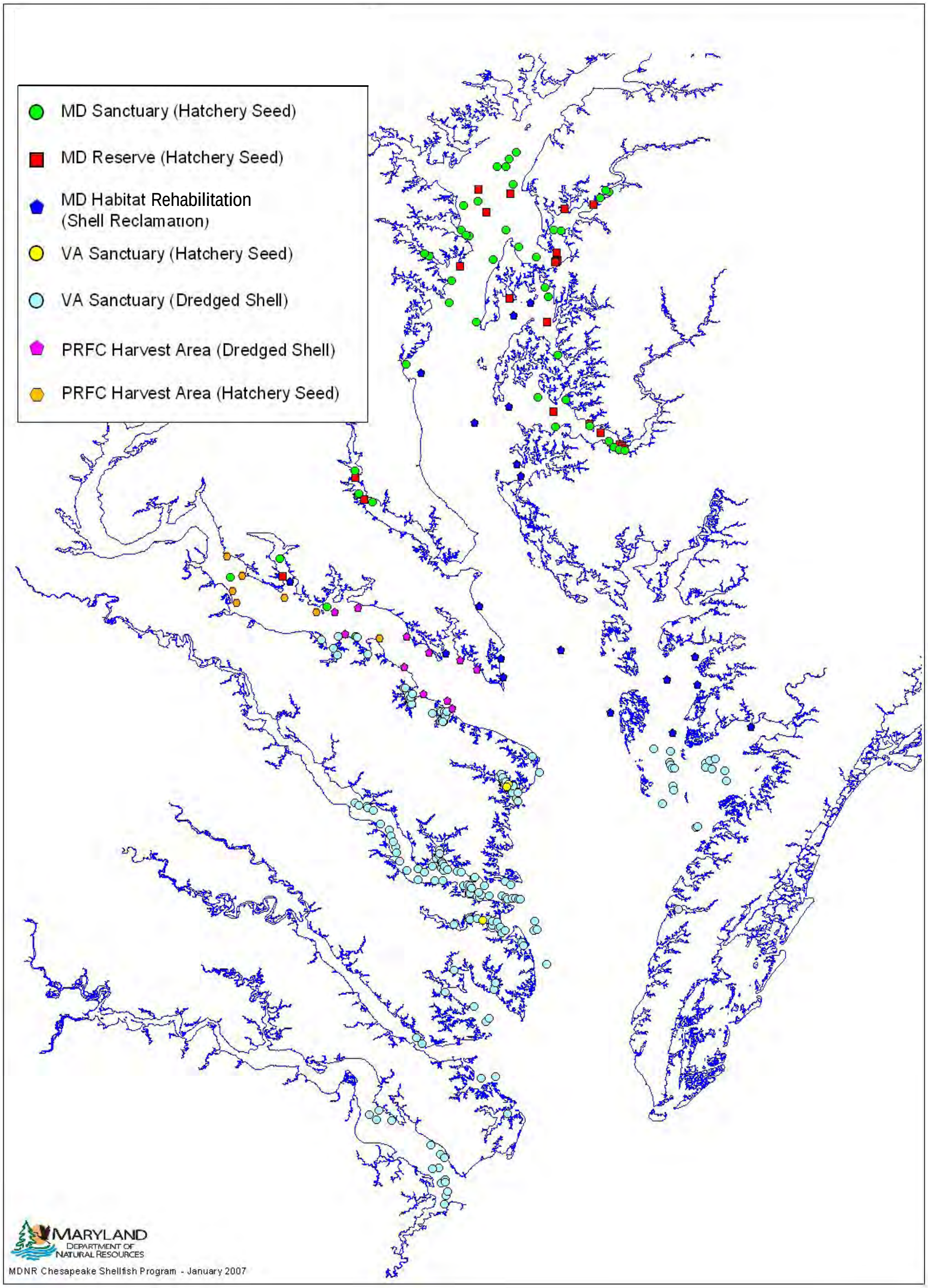

Figure 4-2. Location of oyster spat plantings on sanctuaries, harvest reserves, and open-harvest areas and location of oyster bar rehabilitation activities for Alternative 2a

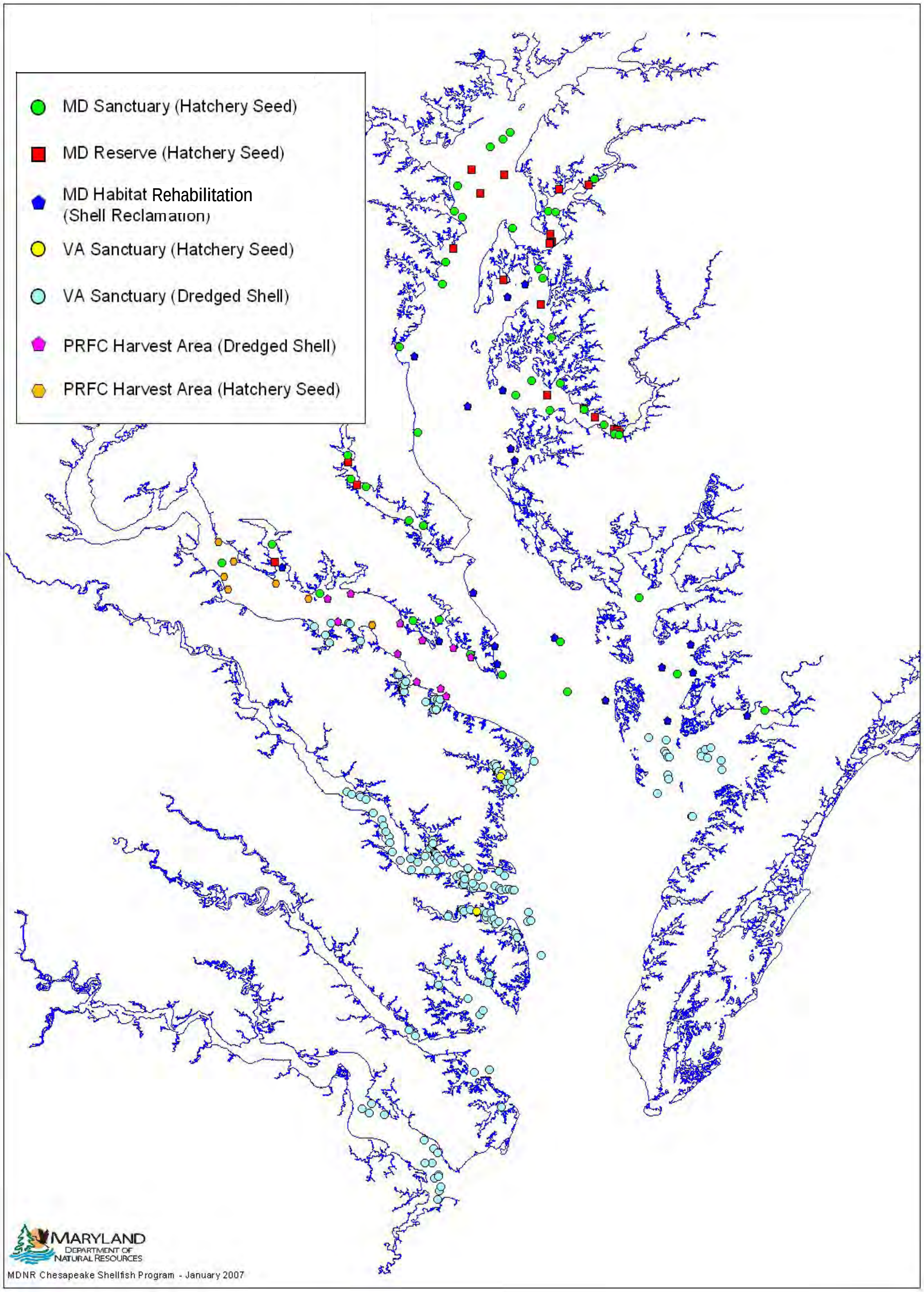

Figure 4-3. Location of oyster spat plantings on sanctuaries, harvest reserves, and open-harvest areas and location of oyster bar rehabilitation activities for Alternative 2b

As discussed in detail for the proposed action and Alternative 1, continuing loss of hard-bottom habitat under this alternative would constrain future growth of the oyster population despite increased restoration activities; however, the magnitude of habitat rehabilitation in some years (Table 4-6) would exceed the estimate of annual habitat loss described previously. The effect of habitat loss on rate of growth of the oyster population under Alternative 2, therefore, would be substantially less than under either the proposed action or Alternative 1. The potential increase in the oyster population in low-salinity areas and the resultant increase in the availability of shell habitat would not substantially enhance recruitment because of the lower reproductive potential of oysters in low-salinity areas; consequently, gains in oyster abundance under this alternative probably would not be self-sustaining. The development of disease resistance could enhance future population growth; however, the amount of time or number of generations that might be required to establish a Bay-wide population of oysters that are resistant to Dermo cannot be estimated at this time.

Table 4-6. Total acres of oyster bars rehabilitated annually within each management area and acres restored in sanctuaries, reserves and open-harvest areas over a 10-year period under Alternative 2.

Region	**Total number of acres of oyster habitat rehabilitated annually**	**Number of acres rehabilitated annually**		
		Sanctuaries	**Reserves**	**Harvest Areas**
Maryland	400	320		80
Potomac	110			110
Virginia	522-2,850	522-2,850		

4.1.4 Alternative 3: Harvest Moratorium

Alternative 3 involves implementing a temporary moratorium on harvesting native oysters and a compensation (buy-out) program for oystermen in Maryland and Virginia or a program that offers displaced oystermen on-water work in a restoration program. The socio-economic implications of this alternative are addressed in other parts of Section 4. The only issue addressed here is the consequence of eliminating harvest for the Bay-wide oyster population.

The implementation details of this alternative would be identical to those of Alternative 1 in terms of the magnitude and extent of restoration activities (i.e., existing restoration and enhancement programs would continue at least 10 years into the future, and funding for those efforts is assumed to continue). The major difference between Alternative 3 and Alternative 1 is that no specific bars would be designated as sanctuaries or reserves because harvest would be prohibited throughout the Bay. Bars in all salinity zones would be expected to experience some increase in abundance because no oysters would be removed. In addition, the loss of shell due to harvesting, albeit small, would be eliminated, which might result in a slight decline in the rate of habitat loss, as is discussed in greater detail below.

Overharvest and use of destructive harvest methods caused a major decline in the population of oysters in Chesapeake Bay from the 1880s to about 1930, as illustrated by a 50% decline in harvest over that period (Section 1.2). Although the historical effects of destructive harvesting are well documented, the effects of harvest activity at the much-reduced levels that have occurred over recent decades and with the kinds of gear used now are less clear. Lenihan et al. (2004) demonstrated that a statistically significant proportion of oysters, up to 10%, are incidentally killed but not harvested during each harvesting event on an oyster reef, as a result of being cracked, broken, or punctured by harvesting gear such as oyster dredges.

Lack of accurate quantification of historical and current exploitation rates for oysters in Chesapeake Bay is a major constraint on predicting the response of the Bay-wide oyster population to a harvest moratorium.

Uncertainty about past and current rates of exploitation of the oyster population complicates the effort to predict the effect of a harvest moratorium on the Bay-wide abundance of oysters. Recent harvest rates were estimated by dividing reported statewide landings of Eastern oysters in Maryland (T. O'Connell, DNR, pers. comm.) by statewide estimates of the oyster population for years 1994 to 2004 (Sections 2.3 and 2.11 of Appendix A, but since revised, see Footnote 2; Figure 1-3). Based on this calculation, an estimated average of 8.7% of all market-size oysters in Maryland (i.e. those more than 3 inches long) were harvested annually during this period. Confidence intervals around the population estimates are quite large (e.g., the estimated population of market-size oysters in Maryland for 2004 is 635.3 million, with 95% confidence limits of 64 million and 1.2 billion; L. Barker, DNR, pers. comm.); therefore, the estimated average harvest rate of 8.7% was considered to have a large, unknown, variance. No data were available from which to estimate an exploitation rate for Virginia. Jordan and Coakley (2005) estimated that annual exploitation rates of market-size oysters in Maryland from 1986 to 2001 varied from 21% to 73%. Some researchers believe that no oyster population could support such rates of exploitation for any extended period of time and, therefore, that the estimates are probably erroneous. An oyster population is unlikely to be capable of sustaining itself at exploitation rates that exceed 20% (E. Powell, Rutgers University, pers. comm.). Oyster landings in Maryland are highly regulated and relatively rigorously documented; therefore, the most likely explanation for overestimating the harvest rate is that the size of the oyster population has been underestimated substantially. The sustained annual exploitation rate in the James River in Virginia ranges from about 4.6% to 6%[5], and in Delaware Bay, the sustainable-fisheries removal of legally harvestable oysters (2.5 inches long or larger) has been about 4% (Mann and Powell 2007).

A population's response to eliminating exploitation that has occurred at a high annual rate (e.g., removal of half of all market-size oysters each year) is likely to be greater than its response to eliminating exploitation occurring at a much lower rate (e.g., 4% to 6% of market-size oysters). Jordan and Coakley (2004) used a time series of fishery-dependent and fishery-independent data to parameterize a model of oyster population dynamics in Chesapeake Bay and predicted that moderate decreases in fishing mortality, alone or in combination with increases in recruitment through stock enhancement, could reverse the decreasing trend in oyster abundance within one to two decades, even without a decrease in disease-related mortality. In the process of estimating mortality rates to be used in population modeling for this PEIS, errors were

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[5] This exploitation rate differs from the rates estimated for the PEIS because it is calculated as bushels of harvested, market-size oysters divided by the estimated population of all oysters (excluding spat), not just market-size oysters; therefore, the percentage of market-size oysters harvested annually would be substantially higher than these figures (R. Mann, VIMS, pers. comm.).

identified in one of the inputs to the model developed by Jordan and Coakley (2004) that would alter their outcome and invalidate their conclusions (Attachment 4 of Appendix A). Exploratory modeling of the response of the Bay-wide oyster population to cessation of harvest for this PEIS suggested a very limited increase in the abundance of a small starting population (i.e., less than doubling of the population after 10 years), even assuming an unrealistically high rate of harvest (Section 6.0 of Appendix A).

Lack of accurate quantification of historical and current exploitation rates in Chesapeake Bay is a major constraint on predicting the response of the Bay-wide oyster population to a harvest moratorium. The factors that could influence the response to cessation of harvest provide a basis for an informed judgment about potential outcomes:

Relative magnitude of annual disease mortality versus annual harvest mortality – Disease mortality generally occurs during warm summer months, but the oyster fishery opens in the fall and continues through the winter. As a result, the two sources of mortality are additive. If the rate of disease-related mortality is high, the contribution of harvest to the total annual mortality rate would be low. The rate of mortality due to disease varies annually according to oyster age, summer salinity, and disease intensity. When salinity and disease intensity were high, average annual mortality of market-size oysters due to disease was estimated at 79% (Table 4 of Appendix A). When salinity and disease intensity were low, estimated annual disease mortality was 10%. The magnitude of the effect of eliminating harvest on the future size of the oyster population would vary substantially depending on the salinity and disease conditions at individual bars. These conditions would vary from year to year depending on annual variation in freshwater discharge into the Bay (Figure 2 of Appendix A).

The magnitude of the effect of eliminating harvest on the future size of the oyster population would vary substantially depending on the salinity and disease conditions at individual bars. These conditions would vary from year to year depending on annual variation in freshwater discharge into the Bay.

Contribution of small oysters to recruitment – Some oysters in any year class become sexually mature and contribute to annual spawning before they reach the legal size for harvest (i.e., oysters in the "small" size category). These oysters would not be exposed to harvest mortality (except as a limited by-catch with legal oysters). A harvest moratorium would eliminate the loss of only the relatively small percentage of "small spawners" typically lost as by-catch.

The greatest increase in oyster abundance likely to occur under current restoration programs would be on protected bars in low-salinity waters. Oysters in low-salinity areas make only a limited contribution to recruitment throughout the Bay; therefore, eliminating harvest in low-salinity areas is not likely to contribute to substantial growth of the Bay-wide population.

Percentage of the stock on protected bars – As described in Sections 4.1.2 and 4.1.4, a significant portion of the habitat rehabilitation and spat planting under this alternative would be on sanctuary and harvest reserve bars, where oysters already are protected from harvest. If oyster abundance increases over time on protected bars, the percentage of the Bay-wide stock subject to harvest would decline, and the effective Bay-wide exploitation rate would decrease, even if the exploitation rate remained high on unprotected bars.

Illegal harvest from protected areas could significantly reduce the benefits of protected bars. The greatest increases in oyster abundance likely to occur under current restoration programs would be on protected bars in low-salinity waters. Oysters in low-salinity areas make only a limited contribution to recruitment throughout the Bay; therefore, eliminating harvest in low-salinity areas is not likely to contribute to substantial growth of the Bay-wide population.

Continuing loss of habitat – As discussed for other alternatives, the continuing loss of hard-bottom habitat would significantly constrain future growth of the oyster population even if harvest were eliminated.

Reduction in shell removal – Eliminating harvest would reduce the rate of shell loss somewhat because oysters would not be removed from the Bay, but the effect would be minimal relative to the rate of shell loss and the magnitude of existing habitat rehabilitation efforts because current harvests are so small. Most Chesapeake Bay oyster landings in recent years have come from Maryland (Figure 1-1). The average harvest in Maryland from 1997 to 2006 was 199,000 bushels and the average from 2002 to 2006 was 83,000 bushels (Attachment 7 of Appendix A). Habitat rehabilitation programs described in Attachment 5 of Appendix A assume the use of 7,500 bushels of shell per acre (to a depth of 3 inches). The average area to be rehabilitated annually would range from 478 acres to 1,739 acres, which would require 3.6 to 13 million bushels of shell per year. The 10-year and 5-year average harvest amounts for Maryland alone, therefore, represent, at most, only 5.5% and 2.3%, respectively, of the minimal volume of shell that would be planted annually under current restoration programs (Attachment 5 of Appendix A). Mann (2007b) calculated that more than half of the annual addition to the shell stock results from the growth of oysters that are older than 2.33 years and in size range targeted by oyster fishermen (i.e., those that exceed the legal size limit). Removing those oysters not only causes an immediate decrease in shell, but also eliminates a significant potential source of new shell.

Development of disease resistance – As discussed for Alternatives 1 and 2, harvesting an oyster population that is severely affected by diseases may slow or prevent the development of disease resistance in the exploited population. Oysters that survive to reach and exceed the legal market size may be individuals that are naturally genetically resistant to disease. Recent data from the James River indicating that the prevalence of Dermo and the proportion of more serious infections level off or decrease among larger, older oysters (Carnegie 2007) support this contention. Oysters that survive to reach or exceed market size despite being exposed to significant disease pressures are likely to confer some degree of disease resistance to subsequent generations. No estimates of the time or number of generations required to develop resistance to MSX or Dermo within the oyster population in Chesapeake Bay are available. Nevertheless, removing a large percentage of oysters that may be exhibiting some level of disease resistance would clearly impede the rate at which such resistance could be propagated throughout the stock. Normal year-to-year fluctuations in environmental conditions also could retard or even reverse the rate of development of disease resistance, which depends on relatively continuous exposure to the disease stressor. Regardless of the time horizon, eliminating harvest

Eliminating harvest clearly would increase the possibility of development of disease resistance in the native oyster population; however, the resulting magnitude of increase in the rate of population growth over time cannot be estimated.

clearly would increase the possibility of development of disease resistance in the native oyster population; however, the magnitude of increase in the rate of population growth over time in response to such a development cannot be estimated.

Studies of existing oyster sanctuaries in Maryland support the conclusion that a harvest moratorium may have only a limited effect on the oyster population. Tarnowski (2005) reported results of monitoring 13 oyster sanctuaries as part of Maryland's annual Fall Oyster Survey between 1996 or 1997 and 2004. The sites monitored represented a cross-section of sanctuaries in different salinity regimes and with varying rehabilitation efforts Environmental conditions, in particular changes in salinity between years in response to freshwater inflow, were the overwhelming determinants of sanctuary success, as measured by spat set and changes in oyster abundance over time. Results at sanctuary bars have been decidedly mixed. Biomass increased on many but at much lower levels than anticipated, especially in the low-salinity zones. Despite the numerous rehabilitation projects within the sanctuaries, many of the sanctuary populations tended to resemble natural populations in relatively short periods of time. There was no evidence of far-field recruitment effects (i.e., that the sanctuaries are sources of larvae for other bars). Overall, it appeared that the sanctuary program to date has fallen far short of its stated goal of contributing to a 10-fold increase in oyster biomass in Chesapeake Bay. The report did not specifically account for any illegal harvest that might have influenced results, and the study period was not sufficient to detect any benefits of development of disease resistance; however, it provided significant evidence that the absence of legal harvest did not result in significant enhancement of the oyster population at the level of individual bars.

Under this alternative, the geographical pattern of change in the oyster population probably would be similar to that expected under Alternative 1 because restoration effort would be the same. The greatest increases in oyster abundance would be expected in oligohaline regions in Maryland because most spat would be planted in Maryland on bars in the oligohaline zone, and less disease-related mortality would be expected at those lower salinities. Attainment of the PEIS goal would be very unlikely.

4.1.5 Alternative 4: Cultivate Eastern Oysters

Alternative 4 involves establishing or expanding State-assisted, managed, or regulated aquaculture operations in Maryland and Virginia using the native oyster. As explained in Section 2.2.4, no particular aquaculture methods or techniques were specified in developing the alternative, and the analysis of this alternative was not designed or intended to identify the economically optimal methods of cultivating oysters in Chesapeake Bay. A specific scenario had to be developed to provide a basis for assessing the environmental consequences of this very general alternative (Appendix C). The PDT decided to define the aquaculture assessment scenario based on economics because private development of a large-scale aquaculture industry in the Bay would be driven by economic factors. The assessment scenario is based on current aquaculture activities in the Bay area and is a reasonable representation of a future, large-scale oyster aquaculture industry in the Bay; it is not a specifically recommended action.

The development of a large-scale aquaculture industry in the Bay would be driven primarily by economic factors.

Units of Measurement for Oysters

Parameter	Units of Measure	Notes
Biomass of an Individual Oyster	grams of dry tissue	$\log_{10}$ weight (g) = -3.7595 + 2.062584 * $\log_{10}$ size class (mm) (1) i.e., a 77-mm oyster = 1.354 g
	grams of carbon	biomass (g carbon) = 0.0002115 * (shell height (mm))$^{1.7475}$ (b) i.e., a 77-mm oyster = 0.419 g
Abundance	Maryland bushel	0.060 cubic yards (c)
		350 market-size oysters (C. Judy, DNR)
	Virginia bushel	0.064 cubic yards
		250-500 market-size oysters (J. Wesson, VMRC)
	bushel for PEIS Econ. Analyses	275 market-size oysters
	weight of a bushel	7 lbs oyster meat = 1 bushel ("market data" per D. Lipton, Univ. of MD)
Size	spat	<40 mm
	small	40 mm to 76 mm
	market	>76 mm
	average market	90 mm (d)

(1) Mid-point of size class with a range of 5-mm; thus, 77 mm for the 75-mm to 80-mm size class; from Jordan et al. 2002

(b) From Cerco (pers. comm.) and Mann & Evans (1998)

(c) From Chesapeake Bay Oyster Population Estimation (CBOPE) (http://www.vims.edu/mollusc/cbope/)

(d) From Cerco (2005a, 2005b)

Development of the assessment scenario for Alternative 4 began with the output of an economic demand model for oysters (Appendix D4) used in the assessment of economic consequences of the proposed action and all alternatives. One output of the model is the estimated annual maximum level of aquaculture production that would be economically viable (i.e., profitable) for a large-scale oyster aquaculture industry in Chesapeake Bay. That estimate was 2.6 million bushels, with a range of 1.7 to 5.4 million bushels,[6] and includes oysters cultured for the half-shell and shucking markets as well as wild-caught oysters. The estimated maximum economically viable production of 2.6 million bushels of oysters is less than the benchmark annual harvest of about 5 million bushels per year between 1920 and 1970, indicating that the current market for oysters is about half the market that existed during that reference period. To account for wild-caught oysters, future wild harvests under this alternative were assumed to be similar to recent annual harvests of wild oysters from Maryland and Virginia combined, which have averaged approximately 138,400 bushels. Subtracting that average from 2.6 million bushels, the maximum economically viable aquaculture production would be approximately 2.46 million bushels, or 676.9 million oysters.[7] The 676.9 million oysters that constitute the cultivated portion of the estimated maximum annual production represent approximately 84% of the estimated current population of market-size oysters in the Bay (809 million). The current oyster population is distributed throughout the Bay; however, cultivated oysters would be concentrated in locations identified in the assessment scenario. Section 4.2 discusses the ecological consequences of such numbers of oysters and their distribution within the Bay.

The annual production of the maximum economically viable oyster aquaculture industry in the Bay is estimated to be 2.6 million bushels.

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[6] Appendix D presents confidence limits for projections of the economic demand model; however, for simplicity only the median values are used in most of the assessments presented in Section 4.

[7] For consistency, we used 275 oysters/bushel (used in Appendix D) as a standard for the aquaculture alternatives.

The next step in developing the assessment scenario was to determine where large-scale aquaculture operations might develop in Maryland and Virginia. With input from aquaculture experts in both states,[8] nine feasible locations were identified based on past aquaculture activity, oystering history, or a consensus of opinion about locations that might be appropriate based on existing infrastructure and logistical support that might contribute to the development or expansion of oyster aquaculture operations (Figure 4-4). The total maximum production was apportioned among those nine locations based on input from those same experts, placing 20% of the production in Maryland waters and 80% in Virginia waters. This allocation reflects the fact that Virginia's existing oyster aquaculture industry is much larger than Maryland's, and the recognition that this distribution is unlikely to change over the next decade without major changes in Maryland's regulations governing shellfish aquaculture. These locations are examples of the kinds of locations at which significant aquaculture operations might be established, not recommended sites. They represent a range of kinds of locations to provide a broad basis for evaluating the potential effects of Alternative 4. Community groups and non-governmental organizations such as the Chesapeake Bay Foundation are operating many small-scale aquaculture and oyster restoration programs around the Bay. This aquaculture alternative was evaluated assuming that an expanded industry would be economically viable; consequently, the analysis of Alternative 4 does not address the efforts of non-profit groups specifically. Table 4-7 shows the number of oysters that might be produced at each of the nine locations based on the representative allocation of the 676.9 million oysters estimated to represent the maximum viable annual aquaculture production. The Maryland locations considered as potential Aquaculture Enterprise Zones are intended to attract growers and do not necessarily have the infrastructure required for aquaculture that might exist in other locations. This scenario was created simply for environmental evaluation purposes; economic analyses presented in Section 4.6.2 consider aquaculture on a consolidated, Bay-wide basis.

Section 2.0 of Appendix C describes the kinds of aquaculture operations that might be employed and the amount of space such operations might occupy. These factors are significant for assessing the potential effects on elements of the environment such as boating and aesthetics, which are addressed in other parts of Section 4. The kinds of oyster aquaculture most commonly employed in the Bay at present include on-bottom (i.e., spat placed on hard-bottom habitat and harvested when the oysters reach market size); off-bottom cages (i.e., spat in cages mounted on supports that keep them suspended just above the bottom and retrieved when oysters reach market size); floats (i.e., anchored floating trays in which spat are maintained near the water surface and harvested when oysters reach market size); and other containment methods (e.g., bags secured to a line and laid on the bottom or bags suspended from floats at various depths). Although most historical aquaculture of native oysters in the Bay was on-bottom, off-bottom cages and floats have been shown to result in enhanced growth and reduced disease mortality of native oysters and are likely to be employed to cultivate native oysters in the future. For example, a relatively new oyster aquaculture firm, Marinetics, uses floats exclusively in its operation on the Choptank River (Figure 4-5). Marinetics deploys 3,000 floats to produce 1 million oysters per year. Recent aquaculture trials in Virginia using triploid Eastern oysters employed primarily off-bottom cages (A. Erkine, pers. comm.). The potential for growing triploid native oysters using on-bottom aquaculture also is great. The Chesapeake Bay Foundation (CBF) recently completed a triploid aquaculture project in partnership with Bevans

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[8] Contributing experts are identified in Appendix C.

Oyster Company, and others are in progress with Cowart Seafood and several individual watermen (T. Legget, CBF, pers. comm.). The results of these efforts are discussed below.

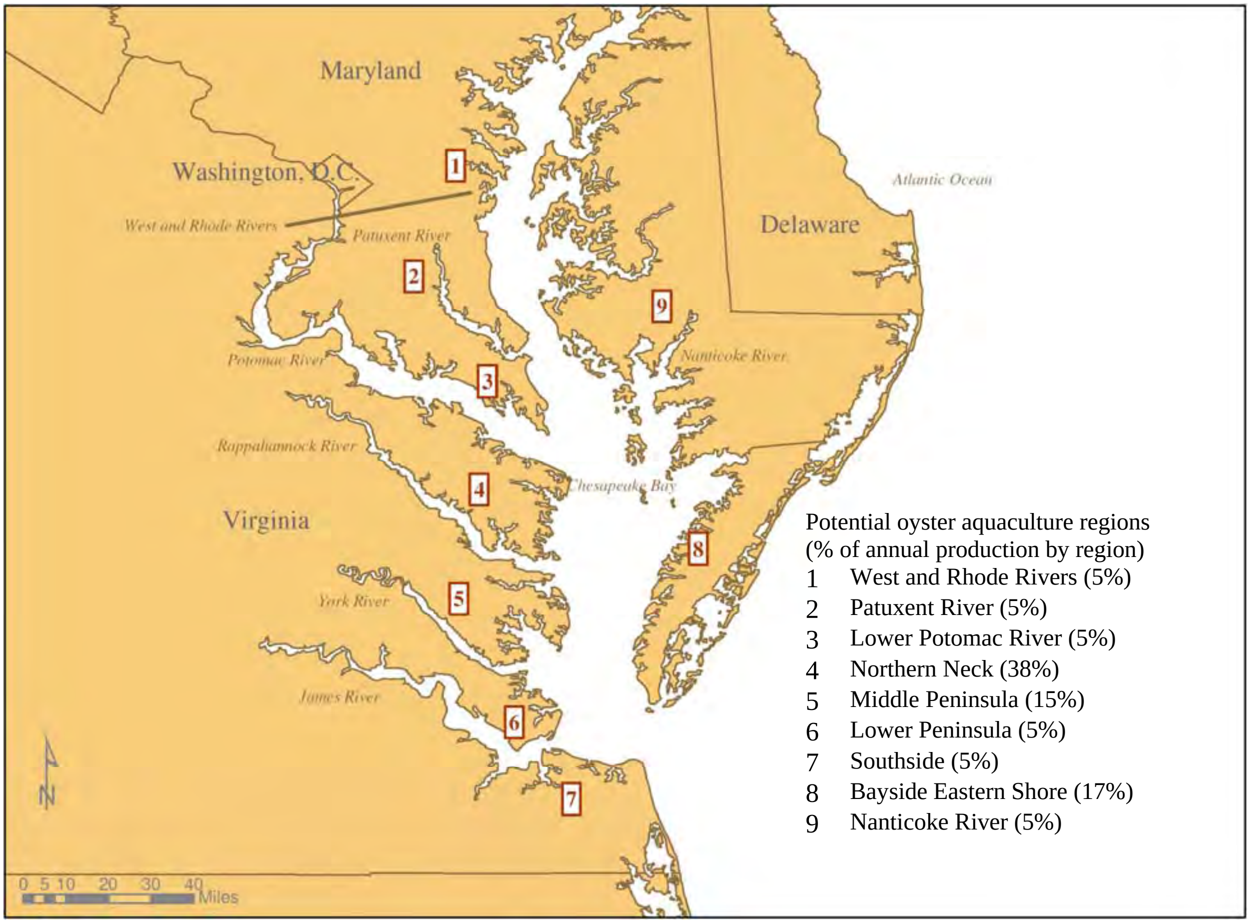

Figure 4-4. Assessment scenario for large-scale aquaculture operations in Chesapeake Bay; locations were selected in consultation with aquaculture experts in the Bay area. The percentage of total annual production that might be expected for each of the locations is identified in the insert.

Table 4-7. Estimated annual production at each of the nine aquaculture locations identified for the assessment scenario.

		Bushels	**Millions of Oysters**
1	West and Rhode Rivers (5%)	123,000	33.8
2	Patuxent River (5%)	123,000	33.8
3	Lower Potomac River (5%)	123,000	33.8
4	Northern Neck (38%)	934,800	257.1
5	Middle Peninsula (15%)	369,000	101.5
6	Lower Peninsula (5%)	123,000	33.8
7	Southside (5%)	123,000	33.8
8	Bayside Eastern Shore (17%)	418,200	115.0
9	Nanticoke River (5%)	123,000	33.8

Figure 4-5. Trains of floats at the Marinetics aquaculture facility on the Choptank River, Maryland. Each float holds 1,000 to 10,000 oysters. Photo courtesy of Chris Judy, DNR.

The area required to produce the projected maximum number of cultivated native oysters would differ depending on whether operators cultivated diploid or triploid[9] oysters and on the form of aquaculture (Section 2.0 of Appendix C).[10] Triploid Eastern oysters grow faster than diploids, reaching market size in 12 to 18 months when grown in off-bottom cages and in 18 to 28 months when grown on-bottom. Diploid Eastern oysters grown on-bottom attain market size in about 36 months. Diploids grown off-bottom or in floats are likely to reach market size in about 24 months. As a result of these differences, three cohorts of diploids or two cohorts of triploids would have to be deployed at any given time to achieve the maximum production annually using on-bottom aquaculture (i.e., the number of oysters placed in the water would have to be triple or double the number of oysters expected to be harvested each year). Most on-bottom aquaculture is done on shell substrate (i.e., existing oyster bars), but other kinds of hard substrate can be used. Off-bottom cages require hard bottom, but not necessarily shell; the substrate must be firm enough to prevent the cages from sinking. Floats or suspended bags provide the greatest versatility because they can be anchored over any kind of bottom; however, floats are vulnerable to high winds and waves, which growers would consider when selecting sites for deployment. In addition, the presence of floats may affect aesthetics and recreation in ways that would limit where they are allowed to be deployed.

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[9] Oysters that are genetically manipulated to be triploid are sterile; consequently, energy is shunted to growth of body tissues instead of reproductive organs, and they grow faster than normal, diploid oysters.

[10] Data used in developing the figures presented here were taken from presentations at an aquaculture workshop, the summary of which is included in Section 2.0 of Appendix C, and from personal communication with oyster culturists around the Bay. Studies that document and contrast growth rates of triploid Suminoe oysters with those of diploid and triploid Eastern oyters were summarized in Section 4.1.1.1.

Information provided by aquaculture operators was used to estimate the area that might be required to generate the maximum economically viable production using the various modes of aquaculture (Table 4-8). Triploids grow faster than diploids; consequently, the area required to cultivate triploids in floats may be somewhat less than this estimate, and the area required to cultivate diploids in floats might be somewhat greater. Triploid Eastern oysters in some circumstances have been found to produce more biomass per unit of shell length (i.e., to be larger at a given shell size) than diploid Eastern oysters. In studies conducted in 2005, a biomass index (gm wet weight/mm shell length) for triploid Eastern oysters for the period January to October was 34% greater than the index for diploid Eastern oysters (data provided by Dr. S. Allen, VIMS). An aquaculture operation using triploids, therefore, probably could produce substantially greater amounts of oyster meat than a similar operation using diploids over the same period of time. In a project sponsored by CBF and conducted with the Bevans Seafood Company, triploid spat-on-shell grown on half an acre of bottom yielded 947 bushels in 18 months (T. Leggett, CBF, pers. comm.). If that level of production could be realized in various locations in the Bay, only 3,590 acres would be required to produce 2.46 million bushels of market-size oysters in on-bottom aquaculture, assuming that two cohorts were deployed annually. That area is an order of magnitude less than the required area estimated using other data discussed at the aquaculture workshop documented in Appendix C.

Table 4-8. Estimated area required to cultivate 676.9 million Eastern oysters annually.(a)

Ploidy	**Form of Aquaculture**	**Years to Market Size**	**Area Needed (acres)**
Diploid	On-bottom	3	73,800(b)
Triploid	On-bottom	2	2,590
Triploid	Floats	1.5	1,952

(a) For reference, the total acreage of tidal waters in Chesapeake Bay is 2,978,163.

(b) See Section 2.0 of Appendix C for details on derivation of all these figures; the diploid estimate is based on very low current Maryland production rates of 100 bushels per acre with three cohorts in the water simultaneously and assumes three years to reach market size.

The assessment scenario for Alternative 4 assumes that the industry would use solely hatchery-produced spat. Many oyster aquaculture operations elsewhere in the world, such as France and China, use devices called spat collectors (examples include “french tubes” and “chinese hats”). These devices are placed in locations where wild oysters spawn naturally. Spat that settle on the collectors are then transported to grow-out areas In France, about 50% of the spat used in aquaculture are acquired using spat collectors (Maurice Heral, French Research Institute for Exploitation of the Sea, pers. comm.). Some oyster growers in Chesapeake Bay consider spat collectors to be cumbersome, difficult, and expensive to use. They consider the traditional method of planting shell to catch wild oyster seed to be most effective simply due to availability and existing infrastructure (A.J. Erskine, Cowart Seafood Corporation, pers. comm.). As discussed in Section 1.2, transplanting seed oysters from areas of high disease intensity to grow-out areas is believed to have contributed to the spread of diseases throughout the Bay. In addition, disease pressure in the high-salinity areas that are optimal for oyster growth has prompted growers to use hatchery strains of the Eastern oyster bred specifically for disease resistance to increase their production efficiency (S. Allen, VIMS, pers. comm.) An economically viable industry would require stability in spat production, but the amount of wild spat available is likely to vary considerably from year to year depending on environmental conditions.

Hatchery production would be the only means of ensuring the availability of specific quantities of spat annually. Hatcheries would, of course, be the only source of triploid spat. Other factors that argue against the use of wild spat are the need to apportion spat equitably among private operators and the potential for further dispersal of diseases throughout the Bay. Another option for obtaining sufficient spat for an expanded aquaculture industry in the Chesapeake Bay area would be to import seed from elsewhere in the country. No growers in the Bay area appear to purchase seed from elsewhere at this time, and no information was available to assess the economic and logistical viability of that option.

The number of hatcheries required to support an aquaculture industry of the estimated size was defined based on the quantity of hatchery-grown spat required to produce the specified number of market-size oysters (Section 4.0 of Appendix C). The quantity of spat that a hatchery can produce is highly variable and subject to many factors that affect the number of eggs that are fertilized, the percentage of those eggs that reach the eyed-larva stage, and the percentage of those larvae that become spat. Success at each stage of production can vary; nevertheless, general figures that represent reasonable estimates of hatchery success were obtained from the operators of existing oyster hatcheries at VIMS and the University of Maryland. The amount of spat required to support the maximum economically viable industry could range from 15 billion to 50 billion. As a rough, conservative generalization (i.e., probably the maximum capacity needed), 15 to 25 hatcheries with production capacity similar to that of the University of Maryland's Horn Point facility would be required to produce sufficient quantities of spat to operate a full-scale aquaculture industry in Chesapeake Bay. Fewer spat and fewer hatcheries would be required if the industry were to be based primarily on triploids; however, those hatcheries would have to be equipped to produce triploids. Fewer spat and fewer hatcheries would be required if the industry were to be based primarily on disease-resistant strains. The concern about a potential genetic bottleneck discussed in the evaluation of Alternative 2 would not pertain to the aquaculture alternatives. Using disease-resistant strains in aquaculture operations might result in a larger percentage of spat surviving to market size.

The size of the industry in the assessment scenario for Alternative 4 was projected solely based on economic viability; however, many factors could prevent such a scenario from being realized. The factors most likely to impede the achievement of an oyster industry of the projected size are discussed here. Other issues, such as effects on boating and aesthetics are discussed in later parts of Section 4, and those discussions assume achievement of the maximum economically viable industry.

Many factors could prevent the maximum oyster aquaculture industry from being attained.

Availability of Habitat – Lack of sufficient habitat to support an industry of the projected size could constrain its form and rate of development. For example, the estimated area required for on-bottom aquaculture of diploids is 73,844 acres of hard bottom; the estimate is conservatively large because it is based on low levels of production observed in recent years in Maryland. For context, the estimated total area of oyster habitat currently available in the Bay is only 76,030 acres (Attachment 1 of Appendix A). That estimate includes bars located in areas where oyster survival, growth, or both might be low; bars designated as sanctuaries; and public bars in Maryland, which regulations prohibit leasing for aquaculture. Cultivating diploid Eastern oysters on the bottom, therefore, would not be a feasible means of attaining the maximum aquaculture industry, particularly in Maryland, unless a considerable area of new habitat for oysters were to be created in areas that are not presently charted as oyster bottom. The estimated area required for on-bottom aquaculture of triploids is 49,229 acres. About 2/3 of all oyster habitat in the Bay would have to be used to obtain the maximum production of cultivated triploids, assuming that production rates would be the same in all salinities and locations in the Bay, which would not be the case.

Cultivated Eastern oysters grow faster in off-bottom cages, which require hard substrate, but not necessarily shell. Development of an off-bottom industry, therefore, would be less constrained by habitat limitations, although aesthetic issues regarding structures such as floats could be equally limiting (Section 4.7). Use of suspended methods, such as floats, might facilitate attainment of the maximum projected production because floats can be deployed over any kind of bottom; however, floats are feasible only in relatively sheltered locations because they are subject to damage during storms. Floats are also subject to fouling and icing and require extensive maintenance. In addition, the effects of floats on aesthetics and recreation probably would constrain where they could be deployed. The area of shell or hard-bottom habitat available in most of the areas identified in Figure 4-4 is insufficient to fully support the projected production using other methods. Several procedures for bottom preparation, however, can be used to make bottom that is otherwise unsuitable for oyster culture productive. In Maryland, for example, large areas of bottom could be made productive if various regulatory constraints were removed (D. Merritt, UMD, pers. comm.).

Production Capacity – Environmental conditions at potential aquaculture sites were not considered in estimating the area required for oyster production. Oysters grow by filtering food from the water column, and growth rates would vary depending on food availability and oyster density. In estimating the areas required to support the maximum industry, all locations were assumed to have food supplies similar to those available at the existing aquaculture operations from which data were obtained. Existing aquaculture operations probably are sited in the subset of the leased or permitted locations that growers have found to be optimal and economically viable. The availability of locations with similar optimal characteristics sufficient to yield the maximum estimated production is not known.

Rate of Industry Development – The United Nations Food and Agriculture Organization reported that 93% of worldwide oyster production in 2000 originated from aquaculture. Chinese growers culture about 40 billion oysters per year; Japanese and Korean growers follow with about 2 billion oysters annually. France (1.5 billion) and the U.S. Pacific Northwest (500 million) round out the top 5 producing areas. In contrast, aquaculture production in Chesapeake Bay in 2005 was 9 million. Sales of farmed oysters more than tripled between 2004 and 2005 and were projected to double between 2005 and 2006 (Crest 2007). Although oyster aquaculture is expanding in Chesapeake Bay, the likelihood that it will continue to expand to a level that would result in production of more than 600 million oysters annually and the length of time required to achieve that production, if it is possible, are not known. Many of the obstacles to development of the industry are discussed below. Given that the maximum economically viable industry is unlikely to attained in the near future, evaluations of Alternative 4 throughout this PEIS that assume the maximum industry are likely to overestimate the magnitude of adverse and beneficial effects of expanding aquaculture operations on all components of the Bay environment.

Regulatory Constraints – Section 5.0 of Appendix C summarizes the complex regulations that govern aquaculture operations in Maryland and Virginia. The regulations are diverse and subsets of them apply to all modes of aquaculture. Virginia's aquaculture industry is much more developed than Maryland's, and Virginia recently revised its regulations to facilitate further expansion of that industry. In Maryland, wild-caught oysters have always dominated the oyster fishery, and the State has restrictive laws and regulations that preclude development of an aquaculture industry of the size projected for Maryland in the assessment scenario for Alternative 4. A major revision of Maryland's laws and regulations would be required to remove those constraints on industry development. Similarly, the compact establishing the Potomac River Fisheries Commission prohibits aquaculture in the Potomac River. The Commission is planning to pursue modifications of the compact to permit aquaculture within the river. Such a modification would be required before oyster aquaculture could occur in the Potomac.

Water Quality – The States' environmental departments regulate the locations from which shellfish can be harvested by monitoring the levels of contaminants present in the water, particularly the levels of fecal coliform bacteria. Levels of contaminants must be below certain criteria for safe shellfish harvesting. In some instances, areas closed to shellfish harvesting might also be closed to aquaculture operations. In Maryland, the law permits operators to raise shellfish in closed waters and then relocate them to approved waters for depuration before harvesting them (D. Merritt, UMD, pers. comm.). Such an operation is likely to have higher operational costs and, thus, to be less attractive to growers. Locations in which aquaculture is implemented would have to be monitored to ensure that they continued to meet water quality requirements. In addition to contaminated waters, aquaculture operations could be constrained by low dissolved oxygen. This constraint would be less likely to apply to suspended aquaculture, such as floats, but it could be significant for on-bottom operations in some locations. Uncertainty about the ability to predict the suitability of locations for aquaculture could deter potential investors from entering the industry.

Economic Factors – The economics of the aquaculture alternatives are addressed in Section 4.6 and in Appendix D. Economics is discussed here only with regard to whether it would constrain development of the industry. The demand model used to estimate the maximum economically viable aquaculture industry in the Bay inherently assumed that market demand would justify private investment in the industry because the industry would be profitable. Expansion of historical forms of cultivation of the Easter oyster on leased bottom using on-bottom techniques is highly unlikely due simply to the effects of disease. Even if the effects of oyster diseases could be overcome through further development of highly disease-resistant strains and culture methods that would reduce disease effects (e.g. floats), investment of this nature still would not be likely in Maryland because of the existing regulatory barriers, which are described in Section 5.0 of Appendix C. Theft of oysters from leased areas in Maryland is another disincentive for expansion (D. Webster, UMD, pers. comm.). As in any other start-up industry, some public investment may be required to stimulate growth. Webster (2007) described the concept of Aquaculture Enterprise Zones (AEZ) being developed by the Maryland Aquaculture Coordinating Council. The Council plans to submit an AEZ plan to the Maryland General Assembly in 2009 as part of a comprehensive legislative package seeking regulatory changes to promote aquaculture. The Council is considering both regulatory and economic incentives that could contribute to fostering growth of the aquaculture industry in the state. The Council views implementing programs through the Department of Agriculture as more appropriate than working through the Department of Natural Resources, given the economic nature of the aquaculture industry. Private investment to develop the industry may be more likely in Virginia, which is more receptive to aquaculture. Public investment in the aquaculture industry in Virginia is limited primarily to support provided by the Aquaculture Genetics and Breeding Technology Center at VIMS; the substantial existing operations are all privately funded. Because of the small profit margins for Eastern oysters, however, some stakeholders believe that public investments may be necessary in the future to enhance the growth of the industry using the native species (A. Erskine, Bevans Oyster Company, Cowart Seafood Corporation, pers. comm.).

4.1.6 Alternative 5: Cultivate a Nonnative Oyster

Alternative 5 involves establishing State-assisted, managed, or regulated aquaculture operations in Maryland and Virginia using a suitable triploid, nonnative oyster species. Triploid oysters generally are considered to be sterile and incapable of reproduction and generally exhibit faster rates of growth than normal, diploid oysters. The objective of this alternative is to permit the use of a nonnative oyster that might perform better than the Eastern oyster in aquaculture operations in a manner that would avoid establishing a reproductively viable population of that species in Chesapeake Bay.

The current method of producing triploids is to breed tetraploid (4n) oysters with diploid (2n) oysters (Guo and Allen 1994). Tetraploids, which have four sets of chromosomes, produce twice as many gametes as diploids (Guo et al. 1996). The triploids resulting from this process are said to be “natural” or “genetic” triploids. An earlier process that produced triploids through chemical induction is thought to be much less efficient than the production of genetic triploids (Downing and Allen 1987; Allen et al. 1989). In that process, eggs were treated with a chemical called cytochalasin B that inhibited the formation of the second polar body during meiosis. This caused eggs to retain two sets of maternal chromosomes and one set of paternal chromosomes resulting in “chemical triploid” offspring. Detailed discussion of the probability of diploids being included in triploid cohorts is presented in Section 4.3 of Appendix B.

4.1.6.1 General Assessment of Consequences for Oyster Abundance

The alternative refers to “…using a suitable ….non-native oyster species…” Based on the findings of reviews of the life history characteristics of several oyster species (Section 2.3.1), only the Suminoe and Pacific oysters appear to have potential for use in aquaculture in the Bay. Insufficient information was available with which to assess the potential effects of expanded aquaculture using the Pacific oyster; consequently, this assessment considers a nonnative industry that uses only the Chesapeake Bay stock of the Suminoe oyster (which is descended from the Oregon stock; Section 1.4). VSC aquaculture trials and biological investigations conducted with triploid Suminoe oysters in recent years provided the basis for an evaluation of this alternative.

The development of assessment scenarios for evaluating the aquaculture alternatives is described in Appendix C and summarized in the discussion of Alternative 4 (Section 4.1.5). For the purpose of assessing these alternatives for the Draft PEIS, most aspects of the assessment scenario for Alternative 5 are the same as for Alternative 4, including the maximum size of an aquaculture industry considered to be economically viable, the number of oysters that industry would produce, the representative locations in which production would occur, and the allocation of that production among the representative locations. In reality, an industry based solely on triploid Suminoe oysters is not likely to develop to the maximum projected size for reasons addressed below, and the characteristics of such an industry probably would differ substantially from an industry based on the Eastern oyster. For example, concerns about the possibility of an unintended release of diploid Suminoe oysters, which are addressed in Section 4.1.6.2, could result in triploid aquaculture being restricted in location, magnitude, or both. The common assessment scenario, however, provides the basis for making a clear distinction between Alternatives 4 and 5.

One major factor responsible for differences between aquaculture operations with triploid Suminoe oysters and those with diploid or triploid Eastern oysters is the faster growth rate of the Suminoe oyster. Triploid Suminoe oysters could reach market size in as little as 9 months and most commonly in less than a year, in contrast to 12 to 18 months for triploid Eastern oysters, and up to 36 months for diploid Eastern oysters, depending on aquaculture methods.[11] The rapid growth of triploid Suminoe oysters means that aquaculture operations would require half or less of the area and half or fewer of the number of structures (e.g., off-bottom cages, floats) needed to cultivate diploid or triploid Eastern oysters. Using triploid Suminoe oysters to produce the maximum economically viable number of cultivated oysters would require about 1,302 acres using floats and about 2,256 acres using off-bottom cages. Deployment of floats would not require any particular bottom type and, thus, would provide somewhat greater flexibility in choice of location, although sheltered areas would still be required. Aesthetic effects and interference with boating and other water-related recreation, however, could severely constrain the areas in which floats might be deployed (Section 4.7). Off-bottom cages would require hard bottom, but not necessarily oyster shell. Field maintenance of these operations would have smaller costs than the costs for larger operations needed for the native oyster, which is discussed further in Section 4.6. Costs associated with biosecurity issues (e.g., certification of spat, state inspectors, monitoring) probably would contribute to increased costs.

Triploid Suminoe oysters appear to produce greater biomass per unit shell length (i.e., are heavier at a given shell size) than Eastern oysters. In limited studies conducted in 2005 and 2006, a biomass index (gm wet weight/mm shell length) for triploid Suminoe oysters for the period January to October was 80% greater than the index for diploid Eastern oysters, and 30% to 60% greater than the index for triploid Eastern oysters (data provided by Dr. S. Allen, VIMS). An operation using triploid Suminoe oysters, therefore, probably would produce substantially greater amounts of oyster meat than a similar operation using either diploid or triploid Eastern oysters over the same period of time. Mr. A.J. Erskine, of the Bevans Oyster Company, Cowart Seafood Corporation, confirmed that outcome based on his experience with cultivating triploid Suminoe oysters in recent pilot studies as part of the Virginia Seafood Trials.

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[11] Grow-out rates of oysters can vary widely depending on the season of deployment of spat, the size of the spat when deployed, the site-specific growing conditions, and water quality, in particular salinity. That variation is evident in data presented in Appendix C that were provided by participants in an aquaculture workshop. Figures presented here are intended to be representative of typical grow-out rates, recognizing that they can vary significantly.

Cultivated triploid Suminoe oysters would have to be contained in structures such as off-bottom cages or floats, based on the assumption that cultivating triploids in containment would be an effective protection against accidentally introducing a reproductively viable population into the Bay. Despite this general assumption, several pathways via which cultivation of triploid Suminoe oysters could result in a diploid introduction have been identified (Section 4.1.6.2). One step in one pathway is loss of triploids into the Bay. Recovery of oysters seeded in on-bottom operations is never complete; consequently, uncontained, on-bottom aquaculture would be likely to result in a substantial cumulative loss of triploid Suminoe oysters over a period of years. Such losses would be significantly reduced in confined operations, in which the only loss would be accidental. Floats, however, pose the greatest risk of accidental release of triploids because they are exposed to wave action during storms, boat collisions, etc.

Triploid Suminoe oysters would have to be produced in hatcheries. Diploid brood stocks of the Suminoe oyster (descended from the Oregon stock) are maintained at the University of Maryland’s Horn Point oyster hatchery and at VIMS. Dr. Stan Allen of VIMS produces all triploid Suminoe oysters used in studies and aquaculture trials in Chesapeake Bay. VSC trials have shown 70% to 90% survival of triploid spat to market size consistently, except at a few sites where all oysters died; the cause of the mortality was not determined. Based on that survival rate, about 750 million to 1 billion triploid spat would be needed to produce the projected maximum number of market-size triploid Suminoe oysters (676.4 million). Dr. Allen indicated that the current brood stocks of diploid Suminoe oysters probably could produce one billion spat per year, but that several years would be required to develop sufficient brood stock to produce that number of spat consistently or to support greater production. A facility with the production capacity of the University of Maryland’s Horn Point hatchery would be required to produce the one billion triploid Suminoe spat. That hatchery would have to be equipped with biosecurity systems for the diploid brood stock and for the processes used to produce triploids; therefore, the cost of producing the number of triploid Suminoe spat needed to support the projected industry would be greater than the cost of producing the required number of diploid Eastern oyster spat. The economic implications of this difference in costs are explored in Section 4.6.2.6.

Available habitat could support the maximum economically viable production of cultivated triploid Suminoe oysters.

Several kinds of mistakes at hatcheries could result in releasing some diploid spat in batches of triploid spat for use in aquaculture operations, which is explored in Section 4.1.6.2. One way to reduce the potential for such errors would be to centralize production in a single, State-certified hatchery. Operators at such a facility would be expected to be highly proficient and to implement rigorous quality controls, thus reducing the risk of human error. Such a hatchery could be used to provide the spat needed for all production throughout the Bay. Spat for use in the on-going aquaculture pilot programs and research with triploid Suminoe oysters are being produced essentially in this manner. Strict operation protocols and compliance monitoring of multiple hatcheries by a State regulatory agency might be an alternative approach to minimizing hatchery errors.

The same factors discussed with respect to Alternative 4 could constrain or prevent the development of the maximum viable industry for cultivated triploid Suminoe oysters

(Alternative 5); however, the outcomes of the factors could differ somewhat. Effects on other elements of the environment, such as boating and aesthetics, are discussed in later parts of Section 4, and those discussions assume the projected maximum industry production of triploid Suminoe oysters.

Availability of Habitat – Habitat would be a lesser constraint for this alternative than it would be for Alternative 4 because on-bottom, unconfined cultivation of triploid Suminoe oysters probably would not be permitted, and only a single cohort of Suminoe oysters would have to be in the water at any given time to reach the maximum production figure. The area required to cultivate triploid Suminoe oysters (about 1,301 acres using floats or 2,255 acres using off-bottom cages) would be substantially less than for Eastern oysters. For example, the aquaculture assessment scenario allocates 38% of total production to the Northern Neck site, where only about 483 acres would be required for maximum production of cultivated Suminoe oysters using floats. This example suggests that available habitat could support the maximum economically viable production of cultivated triploid Suminoe oysters.

Production Capacity – Because of their relatively rapid growth, cultivated Suminoe oysters would be likely to require greater quantities of food than would be needed to cultivate Eastern oysters. The locations used in recent VSC trials with triploid Suminoe oysters are likely to be optimal sites. The availability of a sufficient number of optimal sites to support the maximum production is not known. Food limitations could result in reduced growth rates for triploid Suminoe oysters in some areas, which could result in failure to achieve the projected maximum production. The carrying capacity of any candidate locations for a large-scale aquaculture operation would have to be assessed to avoid the potential for food limitation.

Rate of Industry Development – As discussed for Alternative 4, an industry capable of the maximum projected production would not be likely to develop within the 10-year assessment period established as a benchmark for comparing the alternatives.

Regulatory Constraints – The same regulatory constraints that would limit aquaculture under Alternative 4 would limit aquaculture under Alternative 5, particularly in Maryland. Requirements (e.g., biosecurity systems) that could be needed to obtain permits for using a nonnative species could be additional constraints.

Water Quality **–** Water quality criteria for the locations in which triploid Suminoe oysters could be cultivated would be at least the same as those for Alternative 4. Suminoe oysters may bioaccumulate some contaminants faster than Eastern oysters do (C. Mitchelmore, UMCES, CBL, pers. comm.). If such differences are documented for the parameters used to close waters to shellfish harvest, the criteria for safe harvesting of Suminoe oysters might have to be revised to more restrictive levels.

Economic Factors – All of the economic factors described for Alternative 4 would be applicable to Alternative 5. Several characteristics of the Suminoe oyster could affect its economic value for aquaculture and limit the growth of a Suminoe oyster industry. The species has a shorter shelf life than the Eastern oyster (i.e., it does not survive being out of water for as long as the Eastern oyster), which makes is less suitable for the more lucrative half-shell market. It is also more susceptible to disfiguration by the worm *Polydora*, which creates unattractive "mud blisters" on the shell (Section 4.1.1.2). The consequence of these factors and the additional cost of producing triploid Suminoe oyster larvae for the economics of this alternative are discussed in Section 4.6.2.

4.1.6.2 Potential for Introduction of Diploids as a Result of Cultivating Triploids

The most significant difference between Alternatives 4 and 5 is that Alternative 5 poses the risk of accidentally introducing a reproductively viable population of a nonnative species into Chesapeake Bay. An unintended introduction is considered a risk in this case because the use of sterile triploids in aquaculture is intended to exploit the potential economic benefits of the nonnative species while satisfying the desire of some stakeholders to avoid the potential ecological risks of introducing a nonnative species into the Bay. The pathways by which an inadvertent introduction might occur as a result of implementing Alternative 5 and their associated probabilities are discussed in detail in Appendix B (Sections 4.3.1 and 4.3.2) and summarized here. The likelihood that a diploid introduction would result from cultivating triploids was evaluated using a risk assessment process developed by the U.S. Department of Agriculture for evaluating the potential invasiveness of non-indigenous species (ANSFT 1996; Orr et al. 1993). Qualitative information and quantitative data were gathered to calculate the probability that Alternative 5 could lead to the establishment of a population of nonnative oysters in the Bay within 10 years of implementation. In this analysis, a potential reproductive population was considered to begin with two collocated, reproductive, diploid Suminoe oysters, and collocation was defined as individuals sharing 1 m^2 of space. This is intended to be a conservative definition of a reproductive population.

> The most significant difference between Alternatives 4 and 5 is that Alternative 5 poses the risk of accidentally introducing a reproductively viable population of a nonnative species into Chesapeake Bay.

The approach for this analysis consisted of two parts. The first part involved defining the pathways by which individual diploid Suminoe oysters could be released to the Bay from various aspects of the aquaculture operations. The outcome of the chain of events is expressed in terms of the number of diploid individuals that might result from each pathway for a representative aquaculture operation. The second part involved estimating the likelihood that the resultant diploids would be collocated and, therefore, could have the potential to be an initiating pair. The combined influences of all aquaculture operations were estimated within one of the locations identified in the aquaculture assessment scenario as a possible site for expanded aquaculture (Nanticoke River; Figure 4-4).

Six major pathways were identified that could contribute to the release of diploids. The first four pathways are depicted in Figure 4-6. Each pathway is composed of a series of events that would have to occur in sequence in order for that pathway to be fulfilled. Pathway A deals with the possibility that triploid oysters deployed to the field, although expected to be sterile, could in fact be fertile. If fertile triploids produce viable gametes, then that triploid could mate with a diploid to produce diploid offspring. Alternatively, a fertile triploid could mate with another triploid to produce diploid offspring. This is examined in Pathway B. Pathway C considers how diploids could arise during the diploid-by-tetraploid cross designed to produce triploids. Triploid cells are sometimes known to revert to the diploid state. If this reversion were

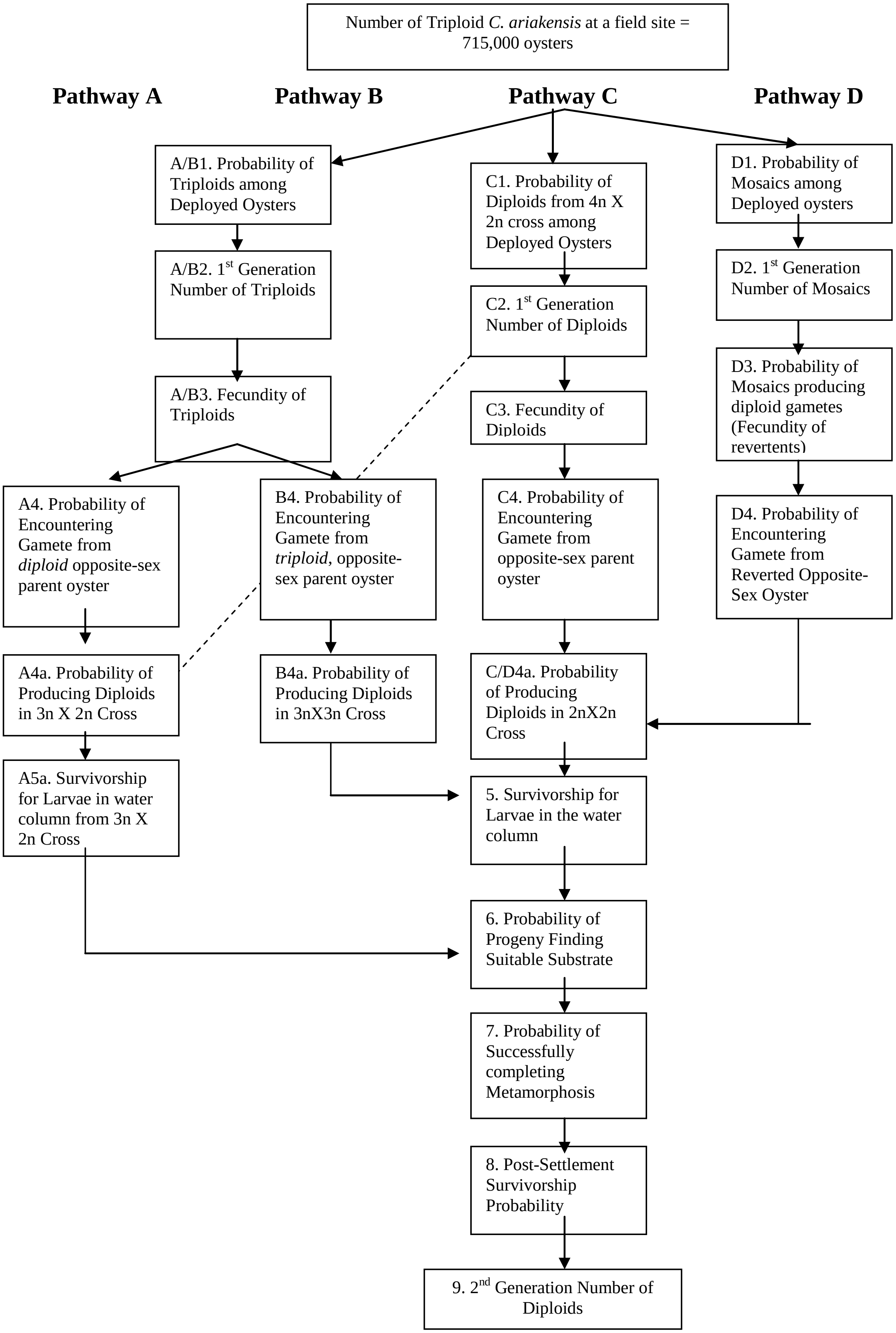

Figure 4-6. Model of pathways for triploid-to-diploid risk assessment; details of the probabilities associated with each element of the chain of events are discussed in Section 4.3.1 of Appendix B.

to occur within gametic cells, it could restore the reproductive capacity in the now triploid-diploid mosaic oyster. Pathway D looks at the likelihood that a revertent could arise and yield diploid offspring. Common elements in the first four pathways include the probability of finding suitable substrate, successful metamorphosis, settlement, and survivorship. The last two pathways (pathways E and F, not shown in Figure 4-6) address accidental releases either from the field site or from a hatchery. Attachment C of Appendix B includes a table describing known accidental releases from all deployments of triploids that have occurred since aquaculture pilot studies and research began in Chesapeake Bay. Such releases occurred, for example, when a Taylor float broke free from the PVC floats due to failure of the plastic ties used to secure it. In another case, an anchor struck and dragged one of the cages six feet. This caused the cage to break open, and the oysters to fall out. The data summarized in that table were used to estimate the probability of release represented by this pathway.

The final pathway (pathway F) considers the release of diploids from a hatchery due to a catastrophic event (e.g., a hurricane destroys a biosecure hatchery facility) or to human error. One example of human error could occur during production of triploids. Diploid-by-tetraploid crosses are engineered in the hatchery to produce triploids. If either the diploids or tetraploids from such crosses were to change sex, then either the diploids or tetraploids could mate with each other. These crosses could give rise to diploid offspring that might subsequently escape from the hatchery (M. Luckenbach, pers. comm.). The risk of an accident of this nature would increase in proportion to the number of facilities at which triploids were being generated because the likelihood of accidental violations of ICES' stringent biosecurity protocols would increase with the number of hatcheries. One means of minimizing this risk would be to centralize the production of larvae and spat to one or two locations that are certified specifically for these operations. Centralization of operations would allow for greater oversight of the implementation of quarantine protocols. In any event, there is no basis for quantifying error probabilities in Pathway F; therefore, the probability for this pathway is unknown and unpredictable. Any diploids arising from pathways E and F would enter pathways A, C, or D.

Another means by which Suminoe oysters might enter the Bay is a "rogue" introduction, in which some party obtains live triploid Suminoe oysters on the open market and places them in the Bay. Those triploids would then enter pathway F, except that the number of triploid oysters purposely placed in the Bay could be significantly larger than the number that might be released by accident. In addition, the planted triploids probably would be in closer proximity to each other than triploids released from aquaculture by accident. These factors would increase the probability of eventual production of diploids from the planted triploids. Also, given the large diploid brood stock of Suminoe oysters being maintained in hatcheries in the Bay area, an individual might somehow be able to obtain diploids from one of the triploid production facilities and plant them with the specific intent to initiate a self-sustaining population. The likelihood of a rogue introduction probably would increase with the number of triploid Suminoe oysters being cultured, but, as in the case of hatchery releases, there is no basis for quantifying the probability of these kinds of event.

A probability was assigned to each step within each pathway for which a probability could be quantified (Section 4.3.1 of Appendix B). All available sources of information for the Suminoe oyster were collected and evaluated for use in the chain of events. Sources of information included peer-reviewed journal articles, conference proceedings, empirical data from experiments in progress, and principal investigators' annual reports to funding agencies. The VSC trials represent some of the largest studies of triploid Suminoe oysters, and information from those studies also was valuable. When information for Suminoe oysters was not available, information for an ecologically similar congener such as the Eastern or Pacific oyster was substituted. The amount of information about the biology of the Suminoe oyster that was useful in this exercise was extremely limited, and numerous assumptions were necessary to carry out this evaluation; therefore, the outcomes of this model must be viewed with caution. Estimates used for each step in the pathways were selected to ensure that the defined risk would be conservative (i.e., would tend to overestimate probabilities of events).

Carrying through the appropriate computations using the probabilities shown in Table 4-2 of Appendix B, the cumulative number of diploid Suminoe oysters that might be "at large" in the Bay through all pathways from a representative aquaculture location after 10 years was 271 oysters. This value was calculated for a hypothetical representative aquaculture operation in a single location in the Bay. The specific number would change in response to changes in the assumed number and concentration of aquaculture operations in any single location.

For successful fertilization to occur, oysters must spawn within close proximity of each other. This evaluation assumed that the presence of 2 or more individuals within 1 m^2 constitutes a reproductive population. Predicting how diploids produced through any of the pathways would be dispersed throughout waters in which aquaculture operations might be sited was beyond the scope of this analysis. A simplifying and conservative assumption was that all the diploids produced would successfully find and set on available habitat in the water body in which they were produced. Considering the amount of oyster habitat available in the representative tributary (8,900,000 m^2 in Nanticoke River, GIS layers from the Maryland Bay Bottom Survey), the probability that at least two diploids yielded by the pathways would be collocated on suitable habitat was estimated to be 0.004, or about 1 in 250 over a period of 10 years. This approach is conservative because it assumes that all diploid larvae produced would find suitable habitat and settle successfully within the relatively small area of suitable habitat within the water body. The hypothetical Nanticoke operations were allocated to produce 5% of the estimated maximum aquaculture production for the Bay; therefore, over the 10-year timeframe, the probability of establishing a reproductive population is estimated to be 8% (0.004*20; Section 4.3.2 of Appendix B). That is, 10 years after implementation of Alternative 5, assuming realization of the maximum industry, the probability that two diploid Suminoe oysters would occur within the same one square meter of habitat somewhere in the Bay would be 8%. This calculation assumes that no diploids would die during that period and that they would not be dispersed beyond the tributary in which the operations were implemented. The probability of collocation of two diploid Suminoe oysters is related to the number of triploid oysters in aquaculture and the availability of substrate. Each of these factors (i.e., an increase in abundance and a decrease in available substrate) would affect the density of individuals and the potential for two individuals to be collocated. The 8% estimate is very conservative because it presumes that the maximum aquaculture industry considered to be economically viable would be in place within Bay waters for 10 continuous years.

If escaped diploids survived for an extended period of time, and the level of triploid aquaculture activity remained high in fixed locations, the number of diploids at large in the Bay could continue to accumulate, and the risk of an unintentional introduction would increase proportionately with time.

The likelihood of occurrence of collocated diploid individuals would decrease if

- an aquaculture industry of the projected size were unable to become established within a decade or ever in the future;
- ICES quarantine protocols were followed properly at hatcheries that produce triploid larvae and spat;
- hatchery production of triploids were concentrated in a central facility;
- sizes of individual aquaculture operations were limited to reduce the probability that two diploids could be present and reproduce;
- the period between deployment and harvest were not to overlap with the reproductive season;
- diploid eggs, larvae, or juveniles were to suffer high mortality (e.g. predation from blue crabs);
- suitable habitat were not available for settling diploid larvae;
- some larvae were to settle on bars that prove to be unsuitable for reproduction (i.e., “sink bars”) and could not contribute to further population growth;
- competition for space with the Eastern oyster were strong for settling larvae;
- collocated diploid recruits were of the same sex or failed to successfully reproduce;
- diploid Suminoe oysters were to become susceptible to diseases in the Bay;
- the rate of reproduction of diploid adults were to be so limited that no sustainable population is ever established.

The likelihood of occurrence of collocated diploid individuals would increase if

- ICES quarantine protocols were not followed properly at hatcheries that produce triploid larvae and spat;
- hatcheries were distributed throughout the Bay, magnifying the potential for human error;
- continuous aquaculture were to occur in the same location over many years;
- triploid Suminoe oysters were deployed at high densities;
- the period between deployment and harvest were to overlap with a reproductive season;
- the number of escaped triploids that revert to reproductive diploids were to accumulate over time;

- larvae were readily able to find suitable habitat on which to settle;
- larvae were to settle on bars demonstrated to produce significant numbers of larvae that disperse to other bars in the Bay;
- competition for space were weak for settling larvae;
- diploid eggs, larvae, or juveniles were to suffer low mortality (e.g., predation from blue crabs) and survive indefinitely;
- diploid Suminoe oysters were to continue to resist diseases occurring in the Bay;
- a rare storm strong enough to damage or destroy a hatchery or other aquaculture facilities were to occur;

- the general public was sold live triploid Suminoe oysters that could be reintroduced to the Bay.

Given the many unknowns in the two component analyses for this evaluation and the variety of possible pathways of introduction, no specific level of risk could be determined for the overall likelihood that implementing Alternative 5 would result in an unintended introduction. Some stakeholders believe that an unintended introduction is a certainty if large-scale triploid aquaculture is implemented; however, no probability analyses have been published to support this view. The level of uncertainty associated with evaluating this risk is high due to lack of information about many contributing factors.

Although the probability that an initiating pair of diploid oysters in close proximity to each other in the Bay could arise from triploid aquaculture appears to be small, no specific level of risk of unintentional introduction resulting from implementing Alternative 5 could be determined because of the many uncertainties involved in the analyses.

The probabilities calculated here do not address the likelihood that the initiating pair (i.e., two reproductively capable oysters within one square meter of each other) would survive to reproductive age and reproduce successfully, or that their progeny would settle and reach reproductive age. If that sequence of events occurred (i.e., actual propagation of a population), the oyster population and ecological consequences would be similar to those discussed for the proposed action (Sections 4.1.1 and 4.2.1). The number of diploids that could be introduced in this manner, however, would be many orders of magnitude less than the number to be seeded in the Bay according to the representative introduction plan for the proposed action; consequently, the time frame over which major changes in oyster populations in the Bay would occur would be extended over much more than a decade. The potential rate of dispersal throughout the Bay cannot be estimated because the specific locations and quantities of larvae that would be introduced cannot be predicted.

The number of reproductive Suminoe oysters that could be released into the Bay as a result of cultivating triploids would be many orders of magnitude smaller than the number to be seeded for the proposed action; therefore, many more years would be required to realize any major consequences in Chesapeake Bay or other East Coast estuaries.

4.1.7 Alternative 8: Combination of Alternatives

4.1.7.1 Combination 8a – Eastern Oyster Only (Alts. 2, 3, & 4)

This combination of alternatives differs from Combinations 8b and 8c in that no reproductively viable (diploid) or sterile (triploid) Suminoe oysters would be introduced into Chesapeake Bay. Under this combination of alternatives, Bay-wide oyster abundance probably would increase in low-salinity waters and remain constant or continue to decline in high-salinity waters in the 10 years following implementation. Some population growth might occur in higher salinities if disease resistance developed in the population. Local increases in oyster abundance would occur where aquaculture operations increased, but many factors could constrain the development of the industry and decrease the likelihood of achieving the maximum economically viable production of oysters. This combination has the least potential of the three combinations for producing a significant increase in oyster abundance. Efforts to increase the abundance of the Eastern oyster included in this combination of alternatives would require significant increases in spat production (approximately 1.5 times greater than current production capacity at the Horn Point hatchery) and a two-fold increase in the amount of habitat restored (from an average of about 1200 acres per year in Maryland and Virginia in recent years to an average of about 2200 acres per year).

4.1.7.2 Combination 8b – Eastern Oyster and Triploid Suminoe Oysters (Alts. 2, 3, 4, & 5)

Under this combination of alternatives, management actions involving a nonnative species would be restricted to those associated with cultivating triploid Suminoe oysters. Bay-wide oyster abundance probably would increase in low-salinity waters in response to continuing restoration efforts and remain constant or continue to decline in high-salinity waters in the 10 years following implementation. Some population growth might occur in higher salinities if disease resistance developed in the population. Local increases in oyster abundance would occur where aquaculture operations were established and expanded, but many factors could constrain the development of the industry and decrease the likelihood of achieving the maximum economically viable production of oysters. The size of operations may be less than under 8a because cultivating triploid Suminoe oysters would require fewer oysters and less space. Large scale and/or long-term cultivation of triploid Suminoe oysters is likely to result in an eventual introduction of reproductively viable Suminoe oysters (Section 4.1.6.2). Significant increases in spat production (approximately two times greater than current production capacity at the Horn Point oyster hatchery) and a two-fold increase in recent levels of habitat restoration would be required to implement restoration activities identified in this combination.

4.1.7.3 Combination 8c – Eastern Oyster and Diploid and Triploid Suminoe Oysters (Proposed Action + Alts. 2, 3, 4, & 5)

This combination has the greatest potential to significantly increase oyster abundance throughout the Chesapeake Bay; however, uncertainty is high regarding whether that potential would be realized because of the many potentially constraining factors (Section 4.1.1). Local increases in oyster abundance would occur where aquaculture operations were established and expanded, but many factors could constrain the development of the industry and decrease the likelihood of achieving the maximum economically viable production of oysters. The size of operations may be less than under 8a because cultivating triploid Suminoe oysters would require fewer oysters and less space. Significant increases in spat production (two to three times greater than current production capacity at the Horn Point hatchery) would be needed to fully implement all of the management measures included in this combination. Implementation of this alternative also would require a two-fold increase in the average amount of oyster habitat that has been restored in recent years.

4.2 OTHER COMPONENTS OF THE ECOSYSTEM

An ERA (Appendix B) was conducted to assess the potential ecological consequences of the proposed action and alternatives on Eastern oysters and all other components of the ecosystem of Chesapeake Bay. The decision to use an ERA as an assessment tool for this PEIS was based on the NRC's recommendation to evaluate the potential ecological outcomes of introducing the Suminoe oyster into Chesapeake Bay before deciding to implement the introduction (NRC 2004). Using an ERA as the basis for assessing the environmental consequences of a proposed action and alternatives is not a typical element of the NEPA process (Section 1.1). Using the results of an ERA to compare the potential benefits of a series of actions in addition to their risks also is atypical; consequently, the results of the assessment are presented differently in the ERA report (Appendix B) than is appropriate for use in a PEIS. Given these disparities, the results of the ERA had to be reorganized and, in some cases, extrapolated to contribute to the assessments presented in this Draft PEIS.

An ecological risk assessment (ERA) provided the basis for characterizing the environmental consequences of the proposed action and alternatives on the Chesapeake Bay ecosystem.

In the context of the stated purpose of action for this PEIS, the key ecological risk of the proposed action and all the alternatives is the risk of failing to restore the Bay-wide population of oysters to the historical reference level and, consequently, failing to restore the level of ecological services that oysters once provided to the ecosystem of Chesapeake Bay. In the terms used in risk assessment as applied in the ERA, therefore, oyster abundance is the "stressor," meaning that changes in the abundance of oysters can affect "receptors" (see Sections 2.2 and 2.3 of Appendix B). Receptors in this case are a wide variety of groups of species that could be affected by changes in the abundance of oysters in the Bay.

Oysters interact with the components of their ecosystem both directly and indirectly in many different ways. Section 2.3 of Appendix B describes the approach used to manage the enormous task of assessing ecological risks across such a wide array of possible interactions between the stressor and many receptors and such a large geographic scale as the entire Chesapeake Bay. Fourteen representative species or communities were designated as receptors for the ERA (Draft PEIS Section 3.2; Appendix B Section 2.3). Collectively they represent the major components of the Bay's ecosystem that could respond to changes in oyster biomass via direct or indirect mechanisms. Descriptions of the potential mechanisms of interaction between oysters and the receptors are provided in Section 3.2 of this PEIS and in Section 2.4.2 of Appendix B.

The researchers who performed the ERA developed a relative risk model (RRM) for Chesapeake Bay to characterize the direct and indirect ecological influences of changes in the abundance of oysters that might result from implementing the alternatives. RRMs have been shown in other applications to be useful tools in the field of risk assessment. RRMs have been developed to evaluate declines in Pacific herring (Landis et al. 2004), environmental conditions in the Willamette and McKenzie rivers in Oregon (Luxon and Landis 2005), rain forest preserves in Brazil (Moraes et al. 2002), and other regional assessments (Landis 2005). The RRM developed for this application required much simplification of the complex interactions between oysters and receptors in Chesapeake Bay in order to make the assessment manageable; nevertheless, it captures the major ways in which oysters influence the entire ecosystem.

An RRM synthesizes quantitative and qualitative information to derive a numerical value called an RRM score. In the ERA for Oyster Restoration Alternatives (Appendix B), RRM scores represent the relative degree of influence that changes in oyster biomass projected to result from implementing an alternative could have on each receptor. The relative degree of influence was derived by considering the various direct and indirect ways that oysters influence other organisms and comparing the magnitudes of those individual kinds of interactions (Section 3.4.3 of Appendix B). The magnitude of change in oyster abundance and the spatial distribution of that change in the Bay would differ among the alternatives (Section 4.1). Those differences would then influence receptors to different degrees in different regions of the Bay. Some receptors, such as reef-oriented fish, use oysters directly for food or habitat, and the relative influence of a change in oyster abundance on such receptors would be high. Other receptors interact with oysters only indirectly, such as by preying on another receptor that might be influenced by oysters in some way. RRM scores were adjusted for direct and indirect relationships according to the proportion of suitable bottom habitat available for oysters in various segments of the Bay (Section 3.4.3.1 of Appendix B). The scores should be viewed in relation to one another and are intended to indicate relative degrees of influence of the stressor on different receptors within one alternative.

RRM scores can be either positive or negative. A positive influence is any consequence of a change in oyster biomass that might support or encourage an increase in the abundance, health, or distribution of the receptor population. A negative influence is any consequence of a change in oyster biomass that might cause or contribute to a decrease in the abundance, health, or distribution of the receptor population. “Positive” and “negative” do not imply “good” or “bad” outcomes for the Bay as a whole from a management perspective; the terms refer only to potential increases or decreases in ecological components. For example, a negative influence on phytoplankton (i.e., a decrease in phytoplankton) might be judged to be good from a management perspective because it could help improve water quality.

RRM scores are presented in stacked histograms (i.e., multicolored bars). Each bar is composed of color-coded segments such that each segment corresponds to an individual receptor. The width of the segment corresponds to the relative magnitude of influence on that receptor. The placement of the segment in relation to “0” on the scale indicates the direction of the influence (i.e., left of 0 represents a negative influence; right of 0 indicates a positive influence). The RRM results for a single alternative are presented separately for each of six state/salinity zones: Maryland oligohaline (MD OH), Maryland mesohaline (MD MH), Maryland polyhaline (MD PH), Virginia oligohaline (VA OH), Virginia mesohaline (VA MH), and Virginia polyhaline (VA PH). These zones were established based on some geographical limitations of exploratory modeling projections of the abundance of Eastern oysters described in Appendix A and data availability. Salinity zones were used in presenting RRM results because the geographical distribution of many of the receptors in the Bay is strongly influenced by salinity, and oligohaline, mesohaline, and polyhaline zones[12] are commonly used in characterizing ecological communities (of which the receptors are members) of the Bay ecosystem. The degrees of influence (i.e., RRM scores) varied by several orders of magnitude; therefore, RRM scores are reported on an approximate logarithmic scale ranging from +5 to -5 to capture both very small and very large influences, as described in Appendix B (Section 3.4.3.1).

Deriving RRM scores required quantifying the expected change in the biomass of oysters over a period of 10 years following implementation for each of the alternatives. RRM scores could not be derived for the proposed action because the Bay-wide abundance of oysters that might result from introducing the Suminoe oyster could not be estimated at this time (Section 4.1.1); consequently, the potential ecological effects of the proposed action were assessed through an interpretive synthesis of findings of applicable research (Section 4.2.1.). The assessment of the proposed action assumes that implementing that action would produce a self-sustaining population of Suminoe oysters and that the species would become widely established and abundant throughout the Bay. This assumption is conservative from the perspective of an impact assessment because the potential for adverse ecological effects would be proportional to the size of the population of Suminoe oysters, and any adverse effects attributable to the introduced oyster would be maximized if the proposed action were “successful” and the Suminoe oyster population met or exceeded the historical reference population goal defined for the PEIS.

Although limitations were prescribed on acceptable applications of the results of exploratory modeling to project changes in oyster abundance that might result from implementing the alternatives (see Note to Readers of Appendix A), modeled projections were used to provide a basis for contrasting potential differences in ecological outcomes at the geographic scale of the six state/salinity zones among the alternatives. All limitations and uncertainties identified for the demographic model are equally applicable to the RRM characterizations.

4.2.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

As noted above, this evaluation assumes a successful introduction of the Suminoe oyster, in which the species would become established and abundant throughout the range of the Eastern oyster in the Bay. This assumption represents a “worst case” scenario from the perspective of

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[12] Exploratory modeling results for individual oyster bars were grouped into low, medium, and high salinity categories that roughly match oligohaline, mesohaline, and polyhaline zones. In the model, salinities of bars vary annually according to modeled freshwater input; therefore, the classification of bars near the boundaries of salinity zones can change from year to year. The assignment of bars to zones was based on the average salinity at each bar over the 1000 simulations for each alternative. The result is that many bars characterized as oligohaline based on model simulations are located in Chesapeake Bay Program segments classified as mesohaline.

stakeholders who believe that introducing a nonnative oyster is undesirable. That is, the following assessments of the potential ecological effects of the proposed action examined the potential consequences if the species were to become abundant and widespread. If an introduction were to fail to establish a large and self-sustaining population of Suminoe oysters throughout the Bay, there would be no potential for adverse ecological effects, except the potential for introduction of new diseases, which is discussed in Section 4.3.1.

4.2.1.1 Provision of Ecosystem Services

If Suminoe oysters were to become established throughout the Bay, the risk that they would not provide ecosystem services similar to those afforded by Eastern oysters is low (Section 4.2.1 of Appendix B). The ability to create habitat by building reefs is one such ecosystem service. Oyster reefs form through many generations of gregarious settlement, growth, and in situ mortality. The resulting reef is a conglomeration of many layers of accreted shell material with a dense cover of live oysters growing on the surface. Nearly all species of oysters throughout the world, including those of the genus *Crassostrea*, form reefs (R. Mann, VIMS, pers. comm.). The ability of oysters to construct reefs is a desirable quality that can have many positive ecological effects. Reefs provide complex, three-dimensional habitat for reef-dwelling organisms such as crabs, worms, and fish. Such biodiverse reefs represent an important food resource for several commercially valuable species that occupy higher trophic levels. The close proximity of oysters to each other on reefs also increases the likelihood of successful fertilization (Pavlos 2004). Another effect of reef-building is its influence on shell budget. Oyster larvae require sediment-free, hard surfaces for successful settlement. Growing and expanding oyster populations require new shell and increased coverage of the bottom with shell. Laboratory studies have demonstrated that the larvae of both Suminoe and Eastern oysters readily settle on the shells of either conspecifics or congenerics (Tamburri et al. 2008). The ERA considered ecological services associated with provision of reef habitat for other Bay species, provision of food for other Bay species, and filtration capacities of both oyster species. If the introduction were successful, the species would be expected to populate historical oyster habitat and other hard substrates in the subtidal zone.

The Suminoe oyster is expected to provide ecological services in the Bay similar to those of the Eastern oyster.

Because the Suminoe oyster can tolerate high loads of suspended sediment and exist in muddy systems (albeit on shell), reefs of the species could provide localized benefits for SAV by buffering the action of waves and currents and by filtering suspended solids from the water. Reefs of the Suminoe oyster would provide habitat for other species; however, no studies have investigated if the small-scale structure of reefs of Suminoe oyster or mixed-species reefs would attract and support the same biological community that reefs of the Eastern oyster do. The ERA concluded that the Suminoe oyster does not appear likely to overgrow soft bottom areas. If the Suminoe oyster were to expand into soft-bottom areas, however, that expansion could begin to compensate for the significant loss of hard-bottom habitat that has occurred in recent decades (approximately 70% loss over the past 20 years; Section 4.1.1).

The ERA concluded that the Suminoe oyster does not appear to be likely to overgrow soft bottom areas.

The presence of a self-sustaining population of Suminoe oysters in Chesapeake Bay would pose a negligible to low risk of diminishing ecosystem services provided by other components of the ecosystem (e.g., soft-bottom benthos; Section 4.2.1 of Appendix B); however, the level of uncertainty associated with that conclusion is moderate. The uncertainty is a consequence of inadequate understanding of all of the many and varied ways in which oysters interact with other components of the Bay ecosystem, as well as lack of knowledge about the characteristics of Suminoe oyster reefs or mixed-species reefs in open waters of Chesapeake Bay. Although species interactions are considered the most important mechanisms by which changes in the abundance or kind of oysters in the Bay could influence other receptors, many of the specific details of these interactions are not well known or quantified. Uncertainty increases with the number of linkages between ecological receptors and oysters (Figure 2-1 of Appendix B).

4.2.1.2 Potential for the Suminoe Oyster to Introduce and Spread Disease

The possibility that introducing the Suminoe oyster could result in introducing and spreading diseases to other species in the Bay is an important potential effect on the Chesapeake Bay ecosystem. East Coast populations of the Eastern oyster have been devastated by diseases introduced through past importations of nonnative oysters (Section 1.2); consequently, the possibility of introducing new diseases that could further compromise the health of shellfish and other species in the Bay is a major concern related to implementing the proposed action. As described in detail in Section 4.2.3 of Appendix B, if ICES protocols are followed, introducing Suminoe oysters from the Oregon stock would pose a negligible risk of introducing new shellfish diseases into Chesapeake Bay.

If ICES protocols are followed, introducing Suminoe oysters from the Oregon stock would pose a negligible risk of introducing new shellfish diseases into Chesapeake Bay.

The NRC (2004) did not consider the possibility that an established population of Suminoe oysters could provide a reservoir for future diseases that may be introduced to the Bay and subsequently pose a risk to other shellfish species. The ERA judged this additional, incremental ecological risk to other bivalve species (e.g., clams, mussels, oysters) in the Bay to be low. The logic for this conclusion is as follows: If a pathogen that is able to infect a variety of bivalve species were to be introduced in the future, its potential host species are already present in the Bay, and the addition of the Suminoe oyster would provide only one more host species. The absence of the Suminoe oyster would not eliminate the future ecological risk. Its presence would represent a small incremental ecological risk to other bivalve species; the magnitude of the additional risk would be proportional to the size of the population of the Suminoe oyster.

The ability of Suminoe oysters to transmit diseases appears to vary with the disease.

Infected oysters in an aquaculture setting can transmit some diseases to other oysters, suggesting that if Suminoe oysters were to become abundant in the Bay, the species could serve as a disease reservoir that would exacerbate infection of the Eastern oyster Under aquaculture conditions, Suminoe oysters with 73% to 92% prevalence of *P. marinus* successfully transmitted the infection to diploid Eastern oysters to prevalence levels of 50% to 60% (Vasta et al. 2006, 2008).

Breitburg et al. (2007) demonstrated that proximity to infected individuals may be important for disease transmission. They found that the infection rate for all oysters (triploid Suminoe oysters, diploid Eastern oysters, and triploid Eastern oysters) was relatively low (prevalence 5%-15%) when they were placed 10 to 12 m away from caged diploid Eastern oysters that had been infected with Dermo. When placed inside the cage with infected diploid Eastern oysters, all oysters had greater infection rates (prevalence of 55% for caged triploid Suminoe, prevalence of 81% for caged diploid Eastern oysters, and prevalence of 87% for caged triploid Eastern oysters) compared to oysters located outside the cages. Burreson et al. (2005) placed *Bonamia*-infected Suminoe oysters in aquaria with Suminoe oysters that had not been previously exposed to *Bonamia*. Analyses at four weeks and at six weeks indicated that *Bonamia* had not been transmitted to the previously *Bonamia*-free Suminoe oysters. The ability of Suminoe oysters to transmit diseases, therefore, appears to vary with the disease.

Reece et al. (2008) showed that the pathogen *Perkinsus beihaiensis* could be transmitted from the oyster *Crassostrea hongkongensis*, a species that is easily confused with the Suminoe oyster based on visual identification, to other bivalve species, including the Eastern oyster, the Suminoe oyster, and the hard clam *Mercinaria mercenaria*. This study reflects the potential for a wild oyster from China to serve as a vector for transmitting disease to other bivalves within Chesapeake Bay if an introduction were to occur without following ICES protocols.

4.2.1.3 Ecological Effects of a Successful Introduction on Other Species

Based on the conclusion that Suminoe and Eastern oysters are likely to provide similar ecological services in Chesapeake Bay, the extent to which the proposed action would influence ecosystem services in Chesapeake Bay would be a function of the extent to which it resulted in an increase in oyster abundance. As discussed in Section 4.1.1, available data, information, and analysis tools are insufficient to predict the likelihood of success of the proposed action or the resulting abundance of oysters in the Bay; consequently, the RRM was not employed to evaluate the ecological consequences of the proposed action. If successful, the proposed action would be likely to result in a substantial increase in ecological services of oysters in Chesapeake Bay, in particular an increase in high-salinity waters where Eastern oysters are most severely affected by Dermo and MSX. These would include services related to providing food and habitat, buffering SAV and shorelines against waves and currents, and increasing water clarity (Section 4.3). The habitat provided by oysters and their influences on algae, SAV, and water quality will affect the other ecological receptors, including the fish and wildlife of the Bay. The relative degree of influence of the Suminoe oyster on other ecological receptors would be proportional to changes in oyster biomass in a manner similar to the influences portrayed for the native oyster. These influences are largely positive, except for some small negative influences associated with reducing the biomass of algae. These include negative influences on species that rely on planktonic algae for food. Given the scale of anticipated reductions, these negative influences on algae biomass would have positive influences on other ecological receptors that use SAV.

4.2.1.4 Potential Outcome of Competition between Suminoe and Eastern Oysters

The possibility that an abundant and self-sustaining population of Suminoe oysters in Chesapeake Bay might drive the Eastern oyster to extinction is another potential ecological effect of significant concern among some stakeholders. This topic is discussed in detail in Section 4.2.2 of the ERA (Appendix B). The ERA concluded that the risk is moderate to high that Suminoe oysters would interact and compete with Eastern oysters. The Suminoe oyster was identified as a candidate for introduction to Chesapeake Bay because its salinity and temperature requirements closely match those of the Eastern oyster (Section 4.1.1); therefore, the two species would be likely to occupy the same habitat. The two species would interact in several ways that were discussed in Section 4.1.1, but their responses to some stressors differ. The Suminoe oyster is more vulnerable to hypoxia and to exposure in intertidal areas, which might provide some degree of niche separation between the species. The Eastern oyster could be favored on deeper bars that may experience episodes of hypoxia or anoxia, and in intertidal areas. The amount of intertidal oyster habitat within the Chesapeake Bay is very limited and represents only a small percentage of total historical oyster habitat in the Bay; therefore, the magnitude of the benefit of the intertidal area to Eastern oysters (i.e., for avoiding competition with the Suminoe oyster) would be small. Although experiments indicate that the Eastern oyster tolerates hypoxia better than the Suminoe oyster (Section 4.1.1), exposure to hypoxia increases the intensity of Dermo and MSX infections in Eastern oysters and the rate of mortality from those diseases (Paynter 1996), which would minimize the Eastern oyster's competitive advantage in areas that experience intermittent hypoxia. The Suminoe oyster's rapid growth and disease resistance would afford the species a competitive advantage in high-salinity waters, but the advantage would be less at low salinities (Section 4.1.1).

The ERA concluded that the risk is moderate to high that Suminoe oysters would interact and compete with Eastern oysters. The Suminoe oyster's rapid growth and disease resistance would afford the species a competitive advantage in high-salinity waters, but the advantage would be less at low salinities.

Although most of the interactions described in the ERA are negative in nature, one positive interaction is possible. A successful population of Suminoe oysters might produce shell for colonization by oyster spat of both species, resulting in the formation of mixed-species reefs. The Suminoe oyster is most commonly found in mixed-species reefs in its native waters. In that circumstance, a naturalized population of the Suminoe oyster could contribute to the sustainability of both species. The ERA concluded that the two species are likely to co-exist, but that the form of that co-existence could range from local extinction of one or the other of the species to mixed reefs (Section 4.2.2 of Appendix B). The relative dominance of either of the species probably would vary with local environmental conditions. Uncertainty about the nature and extent of competitive interactions between the two species is considered moderate to high because nearly all of the available information comes from laboratory studies or limited field trials, which may not accurately characterize the outcomes if both species were present in the same location in the open waters of Chesapeake Bay.

The ERA concluded that the two species are likely to co-exist, but that the form of that co-existence could range from local extinction of either species to mixed reefs.

4.2.2 Alternative 1: No Action

This alternative involves continuing current oyster restoration and repletion programs in Maryland and Virginia and managing oysters under current rules and regulations as described in Section 4.1. The alternative was anticipated to result in little or no increase in Bay-wide oyster biomass over a 10-year period following implementation. Any increase probably would occur in the low-salinity zone in Maryland (Section 4.1.2). Figure 4-7 presents expected RRM outcomes for Alternative 1 that reflect the anticipated zone-specific changes in oyster abundance. The ERA predicted small potential negative influences for phytoplankton (via increased consumption by oysters), the benthic soft-bottom community (via reductions in the amount of organic matter from phytoplankton that reaches the sediment), zooplankton (via competition with oysters for phytoplankton food), planktivorous fish (via reduction in phytoplankton food), and avian soft-bottom feeders (via indirect effects of potential reduction in the soft-bottom community) as a result of increased oyster abundance in the state/salinity zones where oyster abundance would increase (most prominently in the MD OH). Note that the potential for competition for food between oysters and other receptors is based on the interactions among species that share phytoplankton resources either directly or indirectly. Those species are unlikely to be food-limited in Chesapeake Bay, except in circumstances where very high densities of oysters may be present in restricted areas; RRM scores reflect the potential for those interactions to occur because of the biological characteristics of the receptors, but do not represent a predicted Bay-wide effect.

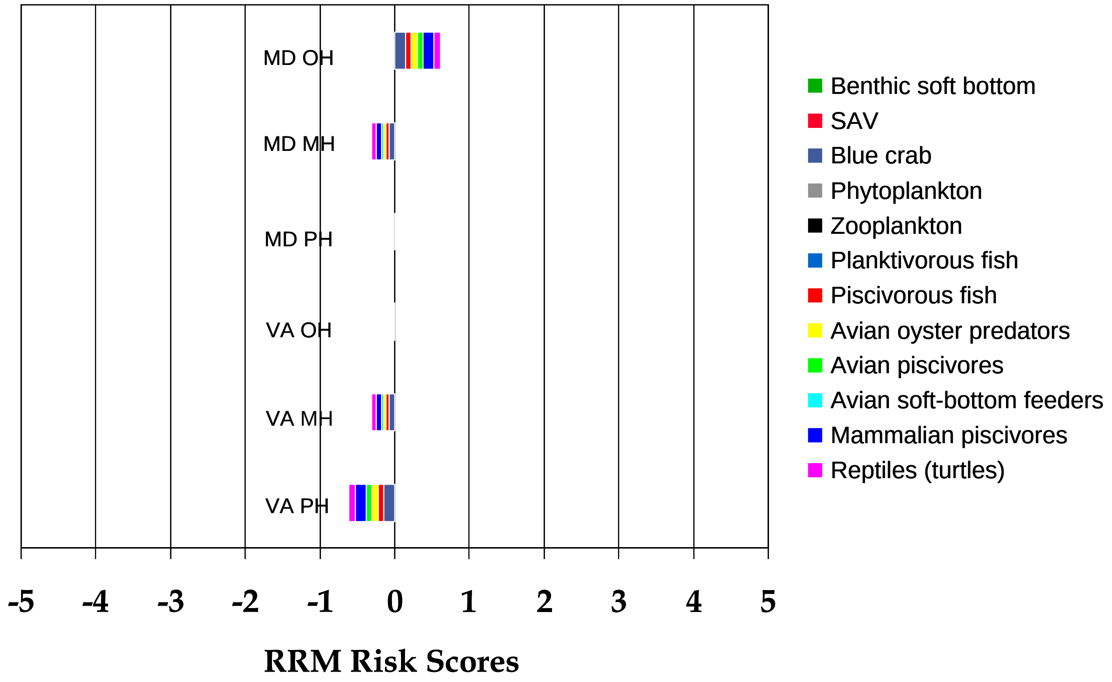

Figure 4-7. RRM outcome for Alternative 1. The scores were adjusted to account for the amount of oyster habitat in the respective salinity zones (Appendix B).

The ERA predicted positive influences for all other receptor groups in the zones with increased oyster biomass; all of those receptors would benefit directly or indirectly from increases in oyster biomass, either as a source of food or habitat, or indirectly through changes in water quality. The most positive influences would occur in the MD OH zone, which reflects the greater increase in biomass anticipated in that zone. In contrast, the most negative influences would occur in the VA PH zone, where the greatest relative decrease in oyster biomass is anticipated. The RRM value for benthic hard bottom and reef-oriented fish (not presented in Figure 4-7) ranged from -1 to 2 in Maryland zones and from -0.01 to -2 in Virginia zones. These differences between the states for benthic hard bottom and reef-oriented fish reflect the relative increase in oyster biomass predicted for the MD OH zone and the relative decrease in oyster biomass predicted for all of the salinity zones in Virginia.

4.2.3 Alternative 2: Enhance Restoration

Alternative 2 represents an enhancement of restoration programs for the Eastern oyster beyond the level of current programs, as described in Section 4.1.3. Restoration under this alternative involves only the Eastern oyster; therefore, ecological interactions involving oysters are expected to be similar to those observed historically in the Bay. As described in Section 4.1.3, the greatest increases in oysters under this alternative would be expected in low-salinity waters in Maryland, and an overall increase of as much as a factor of five in Bay-wide abundance might occur. Potential positive and negative influences for all receptor groups would stem from direct or indirect effects due to increases or decreases in oyster biomass, either as a source of food or habitat, or through changes in water quality. Figure 4-8 presents RRM scores for Alternative 2. All the projected influences on the groups of ecological receptors are small (less than 1), but they are greater than those projected for Alternative 1. The small negative influence that increasing oyster biomass would have on phytoplankton and animals that depend on phytoplankton can be seen within the MD OH zone. As indicated for Alternative 1, the RRM scores reflect the potential for food-related interactions to occur because of the biological characteristics of the receptors, but do not represent a predicted Bay-wide effect. The greater magnitudes and numbers of positive influences in the MD OH zone compared with Alternative 1 reflect the greater increase in oyster biomass anticipated to occur there. The RRM values for benthic hard bottom and reef-oriented fish ranged between 0.1 and 5 in the Maryland zones; they ranged between -1 and 1 in the Virginia zones, where declines or only slight increases are anticipated.

The increase in oyster biomass expected in oligohaline waters in Maryland over the 10 years following implementation of Alternative 2 would be driven primarily by spat planting rather than by enhanced reproduction of a growing in-situ oyster population because oyster reproduction is minimal at low salinities, as described in Section 4.1.3. This suggests that the population would begin to decline after the amount of spat planting reached its maximum, in year 7 of the representative implementation plan (Section 4.1.3). As in the case of Alternative 1, potential development of disease resistance could contribute to greater population growth, while continuing habitat loss would constrain that growth. RRM scores would change in proportion to the change in oyster biomass over time.

4.2.4 Alternative 3: Harvest Moratorium

Alternative 3 involves implementing a temporary moratorium on harvesting native oysters. For the purposes of this PEIS, the moratorium was assumed to be in place over the entire 10-year assessment period. RRM values for this alternative (Figure 4-9) track directly and positively with expected changes in oyster abundance (Section 4.1.4). The potential effects of a harvest moratorium would vary according to unpredictable environmental conditions and the

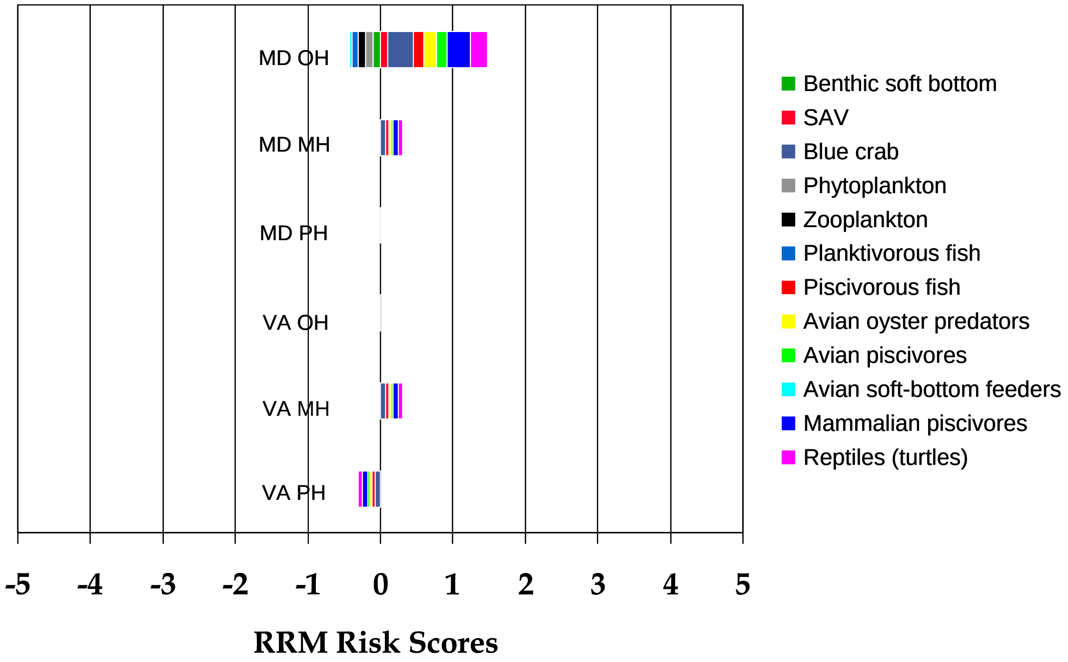

Figure 4-8. RRM outcome for Alternative 2. The scores were adjusted to account for the amount of oyster habitat in the respective salinity zones (Appendix B).

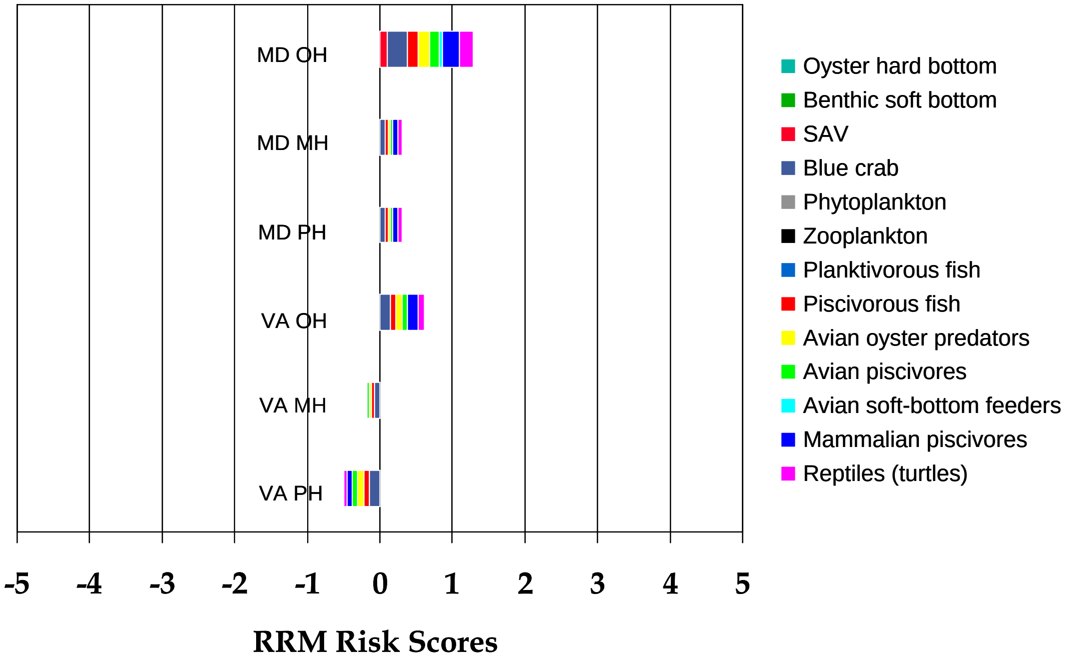

Figure 4-9. RRM outcome for Alternative 3. The scores were adjusted to account for the amount of oyster habitat in the respective salinity zones (Appendix B).

magnitude of past and current harvest rates, which are poorly defined. As a result, the changes in oyster abundance under a harvest moratorium are highly uncertain. Restoration programs under this alternative would be the same as under Alternative 1; consequently, the greatest increases in oyster abundance would occur in low-salinity areas in Maryland and Virginia. Receptors in two zones, VA MH and VA PH, could be negatively influenced, assuming a continuing decline in population in those zones. RRM scores would increase and decrease in proportion to the change in oyster biomass.

A moratorium would eliminate the disturbance of oyster habitat and the incidental mortality of unharvested oysters caused by harvesting.

One consequence of a harvest moratorium that was not addressed in RRM assessments is that it would eliminate the disturbance of oyster habitat caused by harvesting. Regardless of the kind of gear used, harvesting results in the removal of oysters and shell from the bottom and breaks up reef structure. The catch is sorted, and empty shells and oysters that are smaller than market size are returned to the water. Some watermen contend that this manipulation of substrate is analogous to tilling the soil on a farm and that it enhances oyster populations. Given the rate of loss of hard-bottom substrate in the Bay discussed in Section 4.1.1, lifting and redepositing shell might counteract the effects of sedimentation to some extent; however, the disruption of shell structure also might expose the remaining small oysters to increased predation by species such as the cownose ray. Lenihan et al. (2004) found that a statistically significant proportion of oysters, up to 10%, are incidentally killed but not harvested during each harvesting event as a result of being cracked, broken, or punctured by harvesting gear such as oyster dredges. In addition, disruption of the structure of oyster communities on bars could enhance the rate of natural deterioration of shell, a major factor in shell loss (Mann 2007b). If the watermen's contention is true, cessation of harvest could contribute to a greater rate of habitat loss than is projected for Alternative 1. If the latter contentions are true, cessation of harvest could contribute to protecting oysters from predation and eliminate the incidental mortality due to harvest. No studies of the effects of current harvest methods on existing low-profile oyster bars in the Bay have been conducted that provide evidence to support or refute either contention.

A moratorium would eliminate an impediment to the natural development of disease resistance in the population of Eastern oysters.

Another consequence of a harvest moratorium is that it would eliminate an impediment to the natural development of disease resistance in the population of Eastern oysters. As discussed in Section 4.1.2, harvesting an oyster population that is severely affected by diseases may slow or halt the development of disease resistance in the exploited population by removing disease-resistant individuals that would otherwise contribute to the growth of the oyster population and propagate the genetic traits for disease resistance. The length of time (i.e., number of generations of oysters) required for disease resistance to develop throughout the Chesapeake Bay oyster stock has never been established and is likely to be substantial, as discussed in Section 4.1.2.

4.2.5 Alternative 4: Cultivate Eastern Oysters

Increased cultivation of Eastern oysters would contribute only a minimal amount of food and habitat to the ecosystem Bay-wide but would provide increased filtration capacity and the indirect benefits of that ecosystem service.

This alternative involves expanding aquaculture of the Eastern oyster in Chesapeake Bay. The effects of aquaculture on ecological receptors would differ depending on how the aquaculture is implemented. On-bottom, unconfined operations would enhance hard-bottom habitat and the receptors that depend on it. Confined aquaculture in off-bottom cages might contribute some additional habitat, whereas confined aquaculture in floats or suspended bags would provide less. Based on input from aquaculture experts (Appendix C), operations for the Eastern oyster were assumed to be primarily on-bottom because of the cost efficiencies associated with this method. Such on-bottom aquaculture would use spat on shell placed in the Bay. Spat on shell are less vulnerable to predation than unattached oysters. As they grow, planted spat would contribute to an increase in habitat, food, or both, but that increase would be temporary because the cultivated oysters would be harvested when they reach market size. As discussed in Section 4.1.5, planted diploid Eastern oysters would be in place for about 36 months, whereas triploids would be in place for 18 to 24 months before reaching market size. Given the regular manipulation of cultivated oysters (i.e., annual placement and intensive retrieval, which repeatedly disrupt the oyster-reef habitat) and the possibility that some growers would choose off-bottom methods, the contribution of increased aquaculture to the amount of habitat or food available in the ecosystem would be minimal on a Bay-wide scale. The cultivated oysters, however, would offer filtration capacity and the indirect effects associated with that biological function. Benefits might be more substantial on a local basis. Aquaculture assessment scenarios were developed to explore the effects of this alternative on ecological receptors (Section 4.1.5 and Appendix C). The estimated maximum economically viable aquaculture industry is not likely to develop within the 10 years immediately following implementation of Alternative 4, and its distribution within the Chesapeake Bay could vary from the assessment scenario. Changing the size and distribution of expanded aquaculture operations would alter the projected magnitude of ecosystem influences.

The influences associated with the assumptions stated in the aquaculture assessment scenario are illustrated in Figure 4-10. Although the direct effect of habitat and food provided by cultivated oysters is assumed to be negligible, the filtration capacity of the oysters would have small influences on other ecological receptors in the VA OH and VA PH zones (Figure 4-10). These small influences reflect indirect benefits or detriments for receptors due to increases or decreases in food, habitat, or water quality related to increases in oyster biomass. The greater negative influence on plankton in VA PH is due solely to the fact that the aquaculture assessment scenario allocates most of the expanded aquaculture to that zone.

Changes in dissolved oxygen and TSS projected for the proposed action and other alternatives are attributable to the broad spatial scale of the analyses for the PEIS (Section 4.3.1). Larger influences would be expected at the scale of individual tributaries or Chesapeake Bay segments, and the magnitude of effects would be a function of the relative numbers of oysters in the water body and local hydrodynamics. This factor is particularly relevant for evaluating the potential ecosystem effects of the aquaculture alternatives. Aquaculture sites can be selected and are not necessarily dependent on bottom type (e.g., floats and off-bottom cages can be used to culture Eastern oysters in areas where no oyster cultch exists); therefore, aquaculture operations could be concentrated in restricted areas that would optimize the value of the increased filtration capacity for improving water quality. The trade-off is that concentrating operations could overwhelm the food supply available for the cultivated oysters. Decreased food supply could reduce growth rates and adversely affect the economics of the aquaculture operation. Additional analyses for selected tributaries or sites would be required to quantify such interactions and effects.

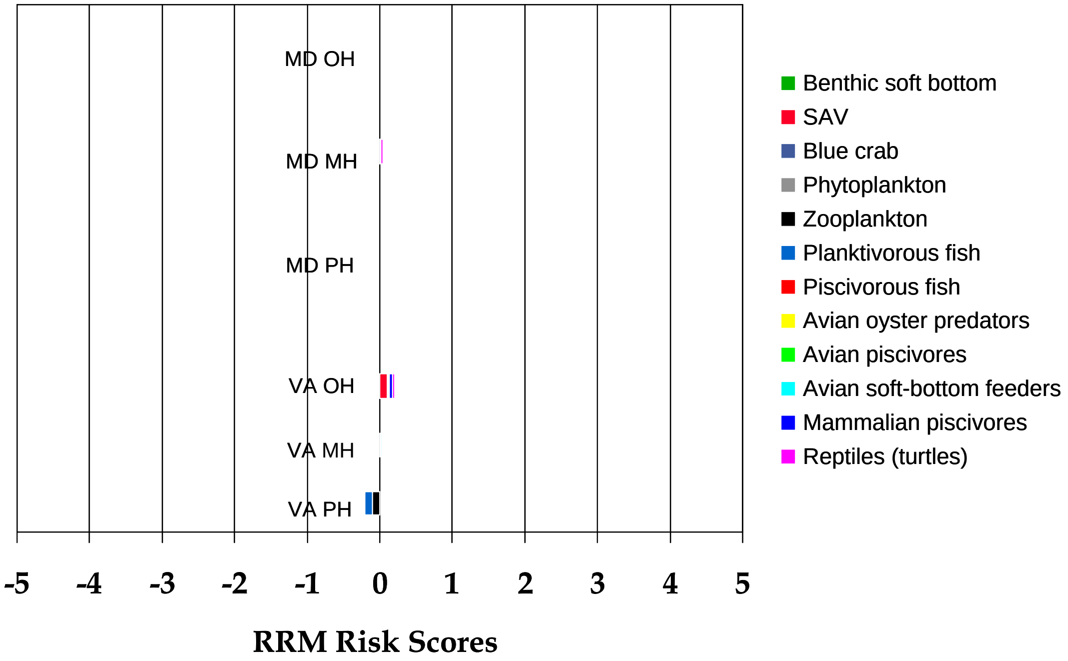

Figure 4-10. RRM risk scores for Alternative 4, assuming that cultivated oysters provide negligible habitat or food for other ecological receptors

Concentrated shellfish aquaculture creates the potential for some adverse effects on water quality, sediment, and benthos (Attachment D of Appendix B). Although the most significant adverse effects have been reported for high-density culture of mussels in confined water bodies, similar effects might occur with oysters. Greater rates of sedimentation and enriched organic content in sediments underneath or near aquaculture units are likely to result from increased biodeposition in the form of pseudofeces excreted by the cultured oysters. These effects are likely to result in an increase in benthic microalgal production in the sediments and possibly secondary production as well. Although reduced oxygen availability in the sediment is possible, current evidence for Eastern oysters indicates that aquaculture does not result in anoxic sediments. Greater percentages of fine-grain substrates associated with aquaculture may make those locations more prone to erosion or sediment redistribution by wave energy. Some studies have reported that aquaculture is associated with changes in the composition of the phytoplankton community because oysters selectively filter larger cells; however, such effects would be similar whether the oysters were cultured or wild and are related only to oyster abundance. Increased concentrations of dissolved nitrate and ammonia nitrogen could be expected through resuspension of biodeposits and excretion. Oysters that fall from off-bottom aquaculture units could attract predators; however, this effect would be no different than that resulting from aggregates of oysters growing unconfined on the bottom.

4.2.6 Alternative 5: Cultivate a Nonnative Oyster

The aquaculture assessment scenario described for Alternative 4 also was used for this alternative. The RRM outputs for Alternative 4 shown in Figure 4-10 are generally representative of expectations for Alternative 5. That is, some small negative influences on phytoplankton and zooplankton and some small positive influences on SAV would be expected in the Virginia zones where aquaculture would be concentrated.

Two differences between Alternatives 4 and 5 could result in somewhat divergent outcomes:

- All aquaculture operations using a nonnative oyster would be required to use confinement; most operations would use off-bottom cages or floats.
- Less area would be required to produce the estimated maximum number of cultivated triploid Suminoe oysters indicated in the assessment scenario because of the species' faster growth rate (Section 4.1.6).

Confined aquaculture would provide habitat that is different in structure and possibly in location than natural oyster-reef habitat. Although such habitat may provide structure and refuge, the likelihood that it would support the same species that inhabit natural oyster bars and reefs is not known. Aquaculture operators would seek to minimize the loss of oysters, which would limit the degree to which cultivated oysters would provide food to the rest of the ecosystem. The potential contribution of Suminoe oysters in this mode of aquaculture would be even smaller than the effect of off-bottom cages described for Alternative 4 because cages of Suminoe oysters would be in the water for a much shorter period than cages of triploid Eastern oysters.

> Habitat created by confined aquaculture of triploid Suminoe oysters would be different in structure and location than natural oyster-reef habitat.

Relative growth rates of the different kinds of oysters also would affect their influence on ecosystem receptors. Appendix C describes the growth rates of diploid and triploid Eastern oysters and triploid Suminoe oysters, the mode of aquaculture, and the required habitat in detail. Although the results of the combinations and permutations of oyster, habitat, and method are variable, some outcomes are predictable. The growth rate of triploid Suminoe oysters, which can reach market size in less than a year, is faster than that of triploid Eastern oysters, which may take 18 to 24 months to reach market size, or diploid Eastern oysters, which may take 36 months. The consequence of these differences is that three times as many diploid Eastern oysters as triploid Suminoe oysters would have to be in cultivation in the Bay at any given time to achieve the target annual production defined in the aquaculture assessment scenario. Suminoe oysters would be cultured in confinement and would not require hard bottom habitat; consequently, the area required to cultivate Suminoe oysters would be one half to one third the area required to produce the same number of cultivated Eastern oysters (Section 4.1.5 and Appendix C). Although individual Suminoe oysters grow faster, they begin life as spat that are the same size as Eastern oyster spat. Eastern oysters in cultivation at any given time would be of three annual cohorts and would have a much greater size distribution than cultivated Suminoe oysters; consequently, the actual total biomass of cultivated oysters might be similar between the two alternatives even though Suminoe oysters are likely to have greater biomass for the same shell length, as described in Section 4.1.6.

Although the maximum aquaculture industry for the Suminoe oyster would occupy a smaller area than for the Eastern oyster, Suminoe oysters would require more food than a similar number of Eastern oysters in a similar location because of their faster rate of growth. Cultivating Suminoe oysters, therefore, could result in greater local effects on water quality parameters such as TSS and water clarity. Similarly, cultivating Suminoe oysters could generate more concentrated biodeposition, creating the potential for the kinds of adverse effects discussed under Alternative 4.

Although the maximum aquaculture industry for the Suminoe oyster would occupy a smaller area than for the Eastern oyster, Suminoe oysters would require more food than a similar number of Eastern oysters in a similar location because of their faster rate of growth.

One risk of cultivating triploid Suminoe oysters is the possibility of inadvertently releasing diploids into the Bay at large, which then might establish a reproducing population of the species. Section 4.1.6 discusses the magnitude of that risk. If a self-sustaining population were to be established in the Bay as a result of this alternative, the ecological consequences would be as projected for the proposed action (Section 4.2.1). The rate of growth of a population of diploid Suminoe oysters resulting from this scenario would be expected to be extremely slow. The number of diploids that might be released from aquaculture operations via the six pathways evaluated (Appendix B) is many times smaller than the number of oysters to be seeded in the proposed introduction program; therefore, effects such as those described for the proposed action, whether considered positive or negative, probably would not be realized for several decades. An unintended introduction resulting from implementing this alternative is viewed as undesirable by many stakeholders, and it would be irreversible. If a reproducing population were to become established, it would not be possible to eradicate it.

If a self-sustaining population of Suminoe oysters were to be established in the Bay as a result of cultivating triploids, the ecological consequences would be the same as projected for the proposed action but would take much longer to become apparent.

4.2.7 Alternative 8: Combination of Alternatives

4.2.7.1 Combination 8a. – Eastern Oyster Only (Alts. 2, 3, & 4)

Increases in oyster abundance as a result of implementing this combination of alternatives would be expected to occur primarily in low-salinity areas of Maryland and Virginia. A small negative influence on phytoplankton and receptors that depend on phytoplankton would be possible under some circumstances and a small positive influence would be expected for other receptors in these areas.

4.2.7.2 Combination 8b. – Eastern Oyster and Triploid Suminoe Oysters (Alts. 2, 3, 4, & 5)

Increases in oyster abundance as a result of implementing this combination would be expected to occur primarily in low-salinity areas of Maryland and Virginia. A small negative influence on phytoplankton and receptors that depend on phytoplankton would be possible under some circumstances in these areas. Aquaculture of triploid Suminoe oysters probably would be limited to off-bottom floats or cages; consequently, the direct effects of the provision of habitat and food would be minimal. The filtration capacity of the oysters could have small influences on other ecological receptors in areas where triploid Suminoe oyster aquaculture is pursued. Concentrated shellfish aquaculture creates the potential for some adverse effects on water quality, sediment, and benthos (Attachment D of Appendix B).

A risk of cultivating triploid Suminoe oysters is the possibility of inadvertently releasing diploids into the Bay, which then might establish a reproducing population of the species. The long-term ecological consequences of this event would be as projected for the proposed action, except that the time required before those consequences were realized would be much longer under this combination.

4.2.7.3 Combination 8c. – Eastern Oyster and Diploid and Triploid Suminoe Oysters (Proposed Action + Alts. 2, 3, 4, & 5)

The ERA indicates that if the proposed introduction of Suminoe oysters were successful, the anticipated increases in oyster biomass would result in positive influences on other ecological receptors. Slight negative influences associated with increases in oyster abundance in localized areas might be associated with reductions in the biomass of algae for species that rely on planktonic algae for food. Given that Suminoe oysters and Eastern oysters would provide similar ecological services in Chesapeake Bay, the extent to which this combination of alternatives would influence ecosystem services is a function of the extent to which the total abundance of oysters of both species would increase. This combination of alternatives appears to have the greatest potential for increasing the Bay-wide abundance of oysters in Chesapeake Bay, and the effects of changes in oyster abundance on ecological receptors (both positive and negative) could be most pronounced for this combination of alternatives if the introduction were successful. An unsuccessful introduction would result in ecological services similar to those of Combination 8b.

4.3 WATER QUALITY

A key assumption about the potential ecological role of oysters in the Bay involves their ability to filter water and the possibility that an increase in the abundance of oysters in the Bay could influence water quality conditions that are related to algal abundance. Section 4.5 of the ERA (Appendix B) presents a more detailed discussion of this topic, which is summarized here. This section presents an overview of water quality in Chesapeake Bay and of the relationship between oysters and water quality. In general, water clarity decreases due to algal blooms and large volumes of sediment runoff and has been shown to increase with increases in filter feeding organisms, such as oysters. Two well-known examples of this phenomenon are worth noting. During the summer of 2004, water clarity in the Magothy River reached an all time high and dissolved oxygen levels were the highest of the period from 2001 to 2007 following a dramatic increase in the population of the dark false mussel, a small filter-feeding shellfish (DNR 2004; Bergstrom 2008). The explosion of that population did not recur, and the improvement in water clarity observed in 2004 was not repeated in subsequent years. A similar dramatic increase in water clarity in some of the Great Lakes followed the accidental introduction and explosive population growth of the zebra mussel, an invasive, nonnative species. Since zebra mussels became established in Lake Erie, water clarity has increased from 6 inches to 30 feet in some areas.

Newell (1988) estimated that, at one time, the oyster population of Chesapeake Bay would have been able to clear a volume of water equal to that of the Bay in two to four days, suggesting that a fully restored oyster population might be capable of controlling spring phytoplankton blooms that contribute to low dissolved oxygen conditions during the summer. Other researchers also have discussed this potential beneficial role of oysters in controlling water quality in the Bay (Jackson et al. 2001; Ruesink et al. 2005; Kemp et al. 2005); however, the hypothesis has been the subject of debate. Pomeroy et al. (2006) and Fulford et al. (2007) argued that the potential role of oysters in controlling algae in the Bay has been overstated and that the various populations of suspension-feeding benthos now present in the Bay should have a filtration capacity approaching that of the pre-Colonial population of oysters. Yet, they do not appear to be controlling algal blooms. Those authors concluded that achieving the restoration goal for oysters in the Bay (i.e., average population level over the period 1920-1970) would be unlikely to result in a significant, Bay-wide reduction in phytoplankton biomass. In a reply publication, Newell et al. (2007c) critiqued those conclusions and maintained that increasing the population of oysters by orders of magnitude could have important effects on water quality and ecological conditions in the Bay. These competing scientific arguments rely on specific sets of assumptions about the timing, spatial distribution, and magnitude of filtration by oysters that are beyond the level of detail that could be addressed in this PEIS. Clearly, however, the greater the number of oysters in the Bay, the greater the amount of water they would filter.

Based on this underlying assumption, the CBEMP was used to evaluate the potential effects of increasing the abundance of oysters in the Bay on its water quality. The publications from which results presented here were drawn are presented in Appendix H of this Draft PEIS (i.e., Cerco and Noel 2005a, 2005b, 2006). CBEMP outputs provided insights into possible effects at the scale of Bay segments and regions. This segment-level evaluation complements the six broad areas (combinations of two states and three salinity zones) considered in the ERA. Using CBEMP results allowed potential small-scale effects to be investigated, unlike most other analyses in the ERA, which focused on Bay-wide outcomes. The only water quality parameters considered are those for which outputs from the CBEMP were available: dissolved oxygen (DO) and total suspended solids (TSS). Submerged aquatic vegetation (i.e., underwater grasses) is addressed here because it responds to changes in TSS. The CBEMP model outputs discussed here do not account for any changes in inputs that might occur over the 10-year assessment period (e.g., increases or decreases in nutrient loading to the Bay); therefore, the evaluations of the potential effects on water quality described here consider only the relationship between water quality and changes in oyster abundance and assume that all other factors would remain constant.

4.3.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

As discussed in Section 4.1.1, no projections of the potential abundance and biomass of a population of Suminoe oysters in the Bay were possible for this PEIS. To assess the ecological risks of the proposed action, the introduced species was assumed to thrive and become widely distributed throughout the Bay. This assumption was intended to represent the "worst case" scenario from the perspective of stakeholders who oppose the introduction of a nonnative oyster. This same assumption was made to assess the potential effects of the proposed action on water quality. Clearly, if the introduction were to be unsuccessful, the abundance of oysters in the Bay would not increase significantly and water quality would not be affected.

Insights into the water quality and ecological benefits of achieving particular levels of oyster abundance and biomass can be gained from modeling work performed by Cerco and Noel (2005a, 2005b, 2006; Appendix H). The starting population for their modeling was the average over the period 1991 to 2000 from Jordan et al. (2002; total biomass 0.57 X 10^9 g dry weight), which is about one fifth the estimated levels for more recent years, including the 2004 base year for analysis (2.7 X 10^9 g dry weight; Figure 1-3). For reference, their assumed historical oyster population level was 94.0 X 10^9 g dry weight. They also conducted model runs assuming zero oyster biomass to evaluate the sensitivity of different water quality and ecosystem variables to the presence or absence of oysters. The modeled 10-fold increase in oyster biomass was distributed unevenly. Oyster abundance in Maryland increased by a factor of 50, whereas abundance in Virginia exhibited only a 4-fold increase. That result is consistent with patterns shown in exploratory modeling for this PEIS presented in Appendix A. For the Bay as a whole, Cerco and Noel (2005a) projected that a 10-fold increase in oyster biomass would result in a 0.25 mg/l increase in summer-average dissolved oxygen at the bottom in deep waters (depth > 12.9 m). As discussed in Section 3.3, oxygen levels below 5 mg/l of water affect the behavior and survival of fish. Concentrations below 2 mg/l are considered to be severely hypoxic and affect the structure, distribution, and productivity of benthic organisms, including oysters. In recent decades, an average of 5.25% of the Bay mainstem volume was hypoxic. An increase of 0.25 mg/l would not alter that condition to any significant degree. The explanation for the small increase in DO was that filtration of phytoplankton from the water column was estimated to result in a net removal of 30,000 kg per day of nitrogen through sediment denitrification and sediment retention. Oysters remove suspended matter from the water column in shallow areas; therefore, the CBEMP projected enhancement of SAV in response to improved water clarity. Calculated summer-average biomass of SAV biomass increased by 25% with a 10-fold increase in oyster biomass.

The modeling results showed that a 10-fold increase in oysters or an elimination of all oysters would have minimal effect on water quality at a Bay-wide, large scale basis; oysters are most likely to affect water quality only on a local and small scale. Cerco and Noel (2005a) investigated the potential for local effects by selecting three of the 35 Bay segments used in their modeling for detailed examination of effects on such a scale (Figure 4-11). These segments provide a range of geometry and environmental conditions and include a deeper mainstem bay segment (CB4), an eastern embayment that encompasses the mouth of the Choptank River (EE2), and the Big Annemessex River (ET9). Oysters can live in only a portion of CB4 but can

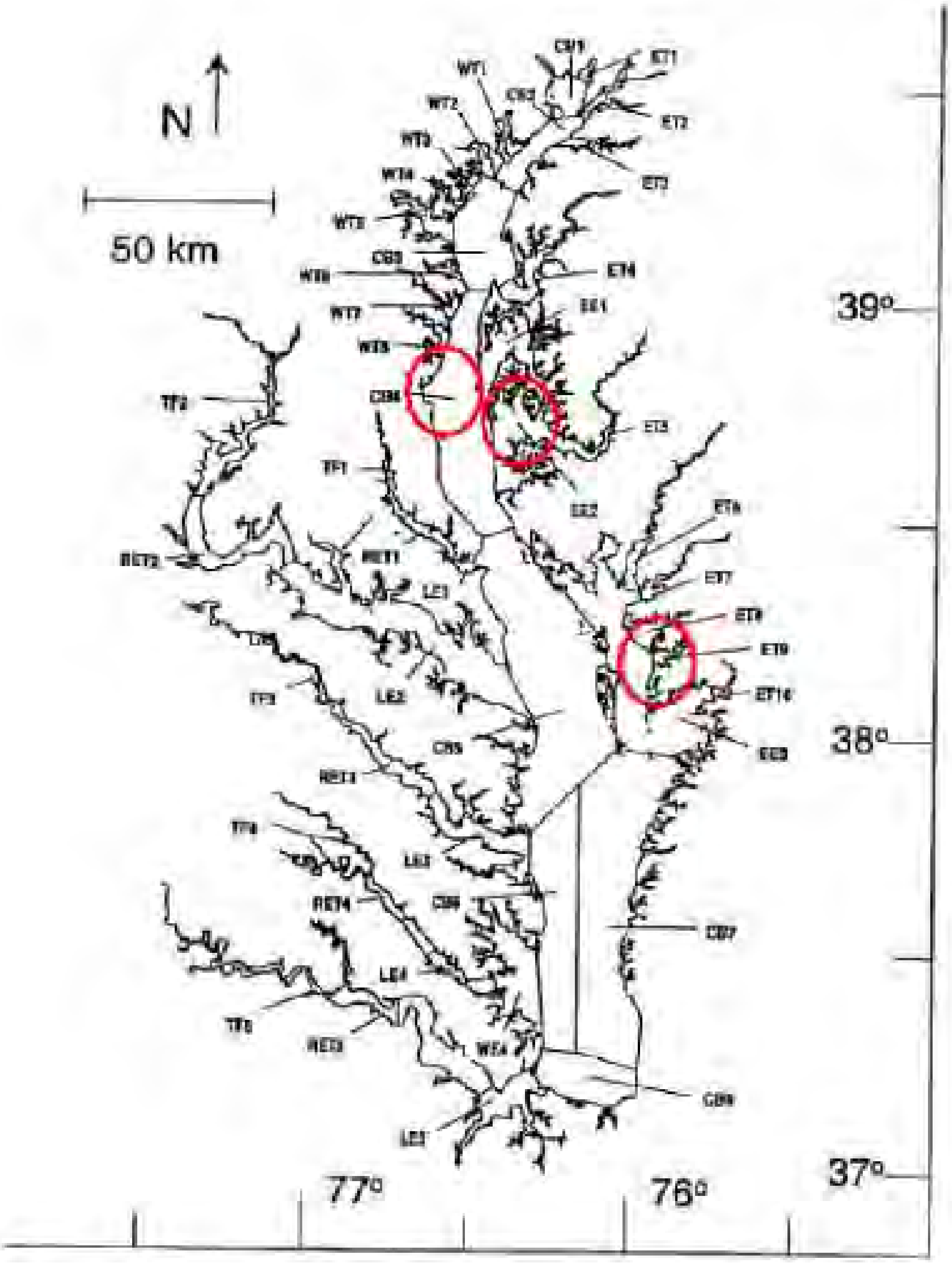

Figure 4-11. Selected segments for detailed evaluation of the effects of oysters.

inhabit most of the other two segments. A summary of influences of oyster abundance/biomass on conditions in these segments is provided in Figures 4-12 to 4-14.

The effects on DO of a 10-fold increase in oysters and an increase to historical levels are shown in Figure 4-12 a through c. The figures indicate that a 10-fold increase in oysters could result in an increase in DO on the order of 0.5 mg/l in bottom water during the summer at the scale of a Bay segment. This effect is larger than the one projected on a Bay-wide basis. Larger changes would occur if oysters were restored to historic levels. Increases in dissolved oxygen were projected for segments CB-4 and EE-2. A counter-intuitive decrease was predicted for segment ET-9. This decrease would occur because the large reduction in phytoplankton through filtering by oysters reduces the oxygen production of the phytoplankton, which in this location is lower than respiration.

A similar presentation of response of water transparency (i.e., a reduction in TSS) to different levels of oyster abundance is shown in Figure 4-13 a through c. Figure 4-13 illustrates that filtration by oysters removes suspended material that decreases attenuation and increases light penetration. These influences have a strong effect on water clarity and, consequently, on the growth of SAV. The response of SAV to the increase in light is illustrated in Figure 4-14 a through c. SAV biomass increases with a 10-fold increase in oyster density and increases by greater than a factor of two with restoration to historic oyster densities.

Cerco and Noel (2005a) noted that oxygen levels in CBEMP projections do not respond as much as might be expected to increases in oysters. They suggested that this occurs because oysters are found in the shoals rather than in the deeper portions of the Bay mainstem. Phytoplankton produced over the mainstem settles to the bottom and contributes to anoxia; whereas, in the shoals, oysters would remove the phytoplankton biomass before it settled to the bottom. A more subtle explanation may lie in the origins of mainstem anoxia. Oxygen depletion in the upper Bay does not originate solely with excess production in the overlying waters. Rather, oxygen depletion is accumulated as net circulation moves bottom water up the channel from the mouth of the Bay. Improving dissolved oxygen in the upper Bay requires reducing oxygen demand in the lower Bay. The oyster restoration strategies proposed in this PEIS would do nothing to diminish oxygen demand in the lower Bay and, consequently, may have only a limited potential to affect water quality in the upper Bay. Cerco and Noel (2005a) noted that, despite the uncertainties in their approach for relating oyster biomass to ecological changes using the CBEMP, they believe their basic findings regarding the nature and magnitude of restoration benefits are valid. They found their results to be consistent with the earlier findings of Officer et al. (1992) and Gerritsen et al. (1994) and with the recent findings of Newell and Koch (2004). Benthic controls of algal production are most effective in shallow, spatially limited regions, as in the example of the dark false mussel in the Magothy River. Effectiveness in that case was enhanced by the fact that the mussels were most abundant on off-bottom substrates and nearer the surface than oysters would be (Bergstrom 2008). The ability to influence deep regions of large spatial extent is limited by the location of oysters in the shoals and by exchange processes between the shoals and deeper regions.

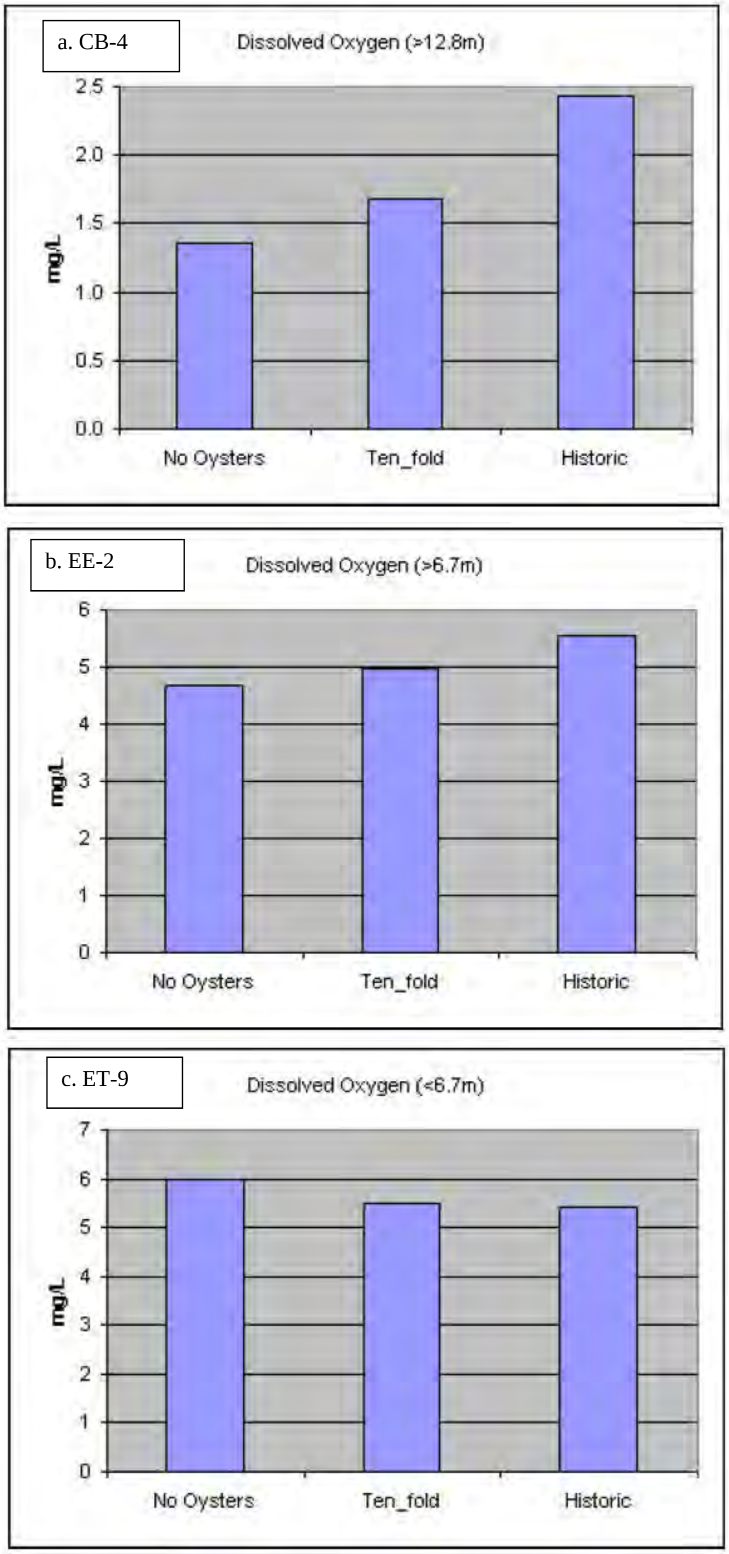

Figure 4-12. Summer bottom dissolved oxygen in Bay Segments CB-4(a), EE-2(b) and ET-9(c) with no oysters, an increase in oyster biomass to 10 times present levels, and under historic levels of oyster abundance (from Cerco and Newell, 2004,2005; Appendix H)

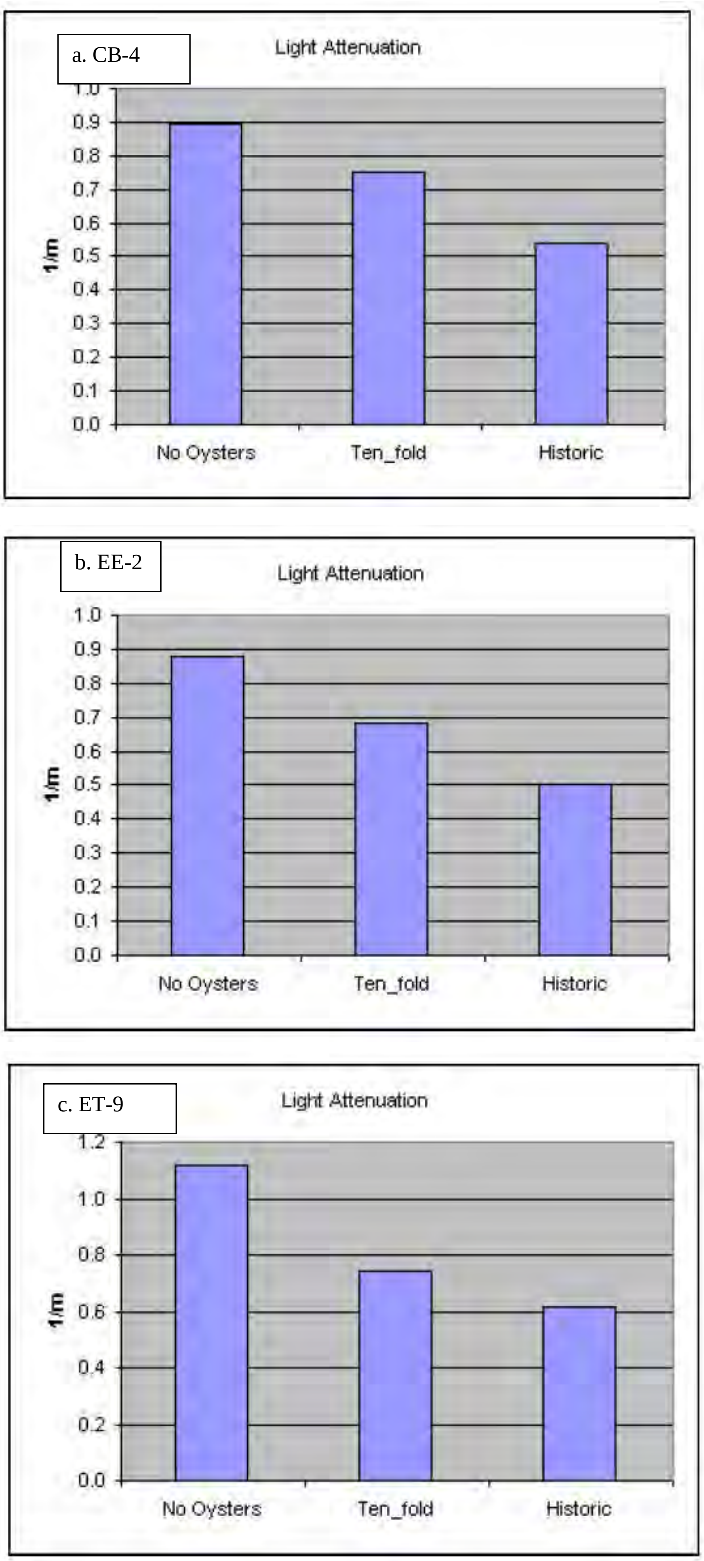

Figure 4-13. Light attenuation (highest with lowest TSS) in Bay Segments CB-4(a), EE-2(b) and ET-9(c) with no oysters, an increase in oyster biomass to 10 times present levels, and under historic levels of oyster abundance (from Cerco and Newell, 2004, 2005; Appendix H). Attenuation is expressed in terms of a vertical attenuation coefficient, defined as the rate of decrease of light per unit distance in the water column (irradiance units drop out in calculating the ratio).

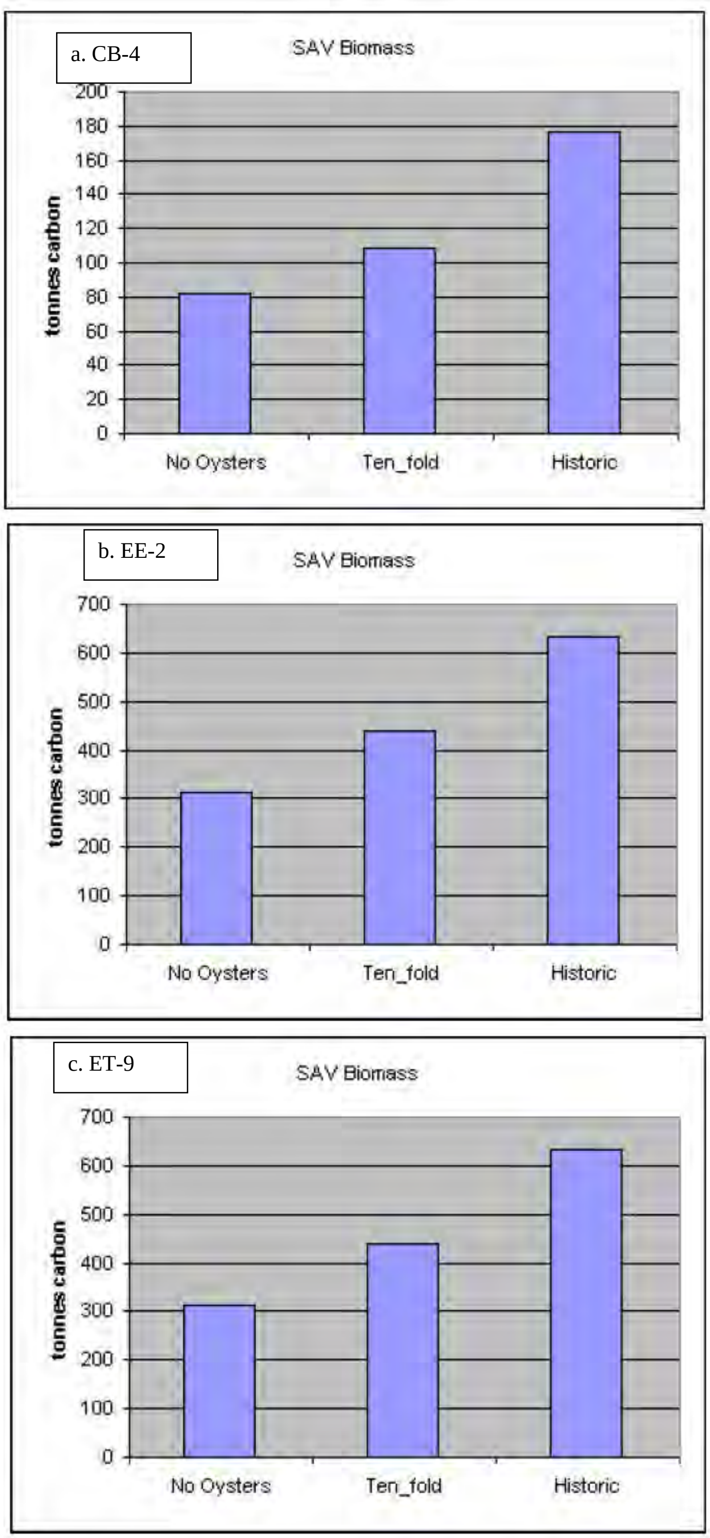

Figure 4-14. Biomass of SAV in Bay Segments CB-4(a), EE-2(b) and ET-9(c) with no oysters, an increase in oyster biomass to 10 times present levels, and under historic levels of oyster abundance (from Cerco and Newell, 2004,2005; Appendix H).

Given that the size and distribution of an introduced population of Suminoe oysters cannot be projected, CBEMP modeling results cannot be applied directly to estimate the affect of the proposed action on water quality and SAV in the Bay. If the introduction were successful, a greater than 10-fold increase in oyster biomass could be a reasonable expectation, and improvements in water quality of at least the magnitude projected by the CBEMP would result. Large population increases in local and relatively restricted areas could result in greater improvements, as discussed for the individual Bay segments. The Suminoe oyster's resistance to MSX and Dermo suggest that a successful introduction could result in greater oyster abundance in the high-salinity waters of Virginia than were projected in the CBEMP, at least in mesohaline areas where *Bonamia* would not pose an obstacle, and in improvements in water quality in that portion of the Bay. Failure of the proposed action to establish a self-sustaining population of Suminoe oysters would result in no change in water quality in high-salinity areas, but increases in Eastern oysters in low-salinity waters in Maryland in response to continuation of existing restoration activities could result in some water quality improvements in local areas, as is discussed further in Section 4.3.3.

4.3.2 Alternative 1: No Action

Given that a Bay-wide increase in oyster abundance on the order of the 10-fold increase modeled by Cerco and Newell (2005a, 2005b, 2006) is very unlikely under Alternative 1 (Section 4.1.2), no Bay-wide changes in water quality would be expected as a result of implementing this alternative. Some increase in oyster abundance was projected in low-salinity waters in Maryland (Section 4.1.2). Although the magnitude of the change in oyster biomass probably would be insufficient to affect water quality at the geographic scale of the ERA analysis (i.e., six state/salinity zones), it could result in some local improvements in water quality in any restricted waters in which substantial amounts of seed are planted.

4.3.3 Alternative 2: Enhance Restoration

Section 4.1.3 suggests that Bay-wide oyster abundance might increase by a factor of five under this alternative but that the majority of the increase would be in low-salinity waters in Maryland. No significant Bay-wide changes in water quality would be likely to result from changes of this magnitude in the size of the oyster population of this magnitude. If all of the projected increase in oyster biomass were concentrated in a limited location (which would require significant deviation from the representative implementation plan for this alternative), the potential for changes in local water quality would be greater. In particular, a positive influence on water clarity might be noticeable in certain low-salinity segments in the upper Bay. If it occurred, this effect could reduce TSS and enhance the growth of SAV in those locations.

4.3.4 Alternative 3: Harvest Moratorium

Changes in oyster abundance under this alternative could reasonably be expected to be similar in location and magnitude to those projected for Alternative 1 and somewhat less than those projected for Alternative 2 (Section 4.1.4). Oyster abundance could increase in high-salinity areas, but the increase probably would not be sufficient to affect water quality, even on a local scale. Small changes could occur at the scale of individual segments in low-salinity areas in Maryland because the current restoration programs would continue under this alternative.

4.3.5 Alternative 4: Cultivate Eastern Oysters

For the ERA (Section 4.4.1.5 of Appendix B) the annual production of the predicted maximum aquaculture industry in the Bay (i.e., 2.6 million bushels distributed over 9 possible locations for concentrated aquaculture operations) was converted to biomass and grouped according to the 6 state/salinity zones to project potential effects on water quality based on CBEMP output. No discernable changes in DO or TSS were projected; however, the geographic scale of the analyses conducted in the ERA is too large to detect local effects, such as in an individual tributary. Changes in water quality that might result from implementing Alternative 4 would be a function of the cumulative size of aquaculture operations (i.e., the number of oysters being farmed), the distribution of operations within bodies of water, and the hydrodynamics of the host waters. Although concentrating oyster production in a limited area would offer the greatest potential to affect water quality locally, aquaculture operators also would have to account for the availability of a sufficient supply of food (e.g., phytoplankton), in essence the carrying capacity of a particular location, in order to achieve economically viable growth rates. For example, an area with a high rate of phytoplankton production may be desired for good oyster growth rates, but the rate of phytoplankton consumption by densely farmed oysters could exceed the rate of phytoplankton production. In that circumstance, the growth rate of the oysters could be slowed, and the efficiency of the aquaculture operation reduced. Optimal positioning of aquaculture operations, so that rate of phytoplankton consumption by oysters (and, thus, the rate of oyster growth) is kept in balance with the rate of phytoplankton production, may not achieve the maximum potential improvement in local water quality.

4.3.6 Alternative 5: Cultivate a Nonnative Oyster

The ERA (Section 4.4.1.6 of Appendix B) treated Alternatives 4 and 5 similarly in its evaluation of water quality effects, while acknowledging that growth rates and the ratio of biomass to shell height of triploid Suminoe oysters are greater than those of both diploid and triploid Eastern oysters (Section 4.1.5 and 4.1.6). Negligible effects on water quality were projected on the scale of the state/salinity zones for the predicted maximum aquaculture industry considered for Alternative 5. Some differences between Alternative 4 and Alternative 5 are possible. The faster growth rate and shorter time to grow to market size for triploid Suminoe oysters might result in fewer Suminoe oysters (one cohort) than Eastern oysters (two to three cohorts) being present in the Bay at any one time and less area within the Bay being occupied by aquaculture operations. This would result in lesser Bay-wide effects on water quality under this alternative than under Alternative 4. Local effects could be similar in specific locations if densities of the two species of cultured oysters were similar. The Suminoe oyster's faster growth may be a function of greater rate of filtering and food consumption; therefore, cultivating the species may have a greater effect on water quality locally than cultivating the same number of Eastern oysters. The same factors discussed under Alternative 4 (i.e., size of the water body, hydrodynamics, and oyster densities) would control the extent to which Alternative 5 would affect water quality locally.

4.3.7 Alternative 8: Combination of Alternatives

Combination 8a. – Eastern oyster only – Local improvements in water quality in low-salinity waters may occur under this combination as described for Alternatives 2 and 4. Local improvements would be expected in locations where concentrated aquaculture operations were initiated; therefore, some local improvements would be possible in high-salinity waters in Virginia.

Combination 8b. – Eastern oyster and triploid nonnative Suminoe oysters. – Improvements in water quality under this combination would be similar to those described for Combination 8a, but the addition of triploid Suminoe aquaculture would increase the potential for local water quality improvements in high-salinity waters in Virginia.

Combination 8c. – Eastern oyster and both diploid and triploid nonnative Suminoe oysters. – This combination of alternatives has the greatest potential to produce significant increases in oyster abundance and, therefore, the greatest potential to improve water quality. A successful introduction of the disease-resistant Suminoe oyster could result in local improvements in water quality would be improved in high-salinity areas both in Maryland and Virginia. Improvements in water quality at the local and possibly tributary levels would be enhanced in low-salinity areas as a result of expanded efforts to restore the Eastern oyster and in specific tributaries where aquaculture might be initiated. The level of improvement would depend on the scale of restoration and/or the magnitude of aquaculture that develops in a given area. If the proposed introduction of the Suminoe oyster were unsuccessful, the local water quality improvements attributable to increased aquaculture still could be realized.

4.4 RARE, THREATENED, AND ENDANGERED SPECIES

In 2004, FWS and NMFS identified 11 species with Federal status as threatened or endangered that are known to occur in Chesapeake Bay and its watershed. The status of these species in Chesapeake Bay and its watershed was verified in 2008. With the exception of the bald eagle, which was delisted in 2007, no changes in status have occurred. Resource agencies in Maryland and Virginia identified additional species with State-listed status and other species of special concern (Table 3-2). The rare, threatened, and endangered (RTE) species being considered in this PEIS include 3 fish, 12 birds, 5 sea turtles, 2 insects, and 1 plant. This assessment of potential effects of the proposed action or alternatives on RTE species considers (1) how anticipated changes in the abundance of oysters in the various state/salinity zones and the possible consequences of those changes for other components of the Chesapeake Bay ecosystem might influence the critical habitat or food resources of RTE species; and (2) how the construction, placement, use, and maintenance of facilities and equipment required to implement the alternatives might influence RTE species directly. Indirect effects are encompassed in the RRM analyses presented in Section 4.2. Evaluations for the two aquaculture alternatives (Alt. 4 and Alt. 5) assume the assessment scenario described in Section 4.1.5 and Sections 2.0 and 3.0 of Appendix C.

The evaluations of the potential effects of changes in oyster biomass on RTE species are based largely on the results of the ERA (Section 4.4 of Appendix B), as described in Sections 4.1 and 4.2. The ERA evaluations assume direct or indirect ecological relationships between oysters and some RTE species that, in many cases, have not been studied or thoroughly documented in the scientific literature; consequently, the evaluations are logical predictions based on conservative reasoning (i.e., note all possible adverse or beneficial effects, regardless of documented precedent) and the weight of available evidence documented in the ERA. Details of the direct and indirect species interactions on which the ERA and the assessments presented here are based are described in Section 2.3 of Appendix B. The evaluations presented here assume the same spatial and temporal scales and are subject to uncertainty from the same sources and of the same magnitudes as described in Section 4.1 and discussed in the ERA (Section 4.6 of Appendix B). Unless stated otherwise, the following evaluations are based on RRM scores derived, in part, from anticipated changes in oyster abundance, taking into account the proportion of bottom area currently covered with oyster cultch (Section 4.4 of Appendix B). Explanations for how the scores were derived are presented in Section 3.4 of Appendix B and are not repeated here. Note that local effects could be greater than effects projected for the six state/salinity zones assessed in the ERA; however, the nature of the effects (i.e., adverse or beneficial) would be expected to be the same. This assessment is a programmatic analysis that is intended to assist decision makers to identify an appropriate or preferred strategy rather than to render a project-based decision.

4.4.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

4.4.1.1 Potential Effects on RTE Fish

Shortnose and Atlantic Sturgeon – The numbers of both species currently using the Bay are small (Section 3.4.1). Both species are bottom feeders that spawn in fresh water. The proposed action to introduce the Suminoe oyster and continue restoration of the Eastern oyster would be unlikely to have any effect on the spawning habitat of these species because Suminoe and Eastern oysters do not inhabit fresh water. Adults and juveniles of both species of sturgeon feed in estuarine waters. The forage species for adults and juveniles of both species are members of the soft-bottom benthic community. The proposed action could have a small negative influence on the soft-bottom benthic community (Section 4.1.1) and, indirectly, on the sturgeon, if the Suminoe oysters were to succeed in producing a substantial increase in oyster biomass in the Bay. To the extent that Suminoe and Eastern oysters might expand oyster bars or reefs over adjacent soft-bottom habitat as a result of increases in population, such an effect might counter the continuing loss of existing hard-bottom habitat occurring in the Bay. Given the uncertainty concerning the potential success of the Suminoe oyster in the Bay (Section 4.1.1) and the minimal projected negative influence of the oyster on the sturgeons' soft-bottom benthic forage species (Section 4.2.1), the magnitude of the potential adverse effect on shortnose and Atlantic sturgeon in Chesapeake Bay probably would be very small.

Spotfin Killifish – The third RTE fish species, spotfin killifish, inhabits salt marshes and feeds on zooplankton and emergent insects. The proposed action could have a small positive influence on SAV (Section 4.3.1), which might result in a minimal increase in habitat for the spotfin killifish. The proposed action could have a small negative influence on zooplankton (indirectly via local reduction of phytoplankton by oysters), which could decrease the supply of food available for killifish. Based on the results of the ERA, the magnitudes of the potential beneficial effect on habitat and the potential adverse effects on food resources for the spotfin killifish probably would be very small and would be most likely to occur only a local basis.

4.4.1.2 Potential Effects on RTE Birds

Bald Eagle – The bald eagle is a large raptor that is Federally protected in the Chesapeake Bay area and on State lists of threatened species in Maryland and Virginia. Bald eagles require large areas of undisturbed mature forest close to aquatic foraging areas. The proposed action could adversely affect the habitat available for bald eagles if hatcheries required to produce spat for the introduction program (Section 4.1.1) were constructed near nesting areas or important foraging areas. Eagles are most vulnerable to disturbance during courtship, nest building, egg laying, incubation, and brooding. Disturbance during this critical period may lead to nest abandonment and mortality of eggs or young from freezing or overheating (FWS 1987). The FWS-recommended buffer zone around eagle nest sites in the Chesapeake Bay area is a radius of 660 feet. Activities within the 660-foot buffer are subject to regulations found within the National Bald Eagle Management Guidelines (1/4 mile). Locations of potential aquaculture and hatchery areas, therefore, should be carefully evaluated to minimize activities near eagle nest sites, and any boating activity involved in an introduction program should not occur within 600 feet of any nest. It is not likely that a significant amount of the boating activity involved in an introduction program would occur within a buffer zone of that size.

Bald eagles eat fish when they are available but will shift to a variety of other birds, mammals, and turtles when fish are scarce. The ERA suggests that the proposed action could have a positive influence on avian piscivores (Section 4.2.1) such as the bald eagle, if the Suminoe oyster were to succeed in producing the projected increase in oyster biomass in the Bay. That positive influence would be due to an indirect relationship in which an increase in oyster abundance would create more habitat for reef-oriented fish, some of which are prey species for some avian piscivores.

Peregrine Falcon – The proposed action would be unlikely to affect peregrine falcons because they nest almost exclusively on cliffs and tall manmade structures (e.g., bridges, buildings, towers) and prey predominantly on waterfowl (Section 3.4.2). Hatcheries constructed to support the proposed action probably would not be sited in the mountainous areas that provide natural habitat for peregrines. The ERA suggests that the proposed action could have a small positive influence on some species of waterfowl (i.e., avian soft-bottom feeders; Section 4.4.2 of Appendix B), which might result in more prey for peregrine falcons. Given the high degree of uncertainty concerning the success of the Suminoe oyster in the Bay (Section 4.1.1) and the small projected positive influence on avian soft-bottom feeders, any detectable beneficial affect on falcons probably would be extremely small.

Wilson's and Piping Plovers – Both species of plover are soft-bottom feeders (Section 3.4.2), although only in the intertidal zone when it is exposed at low tide. The ERA suggests that an increase in oyster biomass that might result from the proposed action would have a minimal negative influence on avian soft-bottom feeders in some state/salinity zones (i.e., MD MH, VA OH, VA PH; Section 4.2.1). The projected negative influence on avian soft-bottom feeders is related to a negative influence on their prey species, which are members of the soft-bottom benthos. The ERA suggests a small positive influence on avian soft-bottom feeders in four of the six state/salinity zones (i.e., not in the MD PH and VA PH zones). This is associated with a positive influence on SAV, which is food for some avian soft-bottom feeders. Plovers would not be affected by this positive influence because they do not consume SAV.

Wilson's plover is not a common breeder anywhere on the U.S. Atlantic coast. Habitat for the piping plover includes sandy beaches and associated intertidal areas within the Bay. The Suminoe oyster would be unlikely to reduce the availability of intertidal soft-bottom habitat for plovers because it appears to be ill-suited to the intertidal environment (Section 4.1.1). Both Wilson's and piping plovers are strictly ocean coastal nesters, always nesting within the sound of surf: therefore, changes in Chesapeake Bay would not influence their nesting. Locations of potential aquaculture and hatchery areas should be carefully evaluated to minimize activities near nest sites. The magnitude of the influence of the proposed action on the two RTE species of plover probably would be very small.

Black Skimmer – The black skimmer is a common transient and summer resident along the Atlantic coast and in the lower Chesapeake Bay. It requires undisturbed beach habitat for nesting colonies and open water for foraging. In Virginia, the species' diet is nearly all fish (90% silversides and killifishes; VAFWIS 2005). The ERA suggests that the proposed action would have a small negative influence on planktivorous fish (Section 4.2.1), which include the black skimmer's prey species. If the Suminoe oyster were to succeed in producing a large increase in oyster biomass in the Bay, the proposed action could have an adverse affect on the availability of prey for the black skimmer. Construction of hatcheries to provide spat for the proposed introduction program could have an adverse effect on habitat for black skimmers, if facilities were sited in areas they are known to use for nesting or foraging.

Brown Pelican – Brown pelicans typically feed in shallow estuarine waters on crustaceans, menhaden, mullet, sardines, and pinfish. The ERA suggests that the proposed action would have a small negative influence on planktivorous fish, such as those consumed by brown pelicans, as well as a small negative influence on the soft-bottom benthos, which include some of the crustaceans consumed by the brown pelican. The magnitude of the negative influences would increase with increasing oyster biomass. If the Suminoe oyster were to succeed in producing a large increase in oyster biomass in the Bay, the proposed action could have a small adverse effect on the availability of prey for the brown pelican. Construction of hatcheries to provide spat for the proposed introduction program could have an adverse effect on habitat for the brown pelican, if facilities were sited in areas that they are known to use for nesting.

Terns – The roseate tern is on the Federal list of endangered species, and five other species (i.e., gull-billed, least, Caspian, royal, and sandwich) have State status in Maryland, Virginia, or both (Table 3-2). The roseate tern is listed as extirpated in Maryland. The roseate, Caspian, royal, and sandwich terns prey primarily on planktivorous fish; the diets of the roseate, Caspian, and sandwich terns also include some soft-bottom benthos. The diet of the least tern includes small crustaceans, and the diet of the gull-billed tern is almost exclusively insects (Section 3.4.2). The ERA suggests that the proposed action would have small negative influences on planktivorous fish and soft-bottom benthos (Section 4.2.1). If the Suminoe oyster were to succeed in producing a large increase in oyster biomass, the proposed action could have a small adverse effect on the availability of prey for most RTE species of terns in Chesapeake

Bay. The gull-billed tern probably would be the least affected because of its reliance on insects for food. The general nesting habitat for all of these species, various kinds of beaches associated with barrier islands, probably would not be affected by the construction of hatcheries to support the proposed introduction program.

4.4.1.3 Potential Effects on RTE Reptiles

Loggerhead Turtle – The loggerhead turtle accounts for nearly 90% of the summer population of sea turtles in the Bay. It is on the Federal list of threatened species and is considered threatened in Maryland and Virginia. Loggerheads eat horseshoe crabs, jellyfish, crustaceans, and mollusks and forage primarily along channels near the mouths of rivers and in areas of the Bay that are more than 13 feet deep. The ERA suggests that the proposed action could have a small negative influence on soft-bottom benthos (Section 4.2.1), which may include some of the crustaceans and mollusks that loggerheads eat; furthermore, the negative influence on soft-bottom benthos might result in a decrease in the abundance of horseshoe crabs, which rely on soft-bottom benthos for food. An increase in hard substrate due to increases in Suminoe oyster populations, however, could provide additional habitat for reproduction of jellyfish such as the stinging sea nettle and, consequently, enhance the food supply available for loggerhead turtles. Together, these direct and indirect influences may cancel each other out and result in a negligible effect on the availability of prey for loggerhead turtles.

Kemp's Ridley Turtle – Chesapeake Bay is a major developmental habitat for immature Kemp's ridley sea turtles; no other location in the world harbors as many immature individuals each summer (Section 3.4.3). They are found during May through November in shallow, near-shore sea grass beds, especially where their preferred food, blue crabs, are abundant. The ERA suggests that the proposed action could have a positive influence on blue crabs because they prey on Suminoe oysters; consequently, the proposed action could have a beneficial effect on the availability of prey for Kemp's ridley turtles. This beneficial effect, however, would be small, particularly given the minimal numbers of this species that occur in the Bay.

Green Turtle – Green turtles forage for jellyfish, mollusks, crustaceans, sponges, and vegetation in sea grass flats in shallow areas of Chesapeake Bay. Juveniles are primarily carnivorous, whereas the diet of adult green turtles includes significant quantities of plant material, including eelgrass, sea lettuce, and macroalgae. The ERA suggests that the proposed action could have a small positive influence on SAV in the Bay (Section 4.3.1). The magnitude of the positive influence would increase with increasing oyster biomass (Section 4.4.1.1 of Appendix B). The proposed action, therefore, could have a small beneficial effect on the availability of food for adult green turtles. An increase in hard substrate due to the Suminoe oyster population could provide additional habitat for reproduction of jellyfish, such as the stinging sea nettle and, consequently, could enhance the food supply for juvenile green turtles; however, the projected small negative influence on zooplankton could affect jellyfish larvae, reducing the net effect on the food supply for juveniles.

Leatherback Turtle – Leatherback turtles feed on soft-bodied, pelagic invertebrates, primarily the moon jellyfish. The proposed action could have a small negative influence on zooplankton that would increase with increasing oyster biomass (Section 4.2.1; Section 4.4.2 of

Appendix B). Jellyfish larvae are part of the zooplankton community; therefore, the negative influence on zooplankton could have an adverse effect on the availability of prey for the leatherback turtle.

Atlantic Hawksbill Turtle – Coral reef is the main habitat of the Atlantic hawksbill turtle. Sighting of hawksbills are rare north of Florida (NMFS 2005). Effects of the proposed action on Atlantic hawksbill turtles, if any, would be related indirectly to the potential negative influence of increasing oyster biomass on phytoplankton and zooplankton (food sources for coral species) and might occur only in the event of dispersal of the Suminoe oyster to neighboring coastal estuaries to the south of Chesapeake Bay (Section 4.15).

4.4.1.4 Potential Effects on RTE Insects

Two RTE species of tiger beetle occur in Chesapeake Bay, the Puritan tiger beetle and the Northeastern beach tiger beetle (Section 3.4.4). Both species are listed as endangered in Maryland and are on the Federal list of threatened species (Table 3-2). Habitat for both species is sandy beaches, where they inhabit vertical burrows in the sand and hunt for lice, fleas, and flies in the moist sand of the intertidal zone. Both species are considered to be particularly sensitive to man-made disturbances. Construction of new hatcheries to provide spat required for the proposed introduction program could adversely affect these beetles, if facilities were sited in areas they inhabit.

4.4.1.5 Potential Effects on RTE Plants

The sensitive jointvetch is an annual marsh plant that occurs in the freshwater tidal river systems in the Bay, mainly in Virginia. The proposed action would not affect this species because oysters do not inhabit fresh water.

4.4.2 Alternative 1: No Action

4.4.2.1 Potential Effects on RTE Fish

Shortnose and Atlantic Sturgeon – The numbers of both species currently using the Bay are small (Section 3.4.1). Both species are bottom feeders that spawn in fresh water. Alternative 1 would not affect their spawning habitat. Adults and juveniles of both species of sturgeon feed in estuarine waters. The forage species for adults and juveniles of both species are members of the soft-bottom benthic community. Under Alternative 1 hard-bottom habitat could decrease in high-salinity waters of Virginia’s portion of Chesapeake Bay as the numbers of oysters decrease. This could create a slight increase in food resources available for sturgeon. Under this alternative, in the oligohaline waters of Maryland, a slight increase in oyster numbers could result in increased hard-bottom habitat, slightly reducing the level of food resources available for sturgeon. Given the minimal projected influence of the oyster on the sturgeons’ forage species (Section 4.2.2), the magnitude of the potential effects on shortnose and Atlantic sturgeon in Chesapeake Bay probably would be very small.

Spotfin Killifsh – The spotfin killifish inhabits salt marshes and feeds on zooplankton and emergent insects. Alternative 1 would have no influence on SAV (Section 4.3.2) and, thus, no effect on habitat for the spotfin killifish. Alternative 1 also would not affect zooplankton, which provides food for killifish. Under this alternative, in the oligohaline waters of Maryland, a slight increase in oyster numbers could result in increased hard-bottom habitat, slightly reducing the level of food resources available for killifish. Based on the results of the ERA, the magnitudes of the potential effects on food resources for the spotfin killifish probably would be very small.

4.4.2.2 Potential Effects on RTE Birds

Bald Eagle – Alternative 1 would not affect the nesting habitat available for bald eagles. Bald eagles eat fish when they are available but will shift to a variety of other birds, mammals, and turtles when fish are scarce. The ERA suggests that Alternative 1 could have a positive influence on avian piscivores (Section 4.1.2) such as the bald eagle, in salinity zones of the Bay where oyster biomass increased. That positive influence would be due to an indirect relationship in which an increase in oyster abundance would create more habitat for reef-oriented fish, some of which are prey species for some avian piscivores. In areas of the Bay where oyster biomass would decrease, Alternative 1 could result in a slight negative influence for avian piscivores like the bald eagle. Decreased hard-bottom habitat would mean diminished habitat for reef-oriented fish and, thus, decreased fish prey for the eagle; however, the bald eagle could shift to other food resources in the absence of fish.

Peregrine Falcon – Alternative 1 would not affect peregrine falcons because they nest almost exclusively on rocky cliffs and tall manmade structures (e.g., bridges and skyscrapers) and prey predominantly on waterfowl (Section 3.4.2). The ERA suggests that Alternative 1 could have a small negative influence on some species of waterfowl (i.e., avian oyster predators and avian piscivores) in zones where oyster numbers would decrease, which might result in less prey for peregrine falcons. Any detectable adverse affect on falcons probably would be very small.

Wilson's and Piping Plovers – Both species of plover are soft-bottom feeders (Section 3.4.2). The ERA suggests that Alternative 1 would not affect avian soft-bottom feeders. Some avian soft-bottom feeders consume SAV, but plovers do not; therefore, plovers would not be affected in any way.

Black Skimmer – The black skimmer requires undisturbed beach habitat for nesting colonies and open water for foraging. In Virginia, the species' diet is nearly all fish (90% silversides and killifishes; VAFWIS 2005). The ERA suggests that Alternative 1 could result in a slight positive influence on avian piscivores like the black skimmer in Maryland's oligohaline areas. In Virginia's polyhaline waters, the ERA suggests a slight negative influence on avian piscivores like the black skimmer. Any effects of Alternative 1 on black skimmer would be extremely minimal.

Brown Pelican – Brown pelicans typically feed in shallow estuarine waters on crustaceans, menhaden, mullet, sardines, and pinfish. The ERA suggests that Alternative 1 could result in a slight positive influence on avian piscivores in Maryland's oligohaline areas. In Virginia's polyhaline waters, the ERA suggests a slight negative influence on avian piscivores.

Brown pelicans consume a varied diet, including soft-bottom benthos like crustaceans. The ERA indicates no on avian soft-bottom feeders due to Alternative 1; therefore, Alternative 1 would be unlikely to affect brown pelicans.

Terns – Roseate, Caspian, royal, and sandwich terns prey primarily on planktivorous fish; the diets of roseate, Caspian, and sandwich terns also include some soft-bottom benthos. The diet of the least tern includes small crustaceans, and the diet of the gull-billed tern is almost exclusively insects (Section 3.4.2). The ERA indicates that Alternative 1 would have no effect on avian soft-bottom feeders or planktivorous fish; therefore, Alternative 1 would not affect terns.

4.4.2.3 Potential Effects on RTE Reptiles

Loggerhead Turtle – Loggerheads eat horseshoe crabs, jellyfish, crustaceans, and mollusks. They forage primarily along channels near the mouths of rivers and in areas of the Bay that are more than 13 feet deep. In Maryland's oligohaline zone, a slight positive influence on reptiles, including turtles is predicted in response to Alternative 1. In other state/salinity zones consider in the ERA (MD MH, VA MH, VA PH), slight negative influences on reptiles, including turtles, are expected, in response to continuing declines in oysters there.

Kemp's Ridley Turtle – The ERA suggests that Alternative 1 could have a positive influence on blue crabs in Maryland's oligohaline zone because they prey on oysters; consequently, Alternative 1 could have a beneficial effect on the availability of prey for Kemp's ridley turtles. In other salinity zones (MD MH, VA MH, VA PH), slight negative influences on blue crabs are predicted under this alternative, and slight negative influences on reptiles, including turtles, would be expected.

Green Turtle – The ERA suggests that Alternative 1 could have a small positive influence on SAV in Maryland's oligohaline region (Section 4.3.2). In that zone, therefore, Alternative 1 could have a small beneficial effect on the availability of food for adult green turtles. In other salinity zones (MD MH, VA MH, VA PH), slight negative influences on SAV are predicted, which might have a negative influence on green turtles. The ERA suggests a slight positive influence on reptiles, including turtles, in Maryland's oligohaline zone and a slight negative influence on reptiles, including turtles, in Maryland's mesohaline and Virginia's mesohaline and polyhaline regions.

Leatherback Turtle – The ERA suggests that Alternative 1 would have a slight positive influence on reptiles, including turtles, in Maryland's oligohaline zone and a slight negative influence on reptiles, including turtles, in Maryland's mesohaline and Virginia's mesohaline and polyhaline regions in response to continuing declines in oysters there.

Atlantic Hawksbill Turtle – Coral reef is the main habitat of the Atlantic hawksbill turtle. Sighting of hawksbills are rare north of Florida (NMFS 2005). Alternative 1 would have no appreciable effect on Atlantic hawksbill turtles.

4.4.2.4 Potential Effects on RTE Insects

Habitat for the Puritan tiger beetle and the Northeastern beach tiger beetle is sandy beaches, where they inhabit vertical burrows in the sand and hunt for lice, fleas, and flies in the moist sand of the intertidal zone. Alternative 1 would not affect their habitat and, thus, would have no effect on either species of tiger beetle.

4.4.2.5 Potential Effects on RTE Plants

The sensitive jointvetch is an annual marsh plant that occurs in the freshwater tidal sections in the Bay, mainly in Virginia. Alternative 1 would not affect this species because oysters do not inhabit fresh water.

4.4.3 Alternative 2: Enhance Restoration

4.4.3.1 Potential Effects on RTE Fish

Shortnose and Atlantic Sturgeon – Enhancing efforts to restore the Eastern oyster would not affect the spawning habitat of the two RTE species of sturgeon because no restoration efforts would occur in fresh water. Under Alternative 2, the soft-bottom benthic community could decrease in some salinity zones of Maryland waters where oyster numbers would increase. This could indirectly influence sturgeon because their food resources might decrease. In some Virginia waters, Alternative 2 could result in an increase in soft-bottom habitat in response to continuing declines in oyster populations in high-salinity areas. In these waters, Alternative 2 could have a positive influence on the soft-bottom benthic community and, indirectly, on the sturgeon. The magnitude of the potential effect on shortnose and Atlantic sturgeon in Chesapeake Bay probably would be very small.

Spotfin Killifish – The spotfin killifish inhabits salt marshes and feeds on zooplankton and emergent insects. Alternative 2 could have a small positive influence on SAV (Section 4.3.3), which might result in a minimal increase in habitat for the spotfin killifish. Alternative 2 could have a small negative influence on zooplankton, which could decrease the supply of food available for killifish. Based on the results of the ERA, the magnitudes of the potential beneficial effects on habitat and the potential adverse effects on food resources for the spotfin killifish probably would be very small.

4.4.3.2 Potential Effects on RTE Birds

Bald Eagle – Alternative 2 could adversely affect the habitat available for bald eagles if hatcheries required to produce spat for the enhanced restoration program (Section 4.1.3) were constructed within the recommended buffer zone around known nesting areas. Bald eagles eat fish when they are available but will shift to a variety of other birds, mammals, and turtles when fish are scarce. The ERA suggests that Alternative 2 could have a positive influence on avian piscivores (Section 4.2.3), such as the bald eagle, if oyster biomass increased in the Bay. That positive influence would be due to an indirect relationship in which an increase in oyster abundance would create more habitat for reef-oriented fish, some of which are prey species for some avian piscivores.

Peregrine Falcon – Alternative 2 would be unlikely to affect peregrine falcons because they nest almost exclusively on rocky cliffs and tall manmade structures (e.g., bridges and skyscrapers) and prey predominantly on waterfowl (Section 3.4.2). The ERA suggests that Alternative 2 could have a small positive influence in most salinity zones on some species of waterfowl (i.e., avian oyster predators and avian piscivores) which might result in more prey for peregrine falcons. Given the small projected positive influence on the peregrine falcon's prey species, any detectable beneficial affect on falcons probably would be extremely small.

Wilson's and Piping Plover – Both species of plover are soft-bottom feeders (Section 3.4.2). The ERA suggests that avian soft-bottom feeders would not be affected under Alternative 2. Wilson's plover is not a common breeder anywhere on the Atlantic coast. Habitat for the piping plover includes sandy beaches and associated intertidal areas within the Bay. Construction of hatcheries to provide spat required for the expanded restoration program would not affect Wilson's plover but might adversely affect habitat for piping plovers, if facilities were sited in areas that they are known to use for nesting or foraging.

Black Skimmer – The ERA suggests that in Maryland's oligohaline zone, Alternative 2 would have a slight negative effect on planktivorous fish (Section 4.2.3), which include the black skimmer's prey species. Construction of hatcheries to provide spat for the expanded restoration program could have an adverse effect on habitat for black skimmers, if facilities were sited in areas that they are known to use for nesting or foraging.

Brown Pelican – The ERA suggests that in Maryland's oligohaline zone, Alternative 2 would have a slight negative effect on planktivorous fish (Section 4.2.3), such as those consumed by brown pelicans. No effect is predicted for avian soft-bottom feeders under Alternative 2, despite a slight negative effect predicted for the benthic soft-bottom community in Maryland's oligohaline zone. Any effects on brown pelicans under Alternative 2 are likely to be extremely minimal.

Terns – Roseate, Caspian, royal, and sandwich terns prey primarily on planktivorous fish; the diets of roseate, Caspian, and sandwich terns also include some soft-bottom benthos. The diet of the least tern includes small crustaceans, and the diet of the gull-billed tern is almost exclusively insects (Section 3.4.2). The ERA suggests that Alternative 2 would have small negative influences on planktivorous fish in Maryland's oligohaline zone. In this area, Alternative 2 could adversely affect the availability of prey for most RTE species of terns. The gull-billed tern probably would be the least affected because of its reliance on insects for food. The general nesting habitat for all of these species, various kinds of beaches associated with barrier islands, probably would not be affected by the construction of hatcheries to support the expanded restoration program.

4.4.3.3 Potential Effects on RTE Reptiles

Loggerhead Turtle – The ERA suggests that Alternative 2 could have a small positive influence on reptiles, including turtles, in Maryland's portion and in Virginia's mesohaline zone (Section 4.2.3). It suggests a small negative influence, however, in Virginia's polyhaline zone, where oysters would continue to decline.

Kemp's Ridley Turtle – The ERA suggests that Alternative 2 could have a small positive influence on blue crabs in some salinity zones because they prey on oysters; consequently, this alternative could have a beneficial effect on the availability of prey for Kemp's ridley turtles.

Green Turtle – The ERA suggests that Alternative 2 could have a small positive influence on SAV in the Bay (Section 4.3.3). The magnitude of the positive influence would increase with increasing oyster biomass (Section 4.4.4 of Appendix B). This alternative, therefore, could have a small beneficial effect on the availability of food for adult green turtles. In some salinity zones, this alternative could have a small negative influence on soft-bottom benthos, which might result in decreases in the availability of some kinds of prey for juvenile green turtles. The ERA suggests a slight negative influence on reptiles, including turtles, in Virginia's polyhaline zone where oysters would continue to decline, but a slight positive influence in most other salinity regions.

Leatherback Turtle **–** Alternative 2 could have a small negative influence on zooplankton in Maryland's oligohaline zone that would increase with increasing oyster biomass (Section 4.2.3; Section 4.4.4 of Appendix B). Jellyfish larvae are part of the zooplankton community; therefore, the negative influence on zooplankton could have an adverse effect on the availability of prey for the leatherback turtle. The increase in availability of oyster shell substrate that might result from this alternative, however, would provide increased habitat for reproduction of some jellyfish, which would have a positive influence on the availability of food for the leatherback turtle. The ERA suggests a slight negative influence on reptiles, including turtles, in Virginia's polyhaline zone, but a slight positive influence in most other salinity zones.

Atlantic Hawksbill Turtle **–** Coral reef is the main habitat of the Atlantic hawksbill turtle. Sightings of hawksbills are rare north of Florida (NMFS 2005). Alternative 2 would have no appreciable effects on Atlantic hawksbill turtles.

4.4.3.4 Potential Effects on RTE Insects

Habitat for both the Puritan tiger beetle and the Northeastern beach tiger beetle is sandy beaches, where they inhabit vertical burrows in the sand and hunt for lice, fleas, and flies in the moist sand of the intertidal zone. Construction of any new hatcheries to provide spat for the expanded restoration program under Alternative 2 could adversely affect these beetles, if facilities were sited in areas they inhabit.

4.4.3.5 Potential Effects on RTE Plants

The sensitive jointvetch is an annual marsh plant that occurs in the freshwater tidal sections of rivers systems in the Bay, mainly in Virginia. Alternative 2 would not affect this species because oysters do not inhabit fresh water.

4.4.4 Alternative 3: Harvest Moratorium

4.4.4.1 Potential Effects on RTE Fish

Shortnose and Atlantic Sturgeon – Alternative 3 would not affect the spawning habitat of the RTE species of sturgeon in Chesapeake Bay because oyster beds are not found in fresh water. Under Alternative 3, the soft-bottom benthic community could decrease in some salinity zones of Maryland waters where oyster numbers increased. This could indirectly influence the sturgeon because their food resources might decrease. In some Virginia waters, Alternative 3 could result in an increase in soft-bottom habitat where oyster numbers would decrease. In these waters, Alternative 3 could have a positive influence on the soft-bottom benthic community and, indirectly, on the sturgeon.

Spotfin Killifish – Alternative 3 could have a small positive influence on SAV (Section 4.3.4), which might result in a minimal increase in habitat for the spotfin killifish. Alternative 3 would not influence zooplankton and therefore would not affect the food supply for killifish. Based on the results of the ERA, the magnitudes of the potential beneficial effect on habitat and food resources for the spotfin killifish probably would be very small (Section 4.2.4).

4.4.4.2 Potential Effects on RTE Birds

Bald Eagle – Alternative 3 would not be expected to affect nesting habitat for bald eagles. The ERA suggests that Alternative 3 could have a positive influence on avian piscivores (Section 4.2.4) such as the bald eagle in most salinity zones where oyster biomass would increase in the Bay. That positive influence would be due to an indirect relationship in which an increase in oyster abundance would create more habitat for reef-oriented fish, some of which are prey species for some avian piscivores. In Virginia's polyhaline zone, oyster biomass may decrease under Alternative 3. In that area, Alternative 3 could result in a slight negative influence for avian piscivores like the bald eagle. Decreased hard-bottom habitat would mean diminished habitat for reef-oriented fish and decreased fish prey for eagles; however, bald eagles could shift to other food resources in the absence of fish.

Peregrine Falcon – Alternative 3 would be unlikely to affect nesting habitat for peregrine falcons because they nest almost exclusively on rocky cliffs and tall manmade structures (e.g., bridges and skyscrapers; Section 3.4.2). The ERA suggests that Alternative 3 could have a small positive influence in Maryland on some species of waterfowl (i.e., avian oyster predators, avian piscivores, and avian soft-bottom feeders), which might result in more prey for peregrine falcons. In the high-salinity zones in Virginia, the ERA suggests a small negative influence on some species of waterfowl, which might result in a slight reduction of prey for the peregrine falcon. Given the very small projected influence on their prey, any detectable affects on peregrine falcons probably would be small.

Wilson's and Piping Plovers – Both species of plover are soft-bottom feeders (Section 3.4.2). The ERA suggests that Alternative 3 could have a minimal positive influence on avian soft-bottom feeders in the Maryland mesohaline zone. In other salinity zones, the ERA suggests that avian soft-bottom feeders would not be affected by the harvest moratorium. The magnitude of the influence of the harvest moratorium on the two RTE species of plover probably would be very small.

Black Skimmer – The ERA suggests that a harvest moratorium would have no influence on planktivorous fish, which are food for the black skimmer. The ERA predicts a positive influence on avian piscivores like the black skimmer in some salinity zones (MD OH and VA OH) but a negative influence on avian piscivores in others (VA PH).

Brown Pelican – The ERA suggests that Alternative 3 would have no influence on planktivorous fish, which are one source of food for the brown pelican. It predicts a positive influence on avian piscivores in some salinity zones (MD OH and VA OH) but a negative influence in others (VA PH). The ERA suggests that the harvest moratorium would not affect the soft-bottom benthos, including some of the crustaceans consumed by the brown pelican, in any state/salinity zone. Any effects on the brown pelican as a result of an oyster harvest moratorium would be slight.

Terns – Roseate, Caspian, royal, and sandwich terns prey primarily on planktivorous fish; the diets of roseate, Caspian, and sandwich terns also include some soft-bottom benthos. The diet of the least tern includes small crustaceans, and the diet of the gull-billed tern is almost exclusively insects (Section 3.4.2). The ERA suggests that a harvest moratorium would not affect the soft-bottom benthos, and would have no influence on planktivorous fish, which some terns consume as prey. It predicts a positive influence on avian piscivores in some salinity zones (MD OH and VA OH) but a negative influence in others (VA PH). The general nesting habitat for all of these species, various kinds of beaches associated with barrier islands, would not be affected under this alternative.

4.4.4.3 Potential Effects on RTE Reptiles

Loggerhead Turtle – Loggerhead turtles account for nearly 90% of the summer population of sea turtles in the Bay. The loggerhead is on the Federal list of threatened species and is considered threatened in Maryland and Virginia. Loggerheads eat horseshoe crabs, jellyfish, crustaceans, and mollusks and forage primarily along channels near the mouths of rivers and in areas of the Bay that are more than 13 feet deep. The ERA suggests that Alternative 3 could have a positive influence on reptiles, including turtles, in all regions of the Bay except Virginia's polyhaline zone (Section 4.2.4). They may, however, experience a decrease in prey availability in areas where oyster biomass would increase if oysters filter larval jellyfish from the water before they can settle on hard surfaces.

Kemp's Ridley Turtle – The ERA suggests that Alternative 3 could have a positive influence on blue crabs because they prey on oysters; consequently, the harvest moratorium could have a beneficial effect on the availability of prey for Kemp's ridley turtles.

Green Turtle – Juveniles are primarily carnivorous, whereas the diet of adult green turtles includes significant quantities of plant material, including eelgrass, sea lettuce, and macroalgae. The ERA suggests that Alternative 3 could have a small positive influence on SAV in the Bay (Section 4.3.4). The magnitude of the positive influence would increase with increasing oyster biomass (Section 4.4.5 of Appendix B). An oyster harvest moratorium, therefore, could have a small beneficial effect on the availability of food for adult green turtles. Increases in jellyfish that might result from increases in oyster biomass in some salinity zones could be benefit juveniles. The ERA suggests that Alternative 3 would have a slight negative influence on reptiles, including turtles, in Virginia's polyhaline zone, but a slight positive influence in most other salinity regions.

Leatherback Turtle – The ERA predicts that a harvest moratorium would have no influence on zooplankton and suggests a slight negative influence on reptiles, including turtles, in Virginia's polyhaline zone, but a slight positive influence in most other salinity regions. Leatherback turtles may, however, experience a decrease in prey availability in areas where oyster biomass would increase if oysters filter larval jellyfish from the water before they can settle on hard surfaces.

Atlantic Hawksbill Turtle – Coral reef is the main habitat of the Atlantic hawksbill turtle. Sightings of hawksbills are rare north of Florida (NMFS 2005). Alternative 3 would have no appreciable effect on Atlantic hawksbill turtles.

4.4.4.4 Potential Effects on RTE Insects

Habitat for both the Puritan tiger beetle and the Northeastern beach tiger beetle is sandy beaches. Alternative 3 would not affect either species of tiger beetle.

4.4.4.5 Potential Effects on RTE Plants

The sensitive jointvetch is an annual marsh plant that occurs in the freshwater tidal sections of river systems in the Bay, mainly in Virginia. Alternative 3 would not affect this species because oysters do not inhabit fresh water.

4.4.5 Alternative 4: Cultivate Eastern Oysters

4.4.5.1 Potential Effects on RTE Fish

Shortnose and Atlantic Sturgeon – Alternative 4 would have no effect on the spawning habitat of either RTE species of sturgeon because aquaculture operations would not occur in fresh water. Alternative 4 would affect the availability of food for sturgeon to the extent that enrichment of substrate under concentrated off-bottom aquaculture operations might enhance soft-bottom benthos.

Spotfin Killifish – The spotfin killifish inhabits salt marshes and feeds on zooplankton and emergent insects. The effects of aquaculture would depend on the location of concentrated operations. In areas of concentrated aquaculture, SAV might benefit, which could result in a minimal increase in habitat for the spotfin killifish. The negative influence on zooplankton that might result from increased filtering by oysters could decrease the supply of food available for killifish.

4.4.5.2 Potential Effects on RTE Birds

Bald Eagle – Alternative 4 could result in enhanced boating and other support activity associated with expanded aquaculture operations. Such activity could affect nesting bald eagles if it were to occur within the recommended buffer zone around nesting sites. The ERA suggests that Alternative 4 would not affect the diet of avian piscivores (Section 4.2.5) such as the bald eagle.

Peregrine Falcon **–** No detectable affects on falcons would be expected as a result of aquaculture.

Wilson's and Piping Plovers – Both Wilson's plover and piping plover are soft-bottom feeders (Section 3.4.2). The ERA suggests that avian soft-bottom feeders would not be influenced by the cultivation of native oysters under Alternative 4. Construction of hatcheries to provide spat required for the aquaculture program would not affect Wilson's plover but might adversely affect habitat for piping plovers, if facilities were sited in areas that they are known to use for nesting or foraging.

Black Skimmer – The ERA suggests that Alternative 4 could have a small negative influence on planktivorous fish, which include the black skimmer's prey species, in Virginia's polyhaline zone; however, no effects on avian piscivores are predicted in any salinity zone. Construction of hatcheries to provide spat for the aquaculture program could have an adverse effect on habitat for black skimmers, if facilities were sited in areas that they are known to use for nesting or foraging. Also, floats could interfere with the black skimmer's normal foraging activity in areas of extensive suspended aquaculture. This bird flies near the water surface with its beak dipped into the water, and black skimmers would be unable to forage in areas occupied by floats.

Brown Pelican – The ERA suggests that Alternative 4 could have a small negative influence on planktivorous fish, which include the pelican's prey species, in Virginia's polyhaline zone; however, no effects are predicted for avian piscivores in any state/salinity zone. Any effects of Alternative 4 on the brown pelican would be slight. As noted for the black skimmer, use of floats for aquaculture could interfere with pelican foraging.

Terns **–** The ERA suggests that Alternative 4 could have a small negative influence on planktivorous fish, which include some terns' prey species, in Virginia's polyhaline zone; however, no effects are predicted for avian piscivores in any state/salinity zone. In the event of any detectable effects, the gull-billed tern probably would be the least affected because of its reliance on insects for food. The ERA suggests that Alternative 4 would not affect the soft-bottom benthos. The general nesting habitat for all of these species, various kinds of beaches associated with barrier islands, could be affected by the construction and maintenance of hatcheries and other infrastructure involved in the aquaculture program.

4.4.5.3 Potential Effects on RTE Reptiles

No trophic effects would be expected for any of the RTE species of turtles; however, adult turtles could become entangled with floats or buoy lines in areas of concentrated aquaculture.

4.4.5.4 Potential Effects on RTE Insects

Construction of infrastructure, such as new docks, shoreline processing facilities, and hatcheries to provide spat required for expanded aquaculture operations could adversely affect tiger beetles, if facilities were sited in areas they inhabit.

4.4.5.5 Potential Effects on RTE Plants

The sensitive jointvetch is an annual marsh plant that occurs in the freshwater tidal sections of river systems in the Bay, mainly in Virginia. Alternative 4 would not affect this species because oysters do not inhabit fresh water.

4.4.6 Alternative 5: Cultivate a Nonnative Oyster

The potential consequences of an accidental introduction of diploid Suminoe oysters resulting from triploid aquaculture operations would be the same as described for the proposed action for all RTE species. Other potential effects of large-scale aquaculture operations are described in the following sections.

4.4.6.1 Potential Effects on RTE Fish

Shortnose and Atlantic Sturgeon – Alternative 5 would have no effect on the spawning habitat of the RTE species of sturgeon because aquaculture operations would not occur in fresh water. Nonnative oysters would be cultivated using confined, off-bottom methods; consequently, substrate beneath culture areas could be enriched, resulting in enhancement of benthos. Such enrichment could increase the availability of food for juvenile sturgeon.

Spotfin Killifish – The spotfin killifish inhabits salt marshes and feeds on zooplankton and emergent insects. The effects of aquaculture on killifish would depend on the location of concentrated operations. In areas of concentrated aquaculture, SAV might benefit, which could result in a minimal increase in habitat for the spotfin killifish. The negative influence on zooplankton that might result from increased filtering by oysters could decrease the supply of food available for killifish.

4.4.6.2 Potential Effects on RTE Birds

Bald Eagle – Alternative 5 could result in enhanced boating and other support activity associated with expanded aquaculture operations. Such activity could affect nesting bald eagles if it occurs within the recommended buffer zone around nesting sites. Construction of infrastructure for aquaculture operations (e.g., docks, hatcheries) could affect eagles if it occurs within the recommended buffer zones around nesting sites. The ERA suggests that Alternative 5 would not affect the diet of avian piscivores (Section 4.2.6) such as the bald eagle.

Peregrine Falcon **–** No detectable affects on falcons would be expected as a result of aquaculture.

Wilson's and Piping Plover **–** Both Wilson's plover and piping plover are soft-bottom feeders (Section 3.4.2). The ERA suggests that avian soft-bottom feeders would not be influenced by cultivation of a nonnative oyster. Construction of hatcheries to provide spat required for the maximum economically viable aquaculture program would not affect Wilson's plover but might adversely affect habitat for piping plovers, if facilities were sited in areas that they are known to use for nesting or foraging.

Black Skimmer **–** The ERA suggests that Alternative 5 could have a small negative influence on planktivorous fish, which include the black skimmer's prey species, in areas of concentrated aquaculture operations; however, no effects on avian piscivores are predicted in any state/salinity zone. Construction of hatcheries to provide spat for the maximum economically viable aquaculture program and other infrastructure for the industry (e.g., docks, shucking houses) could adversely affect habitat for black skimmers, if facilities were sited in areas that they are known to use for nesting or foraging. Also, extensive use of floats and buoys (used to mark off-bottom cages or suspended bags) could interfere with the black skimmer's normal foraging activity in areas of extensive aquaculture. This bird flies near the water surface with its beak dipped into the water, and its foraging could be impaired in areas occupied by floats or numerous buoys.

Brown Pelican **–** The ERA suggests that Alternative 5 could have a small negative influence on planktivorous fish, which include the pelican's prey species, in areas of concentrated aquaculture; however, no effects on avian piscivores are predicted for any state/salinity zone. Any effects of Alternative 5 on the brown pelican would be slight. As with the black skimmer, use of floats and buoys could interfere with foraging.

Terns **–** The ERA suggests that Alternative 5 could have a small negative influence on planktivorous fish, which include some terns' prey species, in areas of concentrated aquaculture; however, no effects on avian piscivores are predicted for any state/salinity zone. In the event of any detectable effects, the gull-billed tern probably would be the least affected because of its reliance on insects for food. The ERA suggests that Alternative 5 would not affect the soft-bottom benthos. The general nesting habitat for all of these species, various kinds of beaches associated with barrier islands, could be affected by the construction and maintenance of hatcheries and other infrastructure involved in a large-scale aquaculture program.

4.4.6.3 Potential Effects on RTE Reptiles

No trophic effects would be expected for any of the RTE species of turtles; however, adult turtles could become entangled with floats or buoy lines in areas of concentrated aquaculture.

4.4.6.4 Potential Effects on RTE Insects

Construction of infrastructure, such as new docks, shoreline processing facilities, and hatcheries to provide spat required for the maximum economically viable aquaculture program could adversely affect tiger beetles, if facilities were sited in areas they inhabit.

4.4.6.5 Potential Effects on RTE Plants

The sensitive jointvetch is an annual marsh plant that occurs in the freshwater tidal sections of river systems in the Bay, mainly in Virginia. Alternative 5 would not affect this species because oysters do not inhabit fresh water.

4.4.7 Alternative 8: Combination of Alternatives

Combination 8a. – Eastern oyster only. - The potential effects of management actions included in this combination on RTE species are summarized in Table 4-9. Categories included in this evaluation include construction of new oyster hatcheries, the direct or indirect effects of changes in oyster abundance on food availability for RTE species, and potential negative interactions with aquaculture floats or buoy lines. The number of RTE species potentially affected by this combination of alternatives is similar to Combinations 8b and 8c; however, because increases in oyster abundance are expected to be relatively small and restricted to low-salinity waters under this combination of alternatives, the magnitude and geographic area in which effects on RTE species might occur would most likely be smaller than for the other combinations.

Combination 8b. – Eastern oyster and triploid nonnative Suminoe oysters. - The potential effects of this combination on RTE species are expected to be similar to combination 8a and 8c (Table 4-9). Some increase in oyster abundance is expected in low-salinity waters and in high-salinity waters as a result of triploid aquaculture; therefore, the magnitude of potential Bay-wide effects on RTE species under this combination is expected to be somewhat greater than for Combination 8a and somewhat lesser than for Combination 8c.

Combination 8c. – Eastern oyster and both diploid and triploid nonnative Suminoe oysters. - Because the potential for widespread increases in oyster abundance is greatest under this combination of alternatives, the magnitude of effects on RTE species due to management actions included in this combination of alternatives is also potentially greater than for Combinations 8a or 8b.

4.5 ESSENTIAL FISH HABITAT

As described in Section 3.5, the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267), sets forth several mandates for the U.S. Department of Commerce (USDOC) National Oceanic and Atmospheric Administration (NOAA), NMFS, regional fishery management councils (councils) and other Federal agencies to identify and protect important habitat for marine and anadromous fish. EFH is different than the critical habitat defined under the Endangered Species Act of 1973 because measures recommended to protect EFH are advisory rather than

Table 4-9. Potentially additive influences of components of Combinations of Alternatives 8a, 8b, and 8c on RTE species in Chesapeake Bay based on individual assessments of the proposed action and alternatives presented in this section.

Potential effect	**Proposed Action (8c)**	**Alternative 2 (8a, b, & c)**	**Alternative 3 (8a, b, & c)**	**Alternative 4 (8a, b, &c)**	**Alternative 5 (8b & c)**
Hatcheries – adverse effect if constructed near important nesting/foraging areas	bald eagle, piping plover, black skimmer, brown pelican, puritan tiger beetle and Northeastern beach tiger beetle	bald eagle, piping plover, black skimmer, brown pelican, puritan tiger beetle and Northeastern beach tiger beetle		bald eagle, piping plover, black skimmer, brown pelican, puritan tiger beetle and Northeastern beach tiger beetle	bald eagle, piping plover, black skimmer, brown pelican, puritan tiger beetle and Northeastern beach tiger beetle
Indirect effect on food availability – potential very small to small negative effect	Atlantic and shortnose sturgeon, spotfin, killifish, Wilsons plover, piping plover, black skimmer, brown pelican, most species of RTE terns, leatherback turtle and Atlantic hawksbill	Atlantic and shortnose sturgeon, spotfin, killifish, black skimmer, brown pelican, most species of RTE terns, leatherback turtle and Atlantic hawksbill		spotfin killifish, black skimmer, brown pelican	spotfin killifish, black skimmer, brown pelican
Indirect effect on food availability – potential very small to small positive effect	bald eagle, peregrine falcon, Kemp's Ridley turtle and green turtle (adult)	bald eagle, peregrine falcon, Kemp's Ridley turtle and green turtle (adult)	Kemp's Ridley green turtle (adult)	Atlantic and shortnose sturgeon	Atlantic and shortnose sturgeon
Potential negative interactions with aquaculture floats or buoy lines				All species of sea turtles	All species of sea turtles

prescriptive. Under the MSFCMA, fishery management plans must identify and describe EFH for the fishery and minimize adverse effects on the fishery to the extent practical (NMFS 2005).

In conducting the EFH analysis, six summary EFH designations specific to major portions of the Chesapeake Bay in Maryland were identified: Chesapeake Bay Mainstem, Chester River, Choptank River, Patuxent River, Potomac River, and Tangier/Pocomoke Sound. Four summary EFH designations specific to major portions of the Chesapeake Bay in Virginia were identified: Chesapeake Bay Mainstem, James River, Rappahannock River, and York River. In addition, summary designations were identified for several discreet areas of the lower Bay in Virginia that are not covered by the other geographical listings (http://www.nero.noaa.gov/hcd/est.htm). Twenty-one Federally managed species have designated EFH within Chesapeake Bay. Table 3-3 in Section 3.5 summarizes EFH for those species. Portions of the lower Bay were designated as habitat areas of particular concern (HAPC) for the sandbar shark (*Charcharinus plumbeus*). Other HAPC that may occur in the Bay has been defined for summer flounder (*Paralichthys dentatus*) and red drum (*Sciaenops ocellatus*).

Performing an EFH assessment for this PEIS is somewhat unusual. Effects on EFH usually are evaluated for one, specifically defined project or action proposed for a particular location (e.g., construction of a new underwater pipeline across a particular body of water). A typical EFH assessment considers how the project or action would alter the environment (e.g., how a particular method of trenching to bury a pipeline might affect water quality and substrate characteristics) and the consequences of that alteration for essential habitat for Federally managed species (e.g., a change in substrate characteristics makes a location less suitable for spawning). This EFH assessment is a programmatic analysis that is intended to assist decision makers to identify an appropriate or preferred strategy rather than to render a project-based decision. It describes representative future actions, and evaluates them to the degree possible given the information presently available. Most specific future proposals will require subsequent environmental analysis to evaluate project-specific details that were not available for this Programmatic EIS. In this Draft PEIS, the proposed action and eight alternatives all are being considered as possible strategies for restoring oysters throughout Chesapeake Bay; no preferred alternative has yet been identified, and no specific projects to implement any strategy have been designed. For this reason, the lead agencies have not yet initiated an EFH consultation with NOAA. The descriptions of the nine actions considered in this Draft PEIS are quite general, and the “project area” is the entire Chesapeake Bay; moreover, successful implementation of many of these strategies would result in intentionally increasing a particular kind of habitat throughout the Bay. Given the scope and scale of this PEIS, this EFH assessment focuses on how changes in oyster abundance in the Bay projected to result from implementing the proposed action and each alternative might affect each of the life stages of the managed species that have designated EFH in the Bay. This necessary focus on the managed species instead of on specific kinds of habitat in a particular location is a departure from standard EFH assessments; nevertheless, this assessment will provide useful guidance for more site-specific assessments in later tiers of NEPA evaluations related to oyster restoration, should they be required.

This assessment of potential general effects on EFH is organized to correspond with the relevant receptor categories employed in the ERA: planktivorous fish, piscivorous fish, and reef-oriented fish. Each managed species was assigned to the most appropriate receptor category to facilitate the use of findings of the ERA for evaluating the potential effects of the proposed action and alternatives. The bottom-dwelling species (i.e., flounders and skates) did not fit well into one of the receptor categories for the ERA and were grouped together and evaluated based on the projected effects on their preferred habitat and food. Section 2.3 and 2.4 of the ERA (Appendix B) describes the potential modes of interaction between oysters and the receptor categories. The findings of the ERA are based on projections of oyster abundance described in Section 4.1, with the anticipated distribution of increases within state/salinity zones drawn from exploratory model runs described in Appendix A. Because of the uncertainties associated with oyster abundance projections, EFH assessments are subject to the same kinds and magnitudes of uncertainty. The results of the EFH assessment are summarized in a table for each of the actions.

4.5.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

If the proposed action were to result in a substantial increase in oyster abundance throughout the Bay, several managed species with designated EFH in the Bay could be affected directly or indirectly. An increase in oyster biomass could affect the managed species classified as reef-oriented fish (Table 4-10) positively because of the increased availability of their preferred habitat, food, or both. An increase in oyster reef in the Bay could affect managed species in the piscivorous fish category positively because it would provide habitat and protection for forage fish that are prey for the larger piscivorous fish. Managed species in the planktivorous category and larvae of other species could be negatively affected by an increase in oyster biomass through indirect competition for planktonic food resources, which would be likely in Chesapeake Bay only on a very local basis. If phytoplankton food resources were to become scarce in such circumstances, growth, reproduction, and survival of planktivorous fish could decline with increasing oyster abundance. If the proposed action were to not result in substantial increases in oyster abundance, none of these effects would be realized.

4.5.2 Alternative 1: No-Action

The effects of Alternative 1 on EFH (Table 4-11) would be small because no substantial increase in oyster abundance would be likely, and abundance might, in fact, decline in most areas. In high-salinity waters of Virginia’s portion of Chesapeake Bay, where oyster numbers would likely decrease, reef-oriented fish could be negatively affected by decreased hard-bottom habitat. Because oysters feed on some kinds of plankton, a decrease in the number of oysters could reduce competition with planktivorous fish for food. Such influences on planktivorous fish could affect piscivorous fish through the food chain (i.e., an indirect effect of changes in oyster abundance). As the numbers of planktivorous fish increase due to an increased food supply, the abundance of piscivorous fish could increase as well. In the oligohaline waters of Maryland, an increase in oyster numbers could result in an increase in hard-bottom habitat at a local level, thus improving conditions for reef-oriented fish, if that habitat is within their preferred salinity range. Piscivorous fish also could be positively affected due to increases in forage fish near new or expanded oyster bars. Planktivorous fish may compete with oysters for food; however, this effect would be minimal for Alternative 1, given the modest projected increase in oysters.

Table 4-10. Potential effects of the proposed action on managed species with designated EFH in Chesapeake Bay.

Species	Stage*	Potential Influences
Planktivorous Fish		
Atlantic herring	A	No large-scale effect. Locally, increased numbers of oysters could compete with adult herring or larval butterfish for food.
Atlantic butterfish	E, L	
	J, A	Increased numbers of oysters could compete with this species for food.
Piscivorous Fish		
Bluefish	J, A	Availability of food could increase as small forage fish increase near reef habitat.
Cobia	E, L	No large-scale effect.
	J, A	Availability of food could increase as small forage fish increase near reef habitat.
King mackerel	E, L, J	No large-scale effect.
	A	Availability of food could increase as small forage fish increase near reef habitat.
Spanish mackerel	E, L, J	No large-scale effect.
	A	Availability of food could increase as small forage fish increase near reef habitat.
Dusky shark	L	No large-scale effect.
	J	Availability of food could increase as small forage fish increase near reef habitat.
Sandbar shark	L	No large-scale effect.
	J, A	Availability of food may increase as small forage fish increase near reef habitat.
Sand tiger shark	L	No large-scale effect.
	A	Availability of food could increase as small forage fish increase near reef habitat.
Atlantic sharpnose shark	A	
Scalloped hammerhead shark	J	
Reef-Oriented Fish		
Red hake	J, A	Increased oyster reef habitat and food availability could occur where oysters increase.
Black sea bass	J, A	Availability of oyster-reef habitat and food could increase where oysters increase.
Scup, porgy	J, A	
Red drum	L	Increased numbers of oysters could compete indirectly with this species for food.
	J, A	Availability of oyster-reef habitat and food could increase where oysters increase.
Skates and Flounders		
Clearnose skate	J, A	An increase in oyster reef habitat could result in a slight decrease in the availability of food (soft-bottom benthos).
Little skate	J, A	
Winter skate	J, A	
Summer flounder	L, J, A	
Windowpane flounder	J, A	
Winter flounder	J, A	

*Stage codes: E = egg, L = larvae, J = juvenile, A = adult

Table 4-11. Potential effects of Alternative 1 on managed species with designated EFH in Chesapeake Bay

Species	Stage*	Potential Influences
Planktivorous Fish		
Atlantic herring	A	No large-scale effect.
Atlantic butterfish	E, L	
	J, A	Increased numbers of oysters could compete indirectly with this species for food. Decreased numbers of oysters could result in reduced competition for food.
Piscivorous Fish		
Bluefish	J, A	Availability of forage fish (prey) could increase where oyster-reef habitat increases but decrease where oyster-reef habitat decreases.
Cobia	E, L	No large-scale effect.
	J, A	Availability of forage fish (prey) could increase where oyster-reef habitat increases but decrease where oyster-reef habitat decreases.
King mackerel	E, L, J	No large-scale effect.
	A	Availability of forage fish (prey) could increase where oyster-reef habitat increases but decrease where oyster-reef habitat decreases.
Spanish mackerel	E, L, J	No large-scale effect.
	A	Availability of forage fish (prey) could increase where oyster-reef habitat increases but decrease where oyster-reef habitat decreases.
Dusky shark	L	No large-scale effect.
	J	Availability of forage fish (prey) could increase where oyster-reef habitat increases but decrease where oyster-reef habitat decreases.
Sandbar shark	L	No large-scale effect.
	J, A	Availability of forage fish (prey) could increase where oyster-reef habitat increases but decrease where oyster-reef habitat decreases.
Sand tiger shark	L	No large-scale effect.
	A	Availability of forage fish (prey) could increase where oyster reef habitat increases but decrease where oyster-reef habitat decreases.
Atlantic sharpnose shark	A	
Scalloped hammerhead shark	J	
Reef-Oriented Fish		
Red hake	J, A	Availability of oyster-reef habitat and food could decrease where oysters decrease and increase where oysters increase.
Black sea bass	J, A	
Scup (porgy)	J, A	
Red drum	L, J, A	
Skates and Flounders		
Winter skate	J, A	An increase in oyster reef habitat would result in a slight decrease in soft-bottom benthos. A decrease in oyster reef habitat could result in a slight increase in soft-bottom benthos.
Clearnose skate	J, A	
Little skate	J, A	
Summer flounder	L, J, A	
Windowpane flounder	J, A	
Winter flounder	J, A	

*Stage codes: E = egg, L = larvae, J = juvenile, A = adult

4.5.3 Alternative 2: Enhance Restoration

Under Alternative 2, oyster populations are likely to increase primarily in low-salinity zones in Maryland (Table 4-12). In these areas, the increase in oyster reef habitat would affect reef-oriented fish positively by providing additional habitat. Planktivorous fish might compete with oysters for food and could decrease in abundance if food resources become limiting. Increases in forage fish near oyster bars could affect piscivorous fish positively. Alternative 2 is projected to result in some reduction in oyster abundance in some Virginia waters. As oyster abundance decreases, decreasing hard-bottom habitat could negatively affect reef-oriented fish species. The ERA projected declines or very minimal increases in reef-oriented species in Virginia waters.

Table 4-12. Potential effects of Alternative 2 on managed species with designated EFH in Chesapeake Bay

Species	Stage	Potential Influences
Planktivorous Fish		
Atlantic herring	A	No large-scale effect.
Atlantic butterfish	E, L	
	J, A	Increased numbers of oysters could compete indirectly with this species for food. Decreased numbers of oysters could indirectly result in increased food availability.
Piscivorous Fish		
Bluefish	J, A	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
Cobia	E, L	No large-scale effect.
	J, A	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
King mackerel	E, L, J	No large-scale effect.
	A	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
Spanish mackerel	E, L, J	No large-scale effect.
	A	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
Dusky shark	L	No large-scale effect.
	J	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
Sandbar shark	L	No large-scale effect.
	J, A	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
Sand tiger shark	L	No large-scale effect.
	A	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
Atlantic sharpnose shark	A	
Scalloped hammerhead shark	J	

Table 4-12. (Continued)

Species	Stage	Potential Influences
Reef-Oriented Fish		
Red hake	J, A	Availability of oyster-reef habitat and food could decrease where oysters decrease. Availability of oyster-reef habitat and food could increase where oysters increase.
Black sea bass	J, A	
Scup (porgy)	J, A	
Red drum	L, J, A	
Skates and Flounders		
Clearnose skate	J, A	An increase in oyster-reef habitat might result in a slight decrease in soft-bottom benthos. A decrease in oyster -reef habitat could result in a slight increase in soft-bottom benthos.
Little skate	J, A	
Winter skate	J, A	
Summer flounder	L, J, A	
Windowpane flounder	J, A	
Winter flounder	J, A	

*Stage codes: E = egg, L = larvae, J = juvenile, A = adult

4.5.4 Alternative 3: Harvest Moratorium

The abundance of native oysters is projected to increase primarily in the oligohaline zones in response to Alternative 3 (Table 4-13). Where oyster abundance increases, hard-bottom substrate also would increase, providing more habitat for reef-oriented fish in those areas. The increase in oyster bars also could provide habitat for small forage fish, which might result in increased abundance of piscivorous species. In areas where oysters increase, planktivorous fish would experience indirect competition for food and could be negatively affected if food becomes limiting. The abundance of oysters would continue to decline in the mesohaline and polyhaline zones in Virginia (Section 4.1.4). Declining oyster abundance could negatively affect reef-oriented fish that depend on hard-bottom substrate. The decrease in oyster populations might affect planktivorous fish positively due to a reduction in indirect competition for food. An increase in planktivorous species might positively influence piscivorous species due to increased availability of prey. The ERA suggests that any effects of Alternative 3 in the polyhaline zones would be very small.

Table 4-13. Potential effects of Alternative 3 on managed species with designated EFH in Chesapeake Bay

Species	Stage*	Potential Influences
Planktivorous Fish		
Atlantic herring	A	No large-scale effect.
Atlantic butterfish	E, L	
	J, A	Increased numbers of oysters could compete indirectly with this species for food. Decreased numbers of oysters could indirectly result in increased food availability.
Piscivorous Fish		
Bluefish	J, A	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
Cobia	E, L	No large-scale effect.
	J, A	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.

Table 4-13. (Continued)

Species	Stage*	Potential Influences
King mackerel	E, L, J	No large-scale effect.
	A	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
Spanish mackerel	E, L, J	No large-scale effect.
	A	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
Dusky shark	L	No large-scale effect.
	J	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
Sandbar shark	L	No large-scale effect.
	J, A	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
Sand tiger shark	L	No large-scale effect.
	A	Availability of food could increase as small forage fish increase where reef habitat increases. Availability of food could decrease where reef habitat decreases.
Atlantic sharpnose shark	A	
Scalloped hammerhead shark	J	
Reef-Oriented Fish		
Red hake	J, A	Availability of oyster reef habitat and food could decrease where oysters decrease. Availability of oyster reef habitat and food could increase where oysters increase.
Black sea bass	J, A	
Scup (porgy)	J, A	
Red drum	L, J, A	
Skates and Flounders		
Clearnose skate	J, A	An increase in oyster reef habitat could result in a slight decrease in soft-bottom benthos. A decrease in oyster reef habitat could result in a slight increase in soft-bottom benthos.
Little skate	J, A	
Winter skate	J, A	
Summer flounder	L, J, A	
Windowpane flounder	J, A	
Winter flounder	J, A	

*Stage codes: E = egg, L = larvae, J = juvenile, A = adult

4.5.5 Alternative 4: Cultivate Eastern Oysters

Under Alternative 4, Eastern oyster spat would be placed in areas of pre-existing hard-bottom habitat. The availability of hard-bottom habitat could increase temporarily, until cultivated oysters reach market size and are harvested (Table 4-14); therefore, some habitat for reef-oriented fish could be created in aquaculture areas. Off-bottom cages could be attractive for species that prefer to associate with structures (e.g., red hake and black sea bass), although the availability of that habitat also would be temporary. The temporary habitat provided by aquaculture operations is not likely to have a significant effect on reef-oriented species. The ERA suggests that aquaculture would have only a minimal effect on water quality and, thus, on plankton populations (Section 4.4.6 of Appendix B). That result, however, is a function of the scale of analysis. Concentrating aquaculture operations in small bodies of water could result in measurable changes in water quality and availability of food for some managed species with EFH in the Bay. Such local changes are unlikely to affect the managed species significantly because the changes would be restricted to a very small portion of any given species' range. Careful siting to avoid concentrating aquaculture operations in areas of unique EFH for any particular species within the Bay would minimize even the potential local effects.

Table 4-14. Potential effects of Alternative 4 on managed species with designated EFH in Chesapeake Bay

Species	Stage*	Potential Influences
Planktivorous Fish		
Atlantic herring	A	No large-scale effect.
Atlantic butterfish	E, L, J, A	
Piscivorous Fish		
Bluefish	J, A	No large-scale effect.
Cobia	E, L, J, A	
King mackerel	E, L, J, A	
Spanish mackerel	E, L, J, A	
Dusky shark	L, J	
Sandbar shark	L, J, A	
Sand tiger shark	L, A	
Atlantic sharpnose shark	A	
Scalloped hammerhead shark	J	
Reef-Oriented Fish Species		
Red hake	J, A	Availability of habitat could increase locally around aquaculture operations due to temporary increases in hard bottom or structure.
Black sea bass	J, A	
Scup (porgy)	J, A	
Red drum	L, J, A	
Skates and Flounders		
Clearnose skate	J, A	Local increase in hard bottom and the presence of structures at aquaculture sites could lead to slight local declines in soft-bottom benthos.
Little skate	J, A	
Winter skate	J, A	
Summer flounder	L, J, A	
Windowpane flounder	J, A	
Winter flounder	J, A	

*Stage codes: E = egg, L = larvae, J = juvenile, A = adult

4.5.6 Alternative 5: Cultivate a Nonnative Oyster

Under this alternative, triploid Suminoe oysters would be cultivated in cages, bags, or floats (Table 4-15). Structures would be deployed at various depths in the water column; consequently, there would be no increase in hard-bottom habitat. Some managed species prefer to associate with structures (e.g., red hake and black sea bass), and these fish species might be attracted to some aquaculture operations. No effect on water quality or plankton would be expected, except locally in the vicinity of operations, and no significant effect on managed species would be expected Bay-wide as a result of local changes in water quality and food availability. Careful siting to avoid concentrating aquaculture operations in areas of unique EFH for any particular species within the Bay would minimize even the potential local effects.

Table 4-15. Potential effects of Alternative 5 on managed species with designated EFH in Chesapeake Bay.

Species	Stage	Potential Influences
Planktivorous Fish		
Atlantic herring	A	No large-scale effect.
Atlantic butterfish	E, L, J, A	
Piscivorous Fish		
Bluefish	J, A	No large-scale effect.
Cobia	E, L, J, A	
King mackerel	E, L, J, A	
Spanish mackerel	E, L, J, A	
Dusky shark	L, J	
Sandbar shark	L, J, A	
Sand tiger shark	L, A	
Atlantic sharpnose shark	A	
Scalloped hammerhead shark	J	
Reef-Oriented Fish		
Red hake	J, A	Availability of habitat for species that prefer to associate with structures may increase temporarily in areas near aquaculture operations.
Black sea bass	J, A	
Scup (porgy)	J, A	
Red drum	L, J, A	No large-scale effect.
Skates and Flounders		
Clearnose skate	J, A	No large-scale effect.
Little skate	J, A	
Winter skate	J, A	
Summer flounder	L, J, A	
Windowpane flounder	J, A	
Winter flounder	J, A	

*Stage codes: E = egg, L = larvae, J = juvenile, A = adult

4.5.7 Alternative 8: Combination of Alternatives

Combination 8a. – Eastern oyster only - This combination has the least potential to increase oyster abundance and, therefore, to effect EFH. In areas where oyster abundance increases, the potential effects of this combination of alternatives would be negative for planktivorous fish, skates, and flounders and positive for piscivorous fish and most reef-oriented fish. Conversely, declines in oyster abundance could positively influence planktivorous fish, skates, and flounders, and negatively influence the remaining species. Local effects of aquaculture are expected to be positive for reef-oriented fish, negative for skates and flounders, and to have no large-scale effect for the remaining species.

Combination 8b. – Eastern oyster and triploid nonnative Suminoe oysters - In the low-salinity areas where oyster abundance is expected to increase as a result of restoration, this combination would have a negative influence on planktivorous fish, skates, and flounders and a positive influence on piscivorous fish and most reef-oriented fish. In areas where oyster abundance continues to decline, the effect could be positive for planktivorous fish, skates and flounders and negative for the remaining RTE species. The effects of aquaculture on EFH species appear to be locally positive for reef-oriented fish and negative for skates and flounders.

Combination 8c. – Eastern oyster and both diploid and triploid nonnative Suminoe oyster. - This combination has the greatest potential to increase oyster abundance throughout Chesapeake Bay and, therefore, could have the largest potential effect on EFH. Widespread increases in oyster abundance could adversely affect planktivorous fish, and skates and flounder and could positively affect piscivorous fish and most reef-oriented fish.

4.6 CULTURAL, SOCIOECONOMIC, AND ECONOMIC EFFECTS

The cultural and socioeconomic environment of the Chesapeake Bay area as it relates to oysters and the oyster fishery was characterized in Section 3.6. Two major support projects were conducted to develop the data and information required to address the consequences of the proposed action and the alternatives for those topics. The final reports of those projects are included in this PEIS as Appendices D (Economics) and E (Cultural and Socioeconomic). Assessments presented here are based on summaries of findings and information presented in detail in the appendices.

4.6.1 Cultural and Socioeconomic Effects

The potential cultural and socioeconomic effects of the proposed action and alternatives were assessed based on interviews, participants' observations, and survey data for eight groups of oyster stakeholders: commercial fishermen (watermen), recreational fishermen, environmentalists, scientists, oyster growers, oyster processors, seafood consumers, and restaurant owners. The entire study pool included individuals from a wide range of other categories of stakeholders (e.g., recreational boaters, wildlife watchers; swimmers/beach users, waterfront property owners, etc.); however, those groups were not addressed separately because this socioeconomic analysis focused on household and community effects within an oyster-related social framework. Much of the following analysis is based on the results of our two surveys. The first survey, distributed in 2004, was designed to collect information about different groups' views of oysters and oyster restoration. The second survey, distributed in 2007, was designed to serve three functions: (1) to obtain additional descriptive information about our stakeholder groups; (2) to refine and test the cultural models we constructed based on the results of the first survey; and (3) to test the existence and distribution of hypothesized effects of each restoration alternative. Details of these approaches (e.g., sample demographics and socioeconomic characteristics, interview and survey methods) are presented in Appendix E. Oyster stakeholders share many of the systems of cultural knowledge assessed in the work reported here. Group knowledge is used to help understand stakeholders' perceptions of oyster restoration from a cultural perspective, and this cultural knowledge is linked to other social and cultural dimensions that have value and meaning for people. Oyster restoration affects that use-value and meaning, and the affected use-value and meaning can affect oyster restoration, in turn, through the offer or lack of public support and the degree of collaboration among stakeholders. These responses can be considered to be cultural facts, not perceptions, and analytically no different than ecological or economic facts.

This section focuses on the most significant cultural and socioeconomic effects of the proposed action and alternatives for the eight groups of stakeholders and synthesizes that information to provide an overview of potential consequences. Three groups of stakeholders depend on oysters directly for their livelihood, at least to some extent: watermen, growers, and processors. Social, economic, and cultural consequences of the proposed action and alternatives are noteworthy, nonetheless, for the other stakeholder groups. Two analytical frameworks were applied to identify potential cultural and socioeconomic effects. First, cultural values of oysters and restoration were identified using a cultural or cognitive model. This approach provided a means of investigating similarities and differences among stakeholders in their beliefs and values, the system of cultural knowledge that they use to understand oyster restoration. This investigation was done first at a descriptive level. In response to informal and formal interview questions, members of the stakeholder groups told us explicitly about their views, practices, and values as they relate to oysters and oyster restoration. Next, those specific statements were reviewed to identify the larger contexts or systems of knowledge or meaning that framed the specific, explicit statements. In other words, the review identified implied frameworks of knowledge and values that were necessary for respondents to answer questions as they did. This approach was applied to all study groups; the shared knowledge system that each group used to understand oyster restoration was treated as a system of cultural knowledge that individuals used to evaluate the effects of different oyster restoration practices. For example, scientists have a system of cultural knowledge based largely on principles of the scientific method; watermen have a system of cultural knowledge based largely on experience "working the water;" and the seafood-eating public has a system of cultural knowledge that helps people understand oyster restoration. The analysis does not evaluate one system of cultural knowledge against another to decide which is correct but, rather, identifies existing, implicit knowledge structures; the degree to which they are shared within and among groups of stakeholders; and how they might affect or be affected by different actions to restore oysters. The latter focus was used to identify cognitive schemas or models. They are largely tacit, but they can be powerful drivers of behavior and valuation or templates for organizing explicit information. Appendix E1 describes the concepts and methods of cultural modeling research as applied to environmental issues for Chesapeake Bay.

An important cultural model for oyster restoration was identified during the course of the research and was labeled "Oyster Restoration for Multiple Goals" (Figure 4-15). This cultural model includes well-known oyster restoration benefits of ecology, economy, and culture and well-known factors or requirements such as policy, science, and recognition of natural cycles; however, all stakeholder groups understood those factors and benefits as an integrated whole. The integration of those benefits and requirements defined stakeholders' views of successful oyster restoration. From this perspective, an increase in the oyster population alone, whether through aquaculture, on managed reserves and sanctuaries, or by itself, would not be construed as oyster restoration from the view of all stakeholders unless it contributed to enhancement of all three sectors shown in Figure 4-15. All stakeholder groups viewed oyster restoration as an integrated goal that would provide ecological, economic, and cultural benefits. Members of the stakeholder groups expressed strong agreement about the importance of these benefits and requirements (80% to 98% of each study group agree; Chapter IV of Appendix E3). Individual stakeholder groups expressed preferences, but they were expressed within the cultural model of oyster restoration to accomplish multiple goals (Chapter IV of Appendix E3).

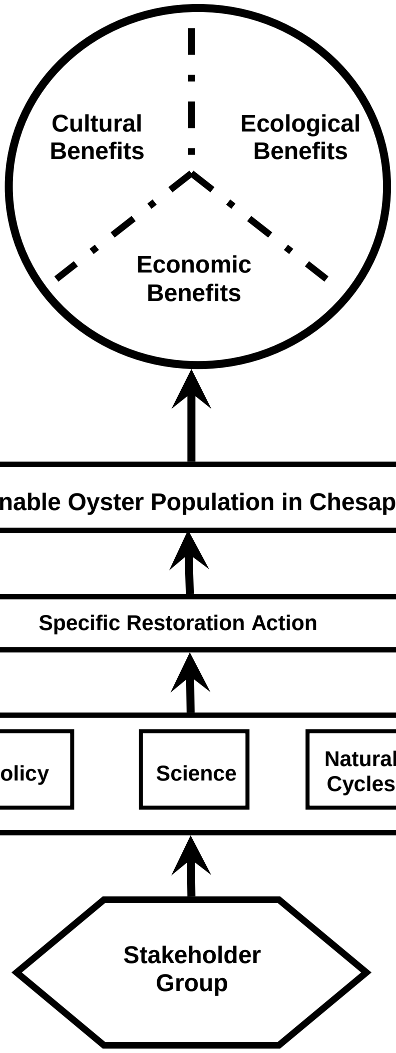

Figure 4-15. Cultural model of oyster restoration to accomplish multiple goals (Chapter IV of Appendix E3)

The second analytical approach used in this effort employed theory and methods from economic anthropology to investigate the economic effects of the proposed action and alternatives within a social context. Here, economic behavior is viewed as embedded within social institutions and structures. Oyster stakeholders are rational decision makers, but their decisions are affected and constrained by existing social conditions at the household and community levels. This socioeconomic approach complements economic analyses presented in Section 4.6.2 by providing data on individual choice under different demographic, social, and household economic conditions.

Using this socioeconomic approach, each stakeholder group was asked about the specific effects of the proposed action and alternatives on their household, business, or consumption of seafood. The criteria used to evaluate effects varied according to stakeholder group. Watermen were asked about effects on harvesting; growers, processors, and shippers were asked about effects on profitable business activity; scientists and environmentalists were asked about effects on research and environmental advocacy; and recreational fishermen and restaurant owners were asked about effects on recreational use and consumption of seafood, respectively. A focus on the outcome that would most affect each group's involvement with oyster restoration, directly or indirectly, was common to all the questions. For some groups and for some questions, the reported effects did not vary significantly across alternatives, or the effect was not perceived to be significant. Others, however, indicated potentially significant socioeconomic effects; therefore, results for each alternative are presented only for the study groups that indicated a significant or noteworthy effect.

The cultural and socioeconomic analyses of the proposed action and alternatives each conclude with two summary analyses. "Oyster Community Consequences," the first summary, provides an overview of some of the most important effects of the restoration strategy on one or more of the stakeholder groups in the study. The second, "Cultural Model of Oyster Restoration," discusses the consequences of the identified socioeconomic effects in terms of the cultural model of oyster restoration to accomplish multiple goals.

4.6.1.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

Section 4.1.1 describes a representative introduction plan and the abundance and distribution of oysters projected to result from implementing the proposed action according to that plan. Although implementing the proposed action might result in a significant increase in the Bay wide oyster population, many factors could preclude the success of an introduction. Survey Interview results indicated that stakeholders understand the proposed action to have the potential to change the status of oysters in the Bay. Most stakeholders who were interviewed understood the proposed action as significantly different from past restoration strategies. Stakeholders' positions, beliefs, and values varied significantly about whether the proposed action should be implemented, about the areas of uncertainty, and about the risks and benefits of action or inaction.

Watermen – In a survey conducted in 2004, 64% (n = 58)[13] of watermen surveyed believed that a nonnative oyster should be introduced immediately. In a subsequent survey in 2007, watermen were asked whether they would harvest more, less, or about the same if a nonnative oyster were introduced, and native oyster restoration were continued at its current levels (See Chapter 3 of Appendix E1 for details about the two surveys). About 71% (n=2 50) of respondents reported that they would continue to harvest at current levels (Table 5.2 in Appendix E1). Only 26% (n=92) of respondents said that they would increase their current harvest effort under the proposed action.

Two factors accounted for most watermen seeing no need to increase oyster harvest effort: (1) The nonnative oyster would be introduced first on sanctuaries that are closed to harvesting; therefore, most of the initial population increase would occur in areas that watermen could not harvest and would provide no immediate benefit for them. Over a 10-year period, the introduced oyster would be expected to expand to harvestable bars near the planted sanctuaries;

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[13] n is the number of respondents included in the stated percentage, not the total sample size for the stakeholder group.

consequently, the number of watermen who planned to increase harvesting effort would be expected to increase over time. The amount of that increase would depend on availability and quality of hard-bottom habitat for nonnative spat to set outside the sanctuaries. Furthermore, the abundance of nonnative oysters on these fishable bars would need to be sufficient to support harvesting for at least a few weeks. Any less abundance (e.g., enough to support only a few days' work) would make "gearing up" and sailing some distance (possibly requiring a motel stay) economically unprofitable and risky (e.g., gear breakdown, bad weather, no place to dock) for watermen. (2) A widespread belief among watermen, particularly in Maryland, holds that current oyster restoration activities are inadequate because repletion has ceased in Maryland. Oysters put on reserves currently or in the foreseeable future would not produce enough market-size oysters for watermen as a group to justify increasing their harvest effort. Maryland oyster harvest for the years 2005 through 2007 totaled 391,713 bushels; only 9,366 of those (or about 2% of the total) were harvested from oyster reserves (DNR 2008). Also, demographic and economic factors may cause many watermen to leave the fishery in the near future, if the availability of harvestable oysters does not increase significantly. Finally, although the availability of market-size oysters on sanctuaries and reserves has been an incentive for a small number of watermen to harvest oysters illegally, overall the vast majority watermen contend that they adhere to the prohibition of harvest from sanctuaries and reserves.

The economic analysis of the net present value of the oyster harvest under the proposed action (Section 4.6.2.1) assumes that a substantial fishery would result in 40% exploitation of market-size oysters on harvestable bars annually over the 10-year assessment period for the PEIS. The development of a fishery of that magnitude is highly uncertain, given the unknowns about the ecological conditions of fishable oyster bars around sanctuaries and the economic costs and risks for watermen.

Growers and Processors – Approximately 43% (n=12) of surveyed growers reported no anticipated change in their growing operations as a result of the proposed action; 32% (n=9) anticipated that the proposed action would benefit them (Table 5.3 in Appendix E1). Growers are aware of the long time period that may be required to establish a population of the Suminoe oyster that would support any significant harvest. As in the case of watermen, some additional benefit to growers would be expected as the introduced population expands from initially seeded locations. In interviews, some growers expressed concern about the possibility that negative ecological consequences associated with introducing a nonnative oyster could cause consumers to develop negative perceptions about oysters overall, potentially reducing the demand for their Eastern oysters. Fear of the economic consequence of public perception of ecological harm is not an unfounded concern. For example, the 1997 *Pfiesteria* scare, which affected only menhaden, resulted in a reduction in consumption of all fish from Chesapeake Bay and a significant loss of revenue for the regional seafood industry. During the time of heightened public concern about *Pfiesteria*, however, no ecological risk information about the dinoflaggelate was available that was comparable to the assessments presented in the ERA about the ecological consequences of introducing the Suminoe oyster (Appendix B).

Shellfish processors and shippers were almost evenly split about whether the proposed action would benefit their businesses: 46% (n=18) expected no change in business; 41% (n=16) expected an increase (Table 5.5 in Appendix E1). Processors' and shippers' positions on the benefit of the proposed action were influenced in part by information about the characteristics of the Suminoe oyster coming from the VSC trials in the Bay (e.g., favorable: does well in turbid environments, tastes good if fried, easy to shuck, more meat inside; unfavorable: too large to be served raw, short shelf life, thin shell).

Scientists and Environmentalists – In the 2007 survey, when scientists were asked whether we should introduce a nonnative oyster now, scientists strongly responded "no" (86% ; n=26). Interview data from scientists suggests that most believe we do not know enough yet to introduce a nonnative oyster. In the 2007 survey, scientist responded that a nonnative oyster should not be introduced at this time, arguing that more research is needed before attempting an introduction. Seventy percent (n=21) of scientists surveyed indicated that a large amount of additional research would be required to provide sufficient scientific support for an introduction (Table 5.7 in Appendix E1). As one scientist stated, "The potential positives are clear. It's the unknowns that are the problem." Fifty-four percent (n=23) of environmentalists surveyed thought that the proposed action would not be important for reducing pollution and revitalizing the natural systems of Chesapeake Bay (Table 5.9 in Appendix E1). The 2004 survey was conducted just as the extensive research on the Suminoe oyster was being initiated. Most of those research studies have been completed or are nearing completion; therefore, current attitudes might differ.

Oyster Community Consequences – The proposed action could provide some increase in the amount of oysters available for harvesting and processing within 10 years after implementation; however, the uncertainty about the size of the increase coupled with significant uncertainty and risks surrounding ecological and economic outcomes suggests that the proposed action might not provide a sufficient financial benefit to watermen and growers within that time A relatively minimal economic benefit would not be sufficient to reverse the current trend of watermen leaving the fishery (Section 4.6.1.2). As watermen leave the oyster fishery, pressure on the blue crab fishery could increase (NRC 2004), with accompanying increased sales of boats and equipment. Interview data suggest that younger watermen may be particularly financially vulnerable, if they have large boat loans and higher expenses associated with younger families (e.g., education, food, health care).

Cultural Model of Oyster Restoration – The proposed action appears to have the potential to accomplish the stakeholders' culturally shared objective of oyster restoration for multiple goals; however, uncertainty about the likelihood of realizing the desired ecological, economic, and cultural (community) benefits is considerable. In interviews and informal discussions, most stakeholders willingly admitted that they "just don't know," even though some might want to proceed because restoration efforts to date have not been successful. The proposed action clearly represents a new approach to oyster restoration, and all stakeholder groups recognize that. Many stakeholders expressed caution mixed with hope that the proposed action could work. Finally, a widely shared expectation among stakeholders expressed in interviews is that scientific results should guide decision-makers' thinking about whether and how to proceed with this alternative.

4.6.1.2 Alternative 1: No Action

Section 4.1.2 describes current restoration programs that would continue under Alternative 1 and predicts continued Bay-wide decline in total oyster abundance, but with some local increases in low-salinity areas in Maryland, particularly on seeded bars where harvest is excluded.

Watermen – Under current regulations, 76% (n=285) of watermen who held an oyster license and reported a harvest over the last 5 years harvested oysters during the 2006 season (Table 3.3 in Appendix E1). Watermen who reported a harvest over the last 5 years averaged about 51 years of age and have "worked the water" commercially for about 30 years (Figures 3.1 and 3.2 in Appendix E1). The average age and number of years working as a commercial fisherman were not significantly different between watermen from Maryland and those from Virginia. Sixty-six percent (n=186) of the watermen who reported a harvest during the 2006 season reported working between 4 and 5 days a week. Another 23% (n= 65) worked an average of 3 days a week (Table 3.4 in Appendix E1). In the 2007 survey, the median daily harvest for watermen who harvested oysters during the 2006 season (n=285) was 10 bushels. Interviews and observations of watermen from Maryland's lower Eastern Shore indicated a dockside value of \$30 to \$45 per bushel. [14]

The contribution of harvested oysters to a commercial waterman's income varied. About 45% (n=148) of watermen who harvested oysters over the last 5 years reported that oysters contributed 31% or more of their commercial income (Figure 3.3 in Appendix E1). About 30% (n=95) of the watermen reported that oyster income represented less than 10% of their commercial fishing income. Approximately 25% (n=83) of watermen who harvested oysters last year reported between 11% and 30% contribution to their commercial fishing income (Figure 3.3 in Appendix E1).

In response to the 2007 survey question about what they would do if oyster harvests do not improve, approximately 60% (n=192) of watermen responded that they would continue harvesting indefinitely even without improvement in the number of oysters available. Almost 38% (n=72) of the watermen who would continue harvesting oysters indefinitely reported earning 40% or more of their fishing income from oystering (Table 3.5 in Appendix E1). Almost 24% (n=76) of watermen responded that they would stop oystering next season if harvests do not improve. Fifty-five percent (n=42) of the watermen who said they would stop harvesting earned 10% or less of their fishing income from oystering (Table 3.5 in Appendix E1). These findings suggest that those earning the least from oystering are the most likely to leave the fishery if harvests do not improve. There were no significant differences in age or years of experience (within 5 years) among watermen who would leave the fishery next season and those who would continue indefinitely. The income earned from part-time oystering is important to watermen during late fall and early winter, when few other earning opportunities are available to them (NRC 2004; Chapter 2 in Appendix E1).

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[14] This price is significantly higher than the minimum economically feasible price of about \$20 discussed in Section 4.6.2, suggesting that demand currently exceeds supply.

Growers and Processors – All growers who responded to the 2007 survey had grown oysters during the previous three years at a variety of scales. The growers who participated reflected the variations in oyster aquaculture between the states; 76% (n=22) of respondents were growers in Virginia, and 24% (n=7) in Maryland. Approximately 30% (n=7) had owned or operated their businesses for 5 years or less. Another 38% (n=9) had been in business for more than 16 years (Table 3.6 in Appendix E1). The long-term owners had diversified operations, either in processing (all but one of the long-term growers served the shucked market), in growing other shellfish (e.g., clams), or in selling seafood. Based on the 2007 survey, most respondents' (82%; n=24) had growing operations that supported 1 full-time job or less, and 78% (n=23) supported 3 or fewer part-time positions.

In the 2007 survey, 59% (n=178) of growers believed that the native oyster can be restored, although in interviews growers shared others' frustration with the lack of success to date. As one grower suggested, "Maryland and Virginia's public success rates have been impacted by their approaches. The public effort has been disappointing, but that doesn't mean *C. virginica* can't thrive in the estuary." That many growers and other stakeholders believe that restoring the abundance of the native oyster is possible is a cultural fact: stakeholders believe it sincerely based on their professional experiences with oysters. Stakeholder groups' definitions of the scale and time frame for successful oyster restoration vary (Appendix E3), even if they are clear on the overall goals of oyster restoration (Figure 4-15).

In the 2007 survey, 82% (n=312) of processors and shippers were confident that the native oyster can be restored. Despite this positive outlook, shippers and processors share the growing frustration with the lack of large-scale successful restoration to date. In interviews and during participant observations, researchers heard statements such as, "We've been doing things for years. I can't believe people who say enough work hasn't been done. Every time a new group gets involved, it's as if we have to start all over again," and "I've done restoration for years and it hasn't made a difference."

Scientists and Environmentalists – In the 2007 survey, 87% (n=256) of scientists and 98% (n=413) of environmentalists reported that they felt that restoration of the native oyster is possible. In interviews, scientists and environmentalists, like other stakeholders, did not feel that current oyster restoration strategies will accomplish ecological, economic, or community goals.

Oyster Community Consequences – All stakeholder groups concurred that oyster restoration as currently practiced has not worked and needs to be changed. Stakeholders' ideas about appropriate changes in restoration strategy and the effects of those changes vary to some degree and are discussed further for the remaining alternatives. Watermen are the stakeholders most clearly affected by a status quo approach to oyster restoration, and approximately a quarter of watermen surveyed reported that they would leave the fishery. Many of the watermen interviewed expressed feeling a psychological and emotional burden (paraphrased) stemming from the effect of the continued low abundance of oysters on their sense of identity as providers for their families and working members of their communities.

Cultural Model of Oyster Restoration – Alternative 1 is highly unlikely to achieve the objective of the cultural model of restoring oysters for multiple goals. A continued, slow decline would be expected in the ability of the oyster population to fulfill the ecological, economic, and cultural/community roles valued by all groups of stakeholders.

4.6.1.3 Alternative 2: Enhance Restoration

Section 4.1.3 describes the enhanced restoration program. Under this alternative, a Bay-wide increase in the oyster population greater than for Alternative 1 would be likely, but the greatest increase would be in low-salinity areas in Maryland. Those increases would be greatest on bars closed to harvest. Significant increases, albeit from a small starting population, might also occur in other state/salinity zones.

Watermen – In the 2004 survey, 72% (n=66) of watermen said they believed that restoring the abundance of the native oyster is possible. This confidence did not translate into a willingness to increase their harvest efforts if actions to restore the native oyster are targeted primarily on reserves and sanctuaries. In the 2007 survey, watermen were asked if they would increase their harvesting effort, decrease it, or keep it the same if native oyster restoration is targeted to reserves and sanctuaries. Sixty-seven percent (n=238) reported that they would not change their oyster harvesting effort (Table 5.13 in Appendix E1). Only 19% (n=68) said that they would go oystering more (Table 5.13 in Appendix E1). Interviews with watermen helped to account for those results. First, oyster restoration on reserves and sanctuaries would not result in sufficient numbers of harvestable oysters to warrant an increased effort. Over the last three years, the oysters harvested from reserves have accounted for an average of only about 2% of the total oyster harvest (DNR 2008). This percentage might increase under Alternative 2 because of the increase in reserves, but the magnitude of the potential increase cannot be estimated. Second, most of the spat planting proposed in Alternative 2 (all for Alternative 2a) would occur in low-salinity areas. Most Chesapeake Bay watermen who reported an oyster harvest in the last five years live closer to areas of middle and high salinity (Figure 4-16). For most watermen, accessing any harvestable oysters made available through expanded plantings on reserves and sanctuaries would involve significant time and expense for fuel and labor. Interviews with watermen confirmed that traveling to low-salinity areas to harvest small amounts of oysters from reserves would not be profitable. In interviews, most watermen consistently expressed a preference for native oyster restoration to be focused on existing harvestable beds throughout the Bay and to include shell repletion, but in the 2007 survey they also recognized the importance of restoration for ecological goals.

Growers and Processors – Oyster growers did not perceive a potential for any significant negative effects of Alternative 2. When asked in the 2007 survey whether their business might increase, decrease, or remain the same as a result of expanding native oyster restoration primarily in reserves and sanctuaries, 46% (n=13) thought their business might increase, and 43% (n=12) thought their business would not be affected (Table 5.14 in Appendix E1). Asked the same question, 60% (n=24) of shellfish processors reported an anticipated increase in business, and 25% (n=10) reported no anticipated change in business (Table 5.15 in Appendix E1). Based on interviews and participant observations, most growers and processors generally believed that a self-sustaining and, ideally, growing native oyster population on sanctuaries and reserves would be an indirect positive for the oyster industry, even if that population did not produce significant increases in oysters for the market.

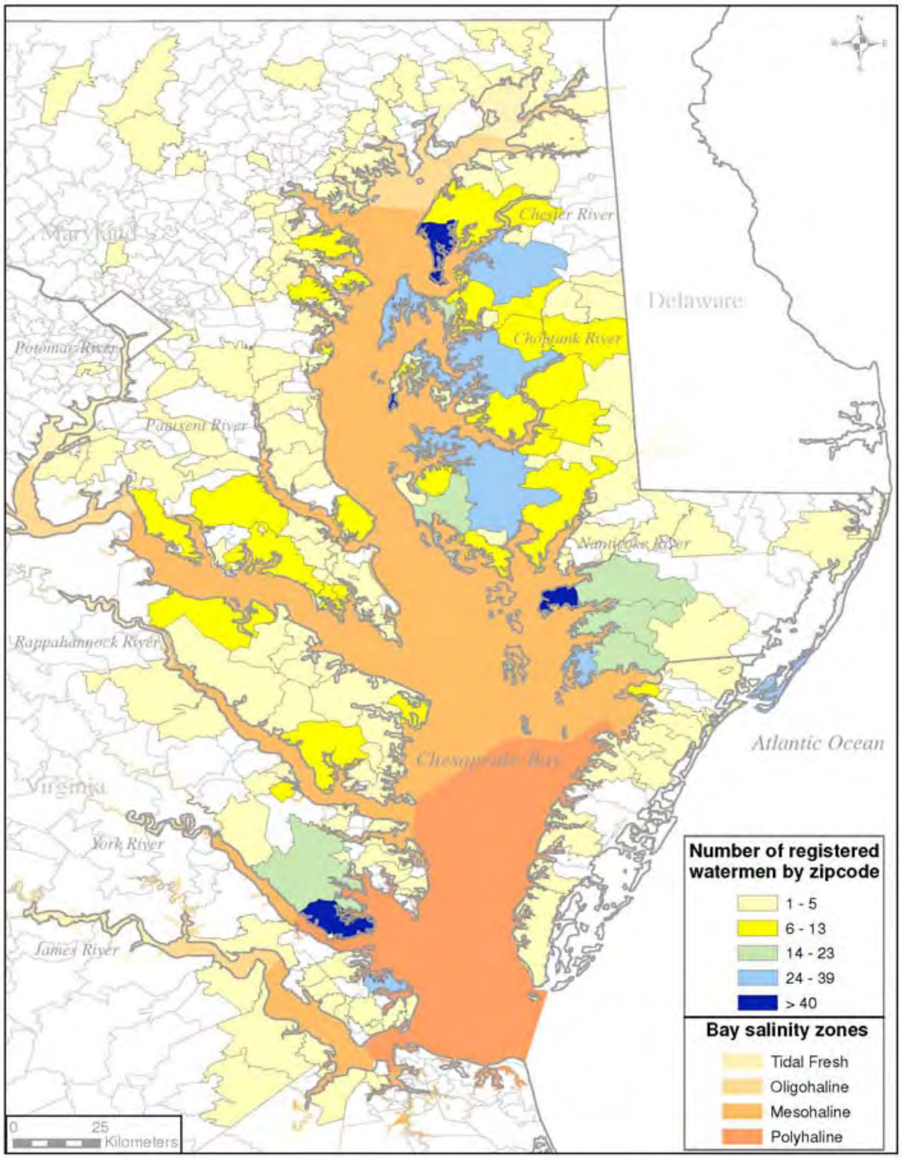

Figure 4-16. Number of registered watermen by zip code and salinity zones; salinity zones are as specified for Chesapeake Bay water quality modeling.

Scientists and Environmentalists – In the 2004 survey, 87% (n=28) of scientists and 98% (n=31) of environmentalists believed that native oyster restoration is possible. In interviews, scientists and environmentalists conceptualized native oyster restoration as local efforts to restore native oysters; they expressed the belief that restoring native oysters at the scale of the entire Chesapeake Bay is unlikely, given the multitude of environmental conditions. Seventy-three percent (n=22) of the scientists in the second survey (2007) believed a large to medium amount of research would be needed to support native oyster restoration; 73% (n=22) also believed that current research funding levels are inadequate to support the additional research needed (Tables 5.16 and 5.17 in Appendix E1). Eighty-one percent (n=34) of environmentalists believed that expanded native oyster restoration on reserves and sanctuaries would be very important for reducing pollution and revitalizing natural systems in the Chesapeake Bay (Table 5.18 in Appendix E1).

Oyster Community Consequences – Alternative 2 would not significantly increase benefits to oyster stakeholders. Some local successes, particularly in areas surrounding sanctuaries and reserves, might produce small increases in oysters available for watermen to harvest and for processors to market. Such local successes might also produce local ecological improvements. Although Alternative 2 could produce some economic, ecological, and community benefits, the scale of these benefits would be very small compared to the stakeholders' dependence upon and interest in restoring the native oyster population.

Cultural Model of Oyster Restoration **–** Alternative 2 is highly unlikely to achieve the objective of restoring oysters for multiple goals for most oyster stakeholders. Local successes, defined in the cultural model as integrated ecological, economic, and cultural benefits, are possible; however, these successes would most likely be driven by spatial (low-salinity areas) and historical (which harvesters reside near reserves) factors that have limited application for other areas of the Bay. Alternative 2 might accomplish the objective of restoring oysters for multiple goals for a few stakeholders in a few areas.

4.6.1.4 Alternative 3: Harvest Moratorium

Alternative 3 involves implementing a temporary moratorium on harvesting native oysters and providing a compensation (buy-out) program for the oyster industry in Maryland and Virginia, or a program that offers displaced watermen on-water work in a restoration program. Restoration efforts under this alternative would be identical to those for Alternative 1, with the possibility of some increases in oyster abundance, particularly in low-salinity areas in Maryland (Section 4.1.4).

Watermen – In the 2007 survey, 42% (n=148) of watermen reported that it would be very difficult to return to harvesting oysters after a 2- to 3-year moratorium, and another 31% (n=111) reported that it would be somewhat difficult to difficult to return to the fishery. Only 27% (n=96) believed that it would not be at all difficult to return to oystering after a 2- to 3-year moratorium (Table 5.37 in Appendix E1). When asked the same question about returning to oystering after a moratorium of 7 years or longer, 67% (n=233) of watermen reported that returning would be very difficult; 15% responded that returning would be somewhat difficult to difficult. Only 18% (n=62) of watermen reported that it would not be at all difficult to return to oystering after a moratorium of 7 years or longer (Table 5.38 in Appendix E1). Comparing the moratorium periods proposed in the questions (i.e., 2 - 3 years and 7+ years), 25% more watermen indicated that returning to the fishery would be very difficult after the longer moratorium, and about 10% fewer watermen reported no expected difficultly with returning to the fishery after a moratorium of 7 years or more. In the 2007 survey, 57% (n=207) of watermen reported that they would not sell their licenses or future rights to harvest oysters (i.e., to a compensation program); 43 % (n=154) of watermen indicated that they would be willing to sell their licenses/rights to harvest oysters if the compensation were fair. During interviews, watermen suggested a wide range of definitions of fair compensation for their licenses. The definitions varied according to how long an individual had worked in the fishery, his current level of dependence on income from oystering, and the strength and value of his sense of identity as a waterman, which for many is a source of pride, accomplishment, and contribution (providing people with seafood).

The harvest moratorium has the greatest potential among the alternatives to negatively affect the ability of watermen to continue in the fishery. The survey samples included only watermen who have purchased oyster-gear licenses, reported harvests, or both during the last five years. Many more Maryland watermen who hold Tidal Fish licenses could pay the oyster surcharge to re-enter the oyster fishery in any future year and, therefore, could be affected by a moratorium.

Growers and Processors – In the 2007 survey, oyster growers were asked if they would expect their business to increase, decrease, or remain the same in response to a harvest moratorium. Fifty-four percent (n=15) believed that their business would decrease. Thirteen of the 15 growers surveyed were in Virginia. Some of these growers also purchase wild-caught oysters. About 39% (n=11) believed that their business would increase (Table 5.39 in Appendix E1). Those who anticipated an increase in business in response to a harvest moratorium may have anticipated reduced competition, increased opportunities for cultivated oysters in markets currently served by wild harvests, or both (Table 5.39 in Appendix E1).

Processors and shippers are very likely to be negatively affected by a harvest moratorium. The duration and scope of the moratorium would determine the magnitude of the effect. Approximately 81% (n=30) believed that a moratorium on harvesting oysters would hurt their businesses (Table 5.40 in Appendix E1). Approximately 63% (n=23) of the processors and shippers surveyed during 2007 rely on the wild harvest to produce 50% or more of the Chesapeake oysters they handle.

Scientists and Environmentalists – The questions posed to scientists and environmentalists focused on harvest reductions to accomplish oyster restoration goals, not explicitly on a moratorium. Our interview data suggest that most scientists and environmentalists believe that ecological goals can be accomplished without a complete harvest moratorium. In the 2007 survey, 97% (n= 28) of scientists and 86% (n= 36) of environmentalists believed that reducing commercial harvest is necessary to restore oysters successfully. In interviews, several scientists and environmentalists raised concerns about the ability of native populations to develop resistance to MSX and Dermo naturally if harvesting removes oysters that have survived the diseases before they can reproduce (i.e., contribute their genetic advantage to the population). Seventy-five percent (n=21) of scientists do not feel that economic factors should be considered in determining how much to reduce harvests (Table 5.41 in Appendix E1). Sixty-one percent (n=25) of environmentalists felt that economic factors should be considered in setting harvest-reduction levels (Table 5.42 in Appendix E1). Some environmentalists exhibited empathy and appreciation for the value of watermen. As one informant said, "… loss of harvest totally from this culture is a degree of disconnection from our natural resources. Connections like that motivate people to care, to change their behavior with sustainable alternatives."

Recreational Fishers and Restaurant Owners – In the 2007 survey, recreational fishermen also were asked about harvest reductions, not directly about a harvest moratorium. Eighty-eight percent (n=130) of recreational fishers believed that reducing the commercial harvest is necessary to accomplish oyster restoration goals. Forty-two percent (n=62) thought that economic factors should influence how much commercial harvest is reduced (Appendix E1). Interestingly, 89% (n=132) would not expect to change the way they fish for oysters as a result of a moratorium on the commercial oyster harvest. Eighty-one percent (n=13) of seafood restaurant owners reported believing that their customers would be willing to pay more for oysters to support a harvest moratorium that aims to restore oyster populations (Table 5.43 in Appendix E1).

Oyster Community Consequences – A harvest moratorium would have some potentially widespread negative consequences for some oyster stakeholders. Many watermen would not return to the fishery after a moratorium of even a few years, and about half of the growers and a little more then two-thirds of processors did not think their businesses would improve. Scientists, environmentalists, recreational fishers, and restaurant owners all indicated support for reducing harvests of oysters to accomplish oyster restoration goals.

Cultural Model of Oyster Restoration – Implementing a harvest moratorium would not achieve the multiple benefits anticipated to result from oyster restoration. Oyster populations would increase less than for Alternatives 1 or 2 (Section 4.1.4), significant numbers of watermen would leave the fishery, and business would not increase for most growers and processors. All three benefits of oyster restoration (ecological, economic, and cultural) would decrease. These results contradict the perception that an oyster moratorium would affect only watermen.

4.6.1.5 Alternative 4: Cultivate Eastern Oysters

The maximum level of production of oysters estimated to be economically viable is 3.2 million bushels, including oysters cultivated for the half-shell and shucked markets and wild-caught oysters (Section 4.1.5). Plausible locations for expanded aquaculture operations were identified based on past aquaculture or oystering history (Figure 4-3). An industry of the maximum viable would produce approximately 2.8 times the current number of market-size oysters in the Bay; however, an industry of that size is unlikely to develop within the 10-year assessment period defined for the PEIS.

Watermen – In the 2007 survey, 71% (n=252) of watermen reported that they would not change their harvesting effort if the native oyster aquaculture industry expands (Table 5.22 in Appendix E1). In the same survey, watermen reported mixed views about whether expanded cultivation of the native oyster would hurt the market for wild-caught oysters: 30% (n=112) thought that effects would be both positive and negative; 26% (n=94) felt that effects would be negative; 23% (n=84) thought that effects would be positive; and 21% (n=78) anticipated no effects (Table 5.20 in Appendix E1). Nearly 57% (n=203) of watermen surveyed in 2007 reported that they would consider getting involved in cultivating native oysters; however, in interviews watermen expressed considerable anxiety about the costs and risks (e.g., theft, lack of market, lack of private bottom) associated with starting a “grower” business. Several watermen expressed interest in exploring the feasibility of entering the aquaculture industry, despite the risks. In major oyster production areas, such as the state of Washington, the oyster industry has evolved to the degree that all oysters are produced through aquaculture and there is no wild harvest.

The potential for expanded aquaculture to affect watermen depends to some extent on the relative geographic distributions of potential aquaculture locations and the current residences of watermen. Figure 4-16 plots the current residences of watermen by zip code along with the nine possible sites for expanded aquaculture identified for the aquaculture assessment scenario (Appendix C). The aquaculture sites in the figure are conceptual and were identified to provide a scenario that could be used to characterize the effects of the two aquaculture alternatives. Figure 4-17 shows the greatest density of commercial watermen, some of whom are likely to be interested in entering the aquaculture industry, on the Eastern Shore; however, only one of the possible aquaculture sites is located on Maryland's Eastern Shore, in the Nanticoke River. Section 4.1.5 suggests that some of the most profitable techniques for cultivating the native oyster would be off-bottom cages and floats, which require more labor (and capital) than traditional on-bottom cultivation. Watermen that live far away from potential sites for aquaculture would not be able to provide sufficient monitoring of these more intensive operations.

Growers and Processors – In the 2007 survey, 60% (n=16) of growers and processors believed that their business would increase as the result of expanded aquaculture (Table 5.24 in Appendix E1). Presumably any State investment in the aquaculture industry would provide direct and indirect benefits to their existing operations; however, the aquaculture assessment scenario does not include any speculations about public funding to support expansion of the industry. Thirty-seven percent (n=10) of the growers surveyed in 2007 did not feel that they would benefit from State-expanded aquaculture. Information from interviews suggests that these growers are already growing and selling at a desirable level and are wary of the economic consequences of expanding operations. That concern appears to be valid, based on results of the economic demand modeling presented in Section 4.6.2.

In the 2007 survey, approximately 55% (n= 22) of shellfish processors believed that they would benefit from expanded native aquaculture. Another 35% (n=14) expected no effect on their business (Table 5.26 in Appendix E1). Those who expect to benefit may believe that expanded aquaculture would provide them with additional sources and a greater volume of product.

Scientists and Environmentalists – Approximately 57% of scientists believed that a medium amount of research would be needed to support science-based restoration through native aquaculture; about 30% (n=10) believed that only a small amount of additional research would be needed (Table 5.30 in Appendix E1). "Restoration" here means increasing the numbers of oysters that might be present in the Bay, not necessarily increasing the wild oyster stock. Environmentalists strongly supported cultivating the native oyster as a means to reduce pollution and revitalize ecosystems. Sixty-seven percent (n=29) of environmentalists rated native oyster aquaculture as very important to reducing pollution and improving ecosystem function in Chesapeake Bay (Table 5.28 in Appendix E1). Another 28% (n=12) believed that native oyster aquaculture would be somewhat important to achieving these ecological goals (Table 5.28 in Appendix E1).

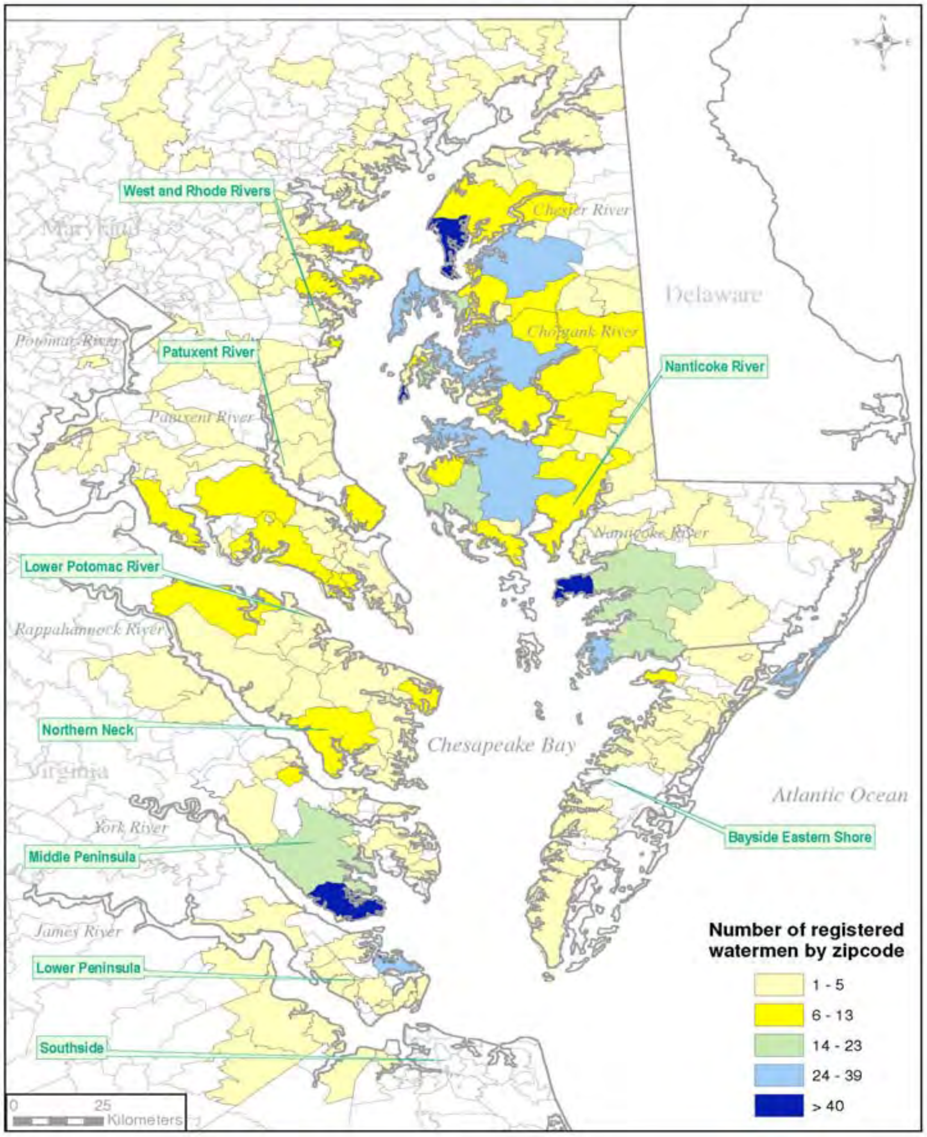

Figure 4-17. Representative sites for expanded oyster aquaculture (Appendix C) and residence of watermen

Oyster Community Consequences – Expanding aquaculture of the native oyster is of interest to all oyster stakeholders, who see possible economic, local ecological, and community benefits. Most watermen would not change their level of harvesting of wild oysters as the result of expanded aquaculture. Most watermen would be interested in exploring the feasibility of entering the aquaculture industry, but the optimal locations for expanded aquaculture operations could limit the number of watermen who would participate. Growers and processors supported the idea of expanding cultivation of the native oyster.

Cultural Model of Oyster Restoration – Expanding aquaculture of the native oyster as proposed would not accomplish the goals of the cultural model of oyster restoration. The ecological benefits that might accrue would be local and would depend on private enterprise decision-making. Watermen would not be able to participate without consideration of their economic constraints. Implementing Alternative 4 might provide the economic benefits of restoration, but those benefits would be realized directly only among private-sector growers and processors, not among other stakeholders. Alternative 4 is inconsistent with the stakeholders' goal to have a sustainable population of oysters in Chesapeake Bay because the aquaculture industry would be based on hatchery-raised spat (Section 4.1.4). Alternative 4 would not satisfy any stakeholders' explicit and implicit expectations of restoration of "public" oysters.

4.6.1.6 Alternative 5: Cultivate a Nonnative Oyster

The only difference between this alternative and Alternative 4 is that triploid Suminoe oysters are assumed to be the only cultivated nonnative species (Section 4.1.6) Triploid Suminoe oysters grow faster than either diploid or triploid Eastern oysters. Because triploid Suminoe oysters reach market size in less than a year, less effort and infrastructure would be required to produce the maximum industry. Triploid Suminoe oysters, however, probably would have to be cultivated in off-bottom cages or bags, which cost more and require more maintenance than unconfined, on-bottom methods. An industry of the estimated maximum size would produce approximately 2.8 times the current number of market-size oysters in the Bay; however, an industry of that size based solely on triploid Suminoe oysters would be unlikely to develop within the 10-year assessment period for the PEIS (Section 4.1.6).

Watermen – In the 2007 survey, 65% (n=228) of watermen reported that they would not change their harvesting if nonnative oysters are cultivated in Chesapeake Bay (Table 5.23 in Appendix E1). In the same survey, watermen reported mixed views about whether cultivating nonnative oysters would affect the market for wild-harvested oysters: 34% (n=125) felt that effects would be negative; 31% (n=113) thought that effects would be both positive and negative; 19% (n=70) thought that effects would be positive; and 16% (n=60) anticipated no effects (Table 5.21 in Appendix E1). These views are similar to those expressed for Alternative 4 (i.e., about 8% more watermen anticipated a negative effect, and about 5% fewer anticipated no effect). According to the 2007 survey, 51% (n=175) of watermen would not consider raising nonnative oysters in aquaculture, and 49 % (n=182) would consider it.

Growers and Processors – Growers' outlook on implementing State-assisted, managed, or regulated aquaculture of a nonnative oyster was more equivocal than their position on expanding native aquaculture. Forty-two percent (n=11) of growers believed that cultivation of a nonnative oyster would decrease their business; 35% (n=9) felt that such an initiative would increase their business (Table 5.25 in Appendix E1). Growers who expected to benefit from nonnative aquaculture probably are considering growing Suminoe oysters (to add to their existing operations) or have diversified or integrated businesses that include components that could benefit from increased supply.

Among processors and shippers, 36% (n=14) believed that cultivating nonnative oysters in Chesapeake Bay would have both positive and negative effects on their business; 33% (n=13) believed that nonnative aquaculture would result in a decrease in business; 31% (n=12) believed it would increase their business. These results suggest considerable uncertainty among processors about whether large-scale cultivation of a nonnative oyster would be good for their businesses. The uncertainty could be due to differences in the scales and kinds of operations among the surveyed processors.

Scientists and Environmentalists – Forty-three percent (n=13) of scientists believed that a large amount of research would be needed to support the development of an aquaculture industry using a nonnative oyster, including studies on growth, habitat conditions, and biological risks; and 37% (n=11) believed that a medium amount would be needed (Table 5.32 in Appendix E1). Fifty-seven percent (n=17) of scientists felt that such research would require more funding than is currently available (Table 5.33 in Appendix E1).

Environmentalists are less convinced that nonnative aquaculture would contribute to reducing pollution. Forty-nine percent (n=20) believed that cultivating nonnative oysters would not be important in addressing the Bay's pollution problems and ecological needs; another 42% (n=17) responded that such aquaculture would be only somewhat important in reducing pollution and providing other ecological services (Table 5.29 in Appendix E1).

Oyster Community Consequences – The consequences for the oyster community of encouraging cultivation of a nonnative oyster are similar to those for expanding cultivation of the native oyster; however, the level of uncertainty and the perceived risks associated with cultivation of a nonnative oyster are greater than for native aquaculture. Also, the dependence on hatchery-raised triploid oyster spat and the need for biosecurity make Alternative 5 a more costly and intensive form of aquaculture, which would present additional challenges for watermen who might be interested in entering the industry, unless technical and financial support were provided. The faster growth and better survival of triploid Suminoe oysters could result in increased profits for growers and processors. The scientific community recognized continued need for more information, and the environmental community was less optimistic about local environmental benefits.

Cultural Model of Oyster Restoration – Cultivation of nonnative oysters as proposed would not accomplish the goals of the cultural model of oyster restoration: ecological benefits that might accrue would be local, private benefits would exceed public benefits, and the location and technological requirements may make participation in the industry very difficult for watermen.

4.6.1.7 Alternative 8: Combination of Alternatives

Cultural and socioeconomic research used in this document focused on the proposed action and alternatives individually. The research did not include considering combinations of alternatives because they had not been defined when the research was undertaken. Although the study results provide some insight into the potential cultural and socioeconomic effects of the three combinations of alternatives, the existing survey results are not likely to capture how stakeholders' views might change when combinations are suggested. The results, therefore, do not provide a basis for evaluating the combinations individually, but some limited general conclusions are possible.

Although Combination 8c, which includes introducing the diploid Suminoe oyster, appears to have the greatest potential for accomplishing the stakeholders' shared objectives of restoring the ecological, cultural, and economic benefits of oysters in Chesapeake Bay, stakeholders probably would view it as having the greatest level of uncertainty and perceived ecological risks. Combination 8a would appear to offer the least risk but would perhaps be least likely to meet the goals shared by all stakeholders. Stakeholders probably would view Combination 8b as a middle ground between 8a and 8c, but some stakeholders still are likely to perceive a high risk of adverse ecological effects posed by cultivating triploid Suminoe oysters Public comments on the Draft PEIS should provide a more definitive view of how stakeholders view the combinations.

4.6.2 Economic Effects

Economics analyses were conducted to develop, where possible, implementation costs associated with the proposed action and the alternatives, and reasonable estimates of the size and nature of the oyster harvesting industry, including both aquaculture and the public fishery, that might emerge following their implementation. The results presented here draw on reports of economic analyses prepared to provide supporting material for the PEIS (Appendices D1 and D3), corresponding peer review comments relevant to those reports (Anderson, Pers. Comm., 2008; Anderson et al. 2007), a manuscript by Dedah et al. (2007), and additional analyses conducted after Appendix D was prepared. Simple and logical approaches were developed based on existing data and studies, and results reflect the large uncertainties involved in making these kinds of predictions.

The predictions that follow are based on historical data and industry relationships; departure from those patterns in the future could lead to outcomes that are markedly different than those predicted here. The following factors could result in the value of the oyster harvest being greater than predicted here:

- A greater share of future Chesapeake oyster production could be sold in the more lucrative half-shell market.
- The output of other major oyster-producing regions could decline, as occurred in the Gulf of Mexico as a result of hurricanes in 2005.
- The oyster industry could engage in effective marketing and retailing that increases the demand for oysters and expands the market. Evidence from observing the development of other aquaculture industries such as salmon, catfish, and tilapia demonstrate this phenomenon of market expansion once a product is established in the marketplace.
- Technological advances in oyster production could significantly lower production costs, allowing more oysters to be produced and sold at a given price. Improved hatchery production and selective breeding are two areas that can lead to significantly lower costs.

Other factors could result in the value being lower than predicted here:

- Awareness of and concern about food-borne illnesses associated with oysters could increase.
- Construction of market infrastructure, particularly new or expanded shucking houses, could be limited by competing uses of near shore land.
- Labor limitations could limit expansion of the processing sector (e.g., blue-crab processors have uncertainties regarding the continued use of H2-B visa laborers).
- Other regions could increase their production levels.
- Imports could become a greater factor.
- The production of competing products such as mussels and hard clams could expand, which might decrease the demand for oysters.

All of these factors, both positive and negative, would affect prices expected to result from any of the alternatives because they would influence the general market for oysters.

A simple, reduced-form, inverse demand model was estimated using data from 1975-2006 to determine the price flexibility of Chesapeake Bay oyster production. Price estimates were obtained from the model for different levels of Chesapeake Bay production assuming that other oyster producing regions of the United States maintain production at average levels for 2002 through 2006. The model was developed using only total harvest quantity and average price data because no more detailed information about the composition of the Chesapeake Bay oyster market was consistently available over the time period of analysis. These analyses illustrate that significant increases in oyster production in Chesapeake Bay resulting from any of the alternatives, regardless of origin (i.e., wild or cultivated), would lead to lower prices in the region, as explained in 2 (Figure 4-18). Analysis of historical data suggested that a minimum economically viable price is about $20 a bushel (expressed in 2006 dollars), which translates into a maximum economically viable annual oyster production in the Chesapeake Bay of about 2.6 million bushels, with 95% confidence limits, holding the other producing regions at their 2002-2006 average, of 1.7 to 5.4 million. This analysis implies that the PEIS goal to reestablish an oyster population in the Bay that could biologically sustain an oyster fishery of 5 million bushels annually is not economically viable (i.e., in Figure 4-18, the price per bushel at that level of production would decline to about $10 and be lower than the cost of production). This finding is interpreted to mean a market for oysters of the size that existed between 1920 and 1970 period no longer exists. The following analyses assume an annual production of 2.6 million as a benchmark for comparing the alternatives. The half-shell market was assumed to constitute 30% of the total market, by volume. The value of the half-shell product is much greater than the value of the shucked product; therefore, deviations from the assumed proportion of the half-shell market could substantially alter the conclusions drawn from the assessments.

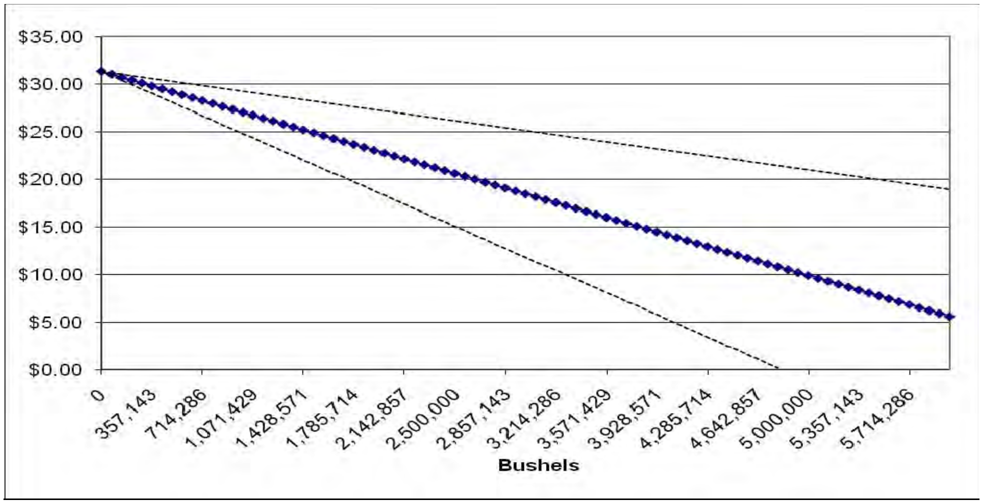

Figure 4-18. Oyster demand showing bushel prices versus bushels harvested. Dashed lines represent 95% confidence limits for Chesapeake Bay production when all other factors effecting price are held at their 2002-2006 average (Figure 1 of Appendix D2, p.6).

Predicting the mix of firms and technologies that might arise to produce oysters to meet this demand is challenging, and all of the following predictions have a very great level of associated uncertainty. Several factors contribute to the uncertainty:

- Oyster production, particularly in the public fishery, is highly regulated through limits on gear and harvest. These limits often prevent firms (i.e., watermen) from operating at levels that would minimize production costs.
- Harvesters are not identical in the gear they use or in their skill in employing the gear.
- Private aquaculture production has an entirely different cost structure than the public fishery, and private aquaculture firms use a variety of techniques (e.g., on-bottom, floats, off bottom cages) with varying levels of success.

The variety of available oyster-production techniques combined with the lack of systematic collection of data on costs and returns for each technique makes determining the structure of an industry that might emerge from an enhanced oyster population extremely difficult. Other important data that were not available for these analyses were capital and operation costs and the increase in production cost for spat grown in biosecure hatcheries versus similar non-secure hatcheries. Analysis of those factors was beyond the scope of this Draft PEIS and the time frame available for producing it but could be generated in later studies that might be needed to support implementation of a preferred alternative. Biosecure hatcheries would be required for production of the triploid nonnative spat to be used for Alternative 5. The following discussion summarizes how these factors might affect the structure of the industry and how they were accounted for in the economic analyses; more detail is available in Appendix D.

A 10-year time horizon was used throughout the economic analyses, primarily because population modeling for that time period was intended for use in some of the calculations. However, the 10-year period is, by itself, a reasonable constraint on this analysis, since economic forecasts beyond 10 years would require an implicit assumption of stability in the economic components of the analysis that would be difficult to justify. Continued globalization in oyster markets, technological change in oyster production, new post-harvest technologies, and other factors that are difficult to foresee greatly limit our confidence in predictions beyond these time limits.

The original intention of this economic analysis of the proposed action and alternatives was to present results in four parts: (1) implementation cost (considering only public costs), (2) fishery benefits, (3) processor/consumer benefits, and (4) indirect benefits. Since preparation of Appendix D, limitations of the modeling outputs that were anticipated for use in this analysis were determined to be of such potential significance that the overall approach was revised. No quantitative projection of potential economic benefits is presented for the Proposed Action, and the projection of benefits for Alternative 1 were derived based on recent fishery data rather than modeling output. Benefits for Alternatives 2 and 3 were then considered to increase or decrease in proportion to the extent to which oyster abundance increased or decreased under those respective alternatives.

4.6.2.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

Implementation Costs – The proposed action involves introducing the Suminoe oyster and continuing current restoration programs. The details of costs for current restoration programs and how they were estimated are described under Alternative 1 (Section 4.6.2.2). Details of the representative plan for introducing the Suminoe oyster used in exploratory modeling documented in Appendix A are presented in Section 4.1.1. Section 4.1.1 noted that production of the required numbers of Suminoe oyster spat would require dedication of the entire capacity of the University of Maryland’s hatchery at Horn Point, or construction of additional hatcheries with similar production capacity. The cost of any additional hatchery operations that might be required is subsumed in the price-per-spat cost. Taking these limitations into account, the total cost of implementing the proposed action is $264.2 million net present value (Table 4-16).

Table 4-16. Estimated 10-year present value (2.6% discount rate) of costs to implement the proposed action ($millions).

	Habitat	Spat	Monitoring & Management	Overhead	TOTAL
MD	$29.9	$110.8	$9.4	$18.0	$168.0
VA	$53.5	$19.2	$5.0	$9.3	$87.0
PRFC	$3.1	$4.6	$0.4	$1.0	$9.1
TOTAL	$86.5	$134.6	$14.8	$28.3	$264.2

Fishery Benefits – The estimation of the harvest benefits of the proposed action is precluded by several factors, including the lack of a quantitative projection of the potential size of a population of diploid Suminoe oysters that might result from an introduction, the inability to predict where and how quickly Suminoe oysters might become established in harvestable areas, and the inability to predict what exploitation rate might be experienced by Suminoe oysters in those harvestable areas (Section 4.1.1). All Suminoe oyster spat planted in the implementation program described in Table 4-2 initially would be planted on sanctuary bars. The species would become subject to harvest only after the planted spat on harvest bars reached legal size (3 inches) and those spat on sanctuary bars reached sexual maturity, the mature oysters spawned, their larvae settled on harvestable bars, and those settled larvae grew to legal size. Given that required chain of events, significant harvest of Suminoe oysters would not likely occur for many years after the implementation program was initiated, most likely beyond the ten years used in the analyses here. If the Suminoe oyster were to become established and very abundant, there would be potential for harvests to be sustained at high levels with little or no additional implementation costs at some time in the future and thus yield overall positive net benefits. A number of factors that might limit the marketability of Suminoe oysters growing in Chesapeake Bay are discussed in Section 4.6.2.6 and could constrain the value of Suminoe oyster harvests. Failure of an introduction program would obviously yield significant negative net benefits, given the estimated implementation costs. Also, sustained high harvest would require that a management regime for oyster harvests be adopted if agencies intended to prevent economic overfishing and the resulting dissipation of positive net economic benefits to fishermen's incomes.

Processor/Consumer Benefits – If a Suminoe oyster were successful and resulted in substantial oyster harvests, processor and consumer benefits from such local production of oysters would be large compared to other alternatives. Consumers in the region would be likely to benefit to the extent that lower prices due to increased oyster abundance were passed on to the consumer. If an introduction were unsuccessful, there would be no resultant processor or consumer benefits beyond those expected under current programs, which are presented in Section 4.6.2.2.

Indirect Benefits – Appendix D4 discusses the indirect economic benefits associated with the oyster resource, particularly the economic value of ecological services. If the Suminoe oyster introduction were successful, ecological services provided by the enhanced oyster population might improve water quality and habitat in ways that could contribute economic benefits:

- support larger populations of other important commercial species in Chesapeake Bay (e.g., striped bass and blue crab), which could result in greater industry profits and consumer benefits related to those fisheries
- support larger populations of recreational species that might contribute to economic benefits
- improve water clarity, which could lead to higher values for other forms of recreation (e.g., swimming and boating) and higher values for waterfront property
- reduce the expenditures required for other management actions (e.g., agricultural best management practices for nutrient reduction) required to meet Chesapeake Bay water quality goals

Estimating the economic benefits related to the ecological services provided by oyster populations would require quantifying ecological changes related to increasing oyster populations. Such changes could not be quantified; therefore, it is not possible to estimate these indirect economic benefits for each alternative. The ERA (Section 3.4 of Appendix B) used a relative risk model to assess the *relative* positive and negative ecological influences of the proposed action and alternatives. This information affords insights into possible increases or decreases in ecological services including the potential for improvement in the Bay's water quality; however, the relative risk model does not predict the actual magnitudes of changes or risks such as increase or decrease in abundance of key species. The ERA is useful only as a general guide to compare the direction of change in potential indirect economic benefits among alternatives.

If a Suminoe oyster introduction were successful, the most likely indirect benefit would be through increased recreational fishing Benefits for recreational fishermen throughout Chesapeake Bay could result from the greater availability of preferred fishing grounds and potentially higher catch rates due to the aggregating function of oyster reefs for fish populations. According to Marine Recreational Fishery Statistics Survey data,[15] more than six million recreational fishing trips were taken in Chesapeake Bay in 2006. Improved recreational fishing due to restored oyster reefs could increase the average value of those fishing trips; however, it is not possible to quantify the potential economic value of such an increase. An unsuccessful introduction would not yield any indirect benefits.

4.6.2.2 Alternative 1: No Action

Implementation Costs – Alternative 1 assumes that current restoration and management programs would continue into the future. Two approaches represent estimates for these costs. First, the efforts described in Section 4.1.2 are those for the year the PEIS was initiated (2004); therefore, the expenditure for that year served as one estimate. A second estimate was derived from a more detailed description of habitat rehabilitation and seeding costs over multiple years (Appendix D).

The oyster restoration programs in Maryland and Virginia are not static in policy or available funding. Strategies have changed over time as information is gained on the effectiveness of different restoration techniques and for a variety of other reasons. The amount of funding from State and Federal sources and the manner in which it was spent has varied greatly from year to year (Table 4-17). The reported State and Federal expenditures for oyster restoration in 2004 totaled about $7.2 million, which is reasonably representative of expenditures in most years. These costs were assumed to be the same in each year of the 10-year time horizon for this analysis.

The present-value equivalent of the 2004 expenditure of $7.2 million was obtained by applying the consumer price index available from the Bureau of Labor Statistics, resulting in a cost of $7.9 million in 2007 dollars. Next, a real discount rate of 2.6% was applied, as specified by Office of Management and Budget for projects of 10 years. The present-value cost of implementing Alternative 1 based solely on reported State and Federal expenditures is estimated at approximately $68.8 million for the 10-year assessment period. This analysis may underestimate the total costs associated with the restoration activities because it reflects only direct State and Federal appropriations for oyster restoration. Extensive monitoring and management activities accompany these restoration efforts. DNR and the PRFC estimated these annual

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[15] http://www.st.nmfs.noaa.gov/st1/recreational/queries/effort/effort_time_series.html

expenditures at $1.7 million, and $0.5 million, respectively. No estimate of the cost of monitoring and management was available for Virginia; therefore, Virginia's costs were assumed to constitute the same percentage of restoration outlays as monitoring and management costs represented in Maryland and the Potomac (i.e., 30% of the restoration costs, or about $0.8 million). Available expenditure data did not include estimates of the opportunity costs associated with full-time State and Federal employees or any percentage of agency overhead charges that should be allocated to the restoration effort (i.e., they do not include expenses such as the costs of a manager of those assigned to such work). Adding annual monitoring and management costs brings the full estimate of the present value based on State and Federal agency expenditures to $101.7 million for the 10-year assessment period.

Table 4-17. Federal and State expenditures ($1,000 dollars, current) for oyster restoration by jurisdiction and placement on sanctuaries or harvest bars, 1994-2006.

Year	**MD**		**Potomac**		**VA**		**Combined**	
	Harvest	**Sanctuary**	**Harvest**	**Sanctuary**	**Harvest**	**Sanctuary**	**Harvest**	**Sanctuary**
1994	$795	$0	$94	$0	$408	$353	$1,297	$353
1995	$1,075	$0	$104	$0	$423	$245	$1,602	$245
1996	$1,427	$0	$102	$0	$278	$246	$1,807	$246
1997	$1,716	$0	$193	$0	$358	$416	$2,266	$416
1998	$2,016	$177	$191	$0	$276	$300	$2,483	$477
1999	$2,131	$187	$160	$0	$502	$390	$2,792	$577
2000	$2,312	$456	$253	$0	$766	$1,030	$3,331	$1,486
2001	$1,974	$270	$58	$0	$1,729	$665	$3,761	$935
2002	$3,051	$1,792	$30	$0	$3,257	$1,737	$6,338	$3,529
2003	$1,762	$1,665	$98	$0	$778	$475	$2,638	$2,140
2004	$3,775	$1,064	$12	$0	$494	$1,808	$4,282	$2,871
2005	$3,612	$1,532	$0	$0	$531	$705	$4,143	$2,236
2006	$4,863	$2,036	$0	$0	$830	$1,043	$5,694	$3,079

Source: Maryland Department of Natural Resources

A second, more detailed approach for estimating implementation costs was developed using yearly, bar-by-bar estimates of the costs of habitat rehabilitation and seeding based on the assessment scenarios (Section 4.1.2). Per-acre cost estimates for habitat restoration and per-unit spat planting costs were obtained from DNR, VMRC, and the PRFC. This approach also involved including estimates of monitoring and management costs and overhead charges. Using this approach, projected annual expenditures for implementation would vary over the 10 years but would average around $12 million. The present value of the 10 years of expenditures at the 2.6% discount rate is $106.4 million (Table 4-18). Although this estimate slightly exceeded the estimate based on adjusted agency expenditures, it was used for Alternative 1 because it could be modified easily and applied to the other alternatives that included similar restoration activities.

Table 4-18. Estimated 10-year present value (2.6% discount rate) of costs to implement Alternative 1 ($ millions).*

	Habitat	Spat	Monitoring & Management	Overhead	TOTAL
MD	$29.8	$17.3	$14.7	$7.4	$69.2
VA	$18.7	$4.3	$6.9	$3.6	$33.5
PRFC	$1.1	$2.2	$0.4	$0.4	$3.7
TOTAL	$49.6	$23.8	$22.0	$11.5	$106.4

*Small discrepancies in column totals in tables throughout this section are the result of rounding.

Fishery Benefits – The starting point for predicting future harvests under this alternative was considered to be the recent landings from Maryland and Virginia. Defining recent landings is problematic. The 10-year average harvest is 1.3 million pounds (approximately 186,700 bushels) with a standard deviation of 1.1 million, and the 5-year average is 0.4 million pounds (approximately 57,100 bushels) with a standard deviation of 0.3 million pounds; the difference in means reflects the extremely poor recent landings record. To ensure that the projections captured at least some probability of higher harvests than experienced over the last five years, as if they were based on average for catch for 7 years (2000-2006). The average harvest was 0.86 million pounds (122,857 bushels), with a standard deviation of 0.87 million. Ten random draws were then taken from a truncated (at zero) normal distribution with this mean and standard deviation corresponding to the pattern of predicted harvests over the next ten years (Table 4-18). The normal distribution was chosen because, based on a Chi-square analysis, it was the best fit among distributions tested for the time series of oyster harvest data.

Table 4-19 summarizes the net returns to the pattern of harvests based on the random draws for oysters in Chesapeake Bay over the 10-year time horizon. Harvesting costs were based on the estimate by Wieland (2008) and is the mid-range of costs from that study. The Chesapeake Bay price is based on the price flexibility from the inverse demand model detailed in Appendix D.

Table 4-19. Projected annual landings, Chesapeake Bay price, gross revenues, harvest costs and net revenues based on random draws from a normal distribution

Year	Landings*	Price	Gross Revenues	Harvest Cost	Net Revenue
1	1,841,000	$4.31	$7,939,714	$5,917,500	$2,022,214
2	1,835,000	$4.29	$7,866,584	$5,898,214	$1,968,370
3	855,000	$4.31	$3,685,607	$2,748,214	$937,393
4	740,000	$4.32	$3,198,311	$2,378,571	$819,739
5	934,000	$4.35	$4,065,886	$3,002,143	$1,063,743
6	155,000	$4.39	$680,958	$498,214	$182,744
7	1,174,000	$4.37	$5,128,923	$3,773,571	$1,355,351
8	1,718,000	$4.37	$7,502,276	$5,522,143	$1,980,133
9	100,000	$4.45	$444,777	$321,429	$123,348
10	1,218,000	$4.40	$5,364,580	$3,915,000	$1,449,580

*Pounds of meats, approximately 7 pounds per bushel (Muth et al. 2000).

The present value of this stream of net revenues using the 2.6% rate of discount is $10.5 million. Based on Wieland's (2008) break-even cost analysis and assumption of a full fishing season of 100 days, this harvest would support an average of 17-35 full-time watermen equivalents over the 10-year period. The actual number of watermen continuing to harvest will be greater than that depending on the fraction of the 100-day season watermen choose to fish.

Processor Benefits/Consumer Benefits – According to Murray (2002), virtually all of Virginia's processed oyster production is from oysters harvested from other states, principally the Gulf of Mexico. The same is true of Maryland-based oyster processors. Under this alternative, it is expected that Chesapeake processors will continue to rely on shellstock from other regions to supply regional markets. These processors and retail markets will supplement this imported shellstock with the continued low level of harvests from Chesapeake Bay waters.

Comprehensive cost and returns data on oyster processing were not available from which to generate estimates of profits to this segment of the industry, and particularly a differential in profits from oysters produced locally versus shellstock transported in from other producing regions. Appendix D4 presents estimates of the wholesale value of oysters based on assumptions regarding the percentage of oysters sold as halfshell (30%) out of the available shellstock. Starting with a wholesale price of $0.20 for halfshell oysters and $48 for a gallon of shucked oysters, the gross revenues for the wholesale value of the Chesapeake Bay harvest was calculated over the 10-year time horizon. Wholesale prices were allowed to fluctuate in direct proportion to harvest prices derived from the inverse demand model. Oyster cost or gross revenue from Table 4-19 was subtracted out since it is what the processor or wholesaler would have to pay for these oysters. Table 4-20 gives the annual gross wholesale value and the value net of oyster cost for the wholesale industry. The estimate of the present value of revenues net of oyster cost at the wholesale level for Maryland harvested oysters under Alternative 1 is $42.5 million. While these revenue estimates cannot be interpreted as a net benefit because all opportunity costs of production are not accounted for, this figure is helpful for comparison with revenue estimates from the other alternatives.

Table 4-20. Estimated wholesale value and revenue net of oyster cost for projected oyster harvest from Chesapeake Bay

Year	Gross Revenue	Oyster Cost	Revenue Net of Oyster Cost
1	$14,789,972	$7,939,714	$6,850,257
2	$14,884,215	$7,866,584	$7,017,631
3	$11,143,848	$3,685,607	$7,458,241
4	$10,248,303	$3,198,311	$7,049,992
5	$9,093,710	$4,065,886	$5,027,823
6	$4,888,155	$680,958	$4,207,196
7	$8,883,201	$5,128,923	$3,754,278
8	$10,401,312	$7,502,276	$2,899,036
9	$1,708,063	$444,777	$1,263,286

Indirect Benefits – The RRM for this alternative shows declining scores for all but the Maryland oligohaline region of Chesapeake Bay. This alternative would be unlikely to lead to additional declines in indirect economic value from the resource because the expected declines would begin from an already significantly reduced level of ecological service provided by oysters in the Bay. The increase in oyster biomass in the Maryland oligohaline region is not anticipated to be sufficient to result in any significant indirect economic benefit in this section of the Bay.

4.6.2.3 Alternative 2: Enhance Restoration

Implementation Costs – Implementing Alternative 2 would require a major increase in investment in the habitat rehabilitation and seeding programs, as outlined in Section 4.1.3. The same cost factors for habitat and spat used to estimate costs for Alternative 1 were used to determine the detailed cost for Alternative 2 (Table 4-21). Implicitly this analysis fails to capture any economies of scale that might accrue with this expanded effort. Although monitoring and management costs would increase somewhat, they probably would not increase in proportion to the overall habitat and seeding program. To account for a limited increase, the monitoring and management costs estimated for Alternative 1 were increased by 10% of the incremental increase in habitat and spat costs for Alternative 2.

Table 4-21. Estimated 10-year present value (2.6% discount rate) of cost to implement Alternative 2 ($millions).

	Habitat	**Spat**	**Monitoring & Management**	**Overhead**	**TOTAL**
MD	$96.8	$102.3	$29.9	$27.5	$256.5
VA	$90.5	$15.0	$15.2	$14.5	$135.1
PRFC	$2.0	$8.1	$1.1	$1.1	$12.5
TOTAL	$189.3	$125.4	$46.1	$43.3	$404.1

Fishery Benefits – As explained for Alternative 1, initial estimates of the fishery benefits under Alternative 2 presented in Table 6.0 of Appendix D1 were developed using the output of exploratory modeling documented in Appendix A. Because of the limitations on the model outputs alluded to above, an alternative approach to establishing benefits has been employed here. The starting point for a prediction of future harvests under Alternative 1 was considered to be the recent landings from Maryland and Virginia. The predicted net present value of 10 years of harvest under that alternative was $10.5 million. In Section 4.1.3 the potential for the oyster population under this alternative to increase to a greater degree than under Alternative 1 was discussed. An initial approach to predicting fishery benefits under this alternative might be to assume that they would increase in proportion to the difference in predicted population size. Exploratory modeling suggested that after 10 years, the population might be as great as five times the population size after that same time period under Alternative 1, suggesting that fishery benefits might be as great as $52.5 million. However, because the greatest increase in oyster abundance would most likely be on sanctuary bars in low-salinity waters in Maryland (Section 4.1.3), a substantial portion of the enhanced population would not be subject to harvest and would not contribute to an increase in fishery benefits. Also, a number of factors, most importantly continuing loss of habitat, could preclude the attainment of the projected growth in oyster abundance (Section 4.1.3). In addition, the rate at which oysters might be harvested in the future cannot be predicted. For all these reasons, the fishery benefits under this alternative after 10 years would be expected to be somewhat greater than the $10.5 million estimated for Alternative 1, but how much greater cannot be estimated.

Processor/Consumer Benefits – As was described for fishery benefits, an initial approach to predicting processor/consumer benefits under this alternative might be to assume that they would increase in proportion to the difference in predicted population size for this alternative versus Alternative 1. The estimate of the present value of revenues net of harvesting costs at the wholesale level for Maryland harvested oysters under Alternative 1 is $42.5 million For all the reasons presented for fishery benefits, the present value of revenues under this alternative after 10 years would be expected to be somewhat greater than $42.5 million, but how much greater cannot be estimated.

Indirect Benefits – The ERA suggested that this alternative would have a significantly greater positive influence on oyster abundance in the Maryland oligohaline zone than for Alternative 1, and positive influences in other areas except the Virginia polyhaline zone (Section 4.4.4 of Appendix B). Because this alternative entails significantly more habitat rehabilitation than Alternative 1, the ERA also suggested significantly greater positive influences for hard-bottom habitat and reef-oriented fish. As discussed in Appendix D4 and analyzed in Hicks et al. (2004), recreational anglers prefer hard-bottom habitat; therefore, Alternative 2 would have a positive economic benefit even if the oyster habitat did not lead to larger populations of recreational fish. In their analysis, a specific set of restoration projects summing to 1,890 restored acres had an annual benefit to recreational anglers of $720,000 (in 2007 dollars), or a net present value of $6.3 million over 10 years. That analysis was dependent on the location of the restoration projects relative to fishing activity in Chesapeake Bay. The specific location of habitat restoration activities in Alternative 2 would provide different results; however, the analysis reported by Hicks et al. (2004) serves as a relative indicator of the magnitude of recreational fishing benefits that might result from restoring oyster habitat. This alternative might also provide some benefits for the commercial fisheries for crabs and finfish, but those benefits were not estimated.

4.6.2.4 Alternative 3: Harvest Moratorium

Implementation Costs – Because current restoration programs would continue under this alternative, cost of spat planting and habitat rehabilitation over a 10-year assessment period would be $106.4 million (Section 4.6.2.3). For harvesters, foregone net income is a measure of the cost of imposing a harvest moratorium. The moratorium would be imposed on the oyster stock, as it exists under current management and restoration programs (i.e., Alternative 1). The foregone net present value of net income associated with implementing Alternative 3 would thus be $10.5 million, and the total implementation cost would be $116.9 million. The compensation program to be implemented under this alternative presumably would be intended to restore harvesters' income lost as a result of a moratorium. A buy-out program that would compensate watermen for foregone net income would not change the estimate of costs; it would simply shift the income loss incurred by the watermen to the public sector. Hiring displaced watermen preferentially to conduct on-water restoration in lieu of a direct buy-out also would not modify the cost, but would simply transfer income from non-displaced watermen or other individuals and firms to displaced watermen.

Fishery Benefits – This alternative specifies that the moratorium would be temporary; therefore, benefits to the fishery could become apparent after the moratorium was lifted. For this analysis, the moratorium was assumed to continue throughout the 10-year evaluation period. The immediate fishery benefits under this alternative would be zero. Future benefits would be those that might result from increased profits to oystermen (compared with Alternative 1) related to any increase in oyster biomass in the future that would lower the cost by increasing the catch per unit of effort.

Processor/Consumer Benefits – Eliminating harvest would result in a decrease in processor and consumer benefits. To the extent that the moratorium reduced the availability of oysters for the market, it could cause prices to increase; however, because the current market is dominated by non-Bay oysters, the magnitude of this effect probably would be limited. As in the case of fishery benefits, there could be increases in future processor/consumer benefits if an increase in the oyster population resulted in an increase in oyster harvest post-moratorium.

Indirect Benefit – According to the ERA, the ecological influences of this alternative are slightly more positive than for Alternative 1, depending on the salinity zone. The slightly greater positive influences would result in slightly greater indirect economic benefits than for Alternative 1.

4.6.2.5 Alternative 4: Cultivate Eastern Oysters

Implementation Costs – Private aquaculture of the Eastern oyster in Chesapeake Bay is limited. Murray and Oesterling (2006) projected that about 5.2 million cultivated oysters were sold in Virginia in 2006. Entrepreneurs in Maryland and Virginia are experimenting with a variety of off-bottom and on-bottom cultivation methods. The analysis of oyster aquaculture in Chesapeake Bay presented in Appendix D4 demonstrates that a variety of methods of cultivating the native species are economically viable at the current high prices for oysters. Significant expansion of production from aquaculture would be expected to lead to lower prices. This would increase the economic risk associated with cultivating oysters and limit the overall size of the industry, unless measures (e.g., increase regional or national marketing) proved successful in increasing the market or the value of Chesapeake Bay oysters. Aquaculture operations in Maryland and Virginia currently receive no direct public funding and, thus, have no direct implementation costs. Maryland funds two groups that work to further aquaculture development in the State, the Aquaculture Review Board (ARB) and the Aquaculture Coordinating Council (ACC). Similarly, Virginia funds the VIMS Aquaculture Genetics and Breeding Technology Center. These organizations provide technical support; they do not directly fund or financially support any private aquaculture operations.

The public would incur costs for this alternative if either State were to implement business-development programs to encourage the growth of the oyster aquaculture industry in Chesapeake Bay. In Maryland, the ACC has initiated discussion about creating Aquaculture Enterprise Zones (AEZs). In an AEZ, the State could provide assistance to aquaculture entrepreneurs in the form of zone permitting (i.e., the State would obtain necessary State permits for a broad area within a waterbody and allocate locations to operators within that AEZ), infrastructure support (e.g., construction of shore-side facilities that operators within an AEZ could share), and other such support. Such public support would be required to expand aquaculture in Chesapeake Bay beyond the level that the market supports currently. Some actions that would encourage expansion of the aquaculture industry may have little or no public cost, such as relaxing or streamlining regulatory constraints in Maryland. Other actions, such as creating the proposed AEZs in Maryland, providing direct subsidies for operators, subsidizing spat production, and making low-interest or no-interest loans to operators, could involve substantial public costs and would require legislative action. The incremental increase in the cost of water quality monitoring performed by the Maryland Department of the Environment and the Virginia Department of Health for all aquaculture operations would be included among the public costs of implementing this alternative.

The private sector would absorb much of the cost of expanding aquaculture production in the Bay. As discussed in Appendix D4, operators could bear these costs if the price of oysters remained high enough to cover them and provide a return on investment and management. New or expanded aquaculture could result in some increased costs to government agencies for activities such as water quality monitoring, permit processing, etc.; however, the magnitude of such costs could not be estimated. Benefits discussed below are the net gains, after accounting for estimated private costs.

Fishery Benefits – To evaluate this alternative, the wild fishery was assumed to continue as in Alternative 1. Cultivated oysters would supplement the wild harvest from Chesapeake Bay. The analysis presented in Appendix D4 indicates the potential for a private aquaculture industry based on Eastern oyster production for the half-shell market of about 330,000 bushels a year sold at about $0.19 per oyster. This level of aggregate production would support approximately 94 “representative size” aquaculture firms producing about 3,500 bushels each of Eastern oysters for the half-shell market. The actual number of individuals or firms participating could be higher if the firm scale of operation is smaller than the representative firm scale. The Monte Carlo simulations used to project this operation show a great deal of uncertainty in economic performance. For comparison with the other alternatives, the analysis assumed 10 firms corresponding to the participants in the VSC trials. The number of firms was assumed to increase by 10 each year and 4 in the tenth year to achieve the predicted equilibrium of 94 representative firms by year 10. The net present value of the industry for the 10-year time horizon was then computed. The first 10 firms are credited with $190,000 each and would contribute $1.9 million. The firms that enter in the second year would contribute only $179,000 each, and each subsequent year’s firms would contribute less (Table 4-22). The minimum and maximum values in Table 4-22 correspond to the range of one standard deviation from the predicted value. Under this scenario, an expanded aquaculture industry using the Eastern oyster would contribute about $8 million in net present value, but the amount could range from $6 million to $15 million (Appendix D4).

Data that would support a detailed analysis of production costs for an extensive oyster aquaculture industry in Chesapeake Bay were very limited. Data (Attachment A of Appendix C) provided at a workshop held in February, 2006, included some estimated costs to obtain wild, diploid Eastern oyster spat. The wild spat described in that data was subject to high mortality; however, assuming mortalities typical for Chesapeake Bay, the average cost per harvested bushel was about $82, whereas the price received was about $30. Under those conditions, survival would have to be 16% to break even on spat costs, but that evaluation did not include additional costs, such as labor. An extensive production industry for triploid or other fast-growing strains of Eastern oyster (e.g., a disease resistant strain or one with a higher growth rate) could be viable. To the extent that substantial aquaculture using such specially adapted Eastern oyster develops, it has the potential to supplement or compete with current modes of aquaculture, and if the production costs can be reduced enough through high survival and economies of scale, become a viable source of product to compete for the lower-priced shucked oyster market. Other data to further analyze extensive aquaculture production were not available for this PEIS. Potentially less expensive alternatives to hatchery production of spat include use of spat collectors to collect larvae produced by wild oysters, as is done in aquaculture in France, China and elswhere, or the purchase of spat from outside the Chesapeake Bay area. As discussed in Section 4.1.5, these alternatives are not considered by existing oyster growers to be applicable to aquaculture in the Bay. No data were available from which to assess their potential for enhancing profitability of Bay operations.

Table 4-22. A scenario for growth and estimated net present value (NPV) of an Eastern oyster aquaculture industry for the 10-year PEIS assessment period.

Year	New Firms	NPV	Total NPV	Min	Max
1	10	$190,000	$1,900,000	$1,102,000	$2,698,000
2	10	$179,000	$1,790,000	$1,038,200	$2,541,800
3	10	$167,000	$1,670,000	$968,600	$2,371,400
4	10	$163,000	$1,630,000	$945,400	$2,314,600
5	10	$133,000	$1,330,000	$771,400	$1,888,600
6	10	$116,000	$1,160,000	$ 672,800	$1,647,200
7	10	$58,000	$580,000	$336,400	$823,600
8	10	$29,000	$290,000	$168,200	$411,800
9	10	$0	$0	$ -	$ -
10	4	$0	$0	$ -	$ -
TOTAL	94		$10,350,000	$6,003,000	$ 14,697,000

The available data indicate that if current market factors remain constant in the future, an economically viable industry would not be likely to reach the maximum calculated size, within or even after the 10-year PEIS assessment period. However, as mentioned earlier, evidence with other aquculture species suggest that market factors often change to the advantage of greater aquaculture production. Expansion of markets and technological improvments could result in an aquaculture industry larger than is predicted here.

Indirect Benefits – The ERA results presented in Section 4.3.5 show that even at its maximum economically viable size, oyster aquaculture would have very limited ecological effects at the scale at which the analysis was performed. On a smaller scale, such as an individual tributary, water clarity improvements and associated ecosystem responses would be expected. Conversely, benthic enrichment and the associated ecological effect also would be possible, depending on the concentration of aquaculture operations and the hydrodynamic characteristics of the aquaculture site. For the purposes of this PEIS, it is not possible to estimate potential indirect economic benefits from such uncertain outcomes. Depending on the form aquaculture is pursued, interference with boating and recreational fishing would be possible, depending on the methods of aquaculture; for example, floats or buoys used to mark off-bottom cages could create obstructions Such interference could have an indirect cost, but such costs cannot be estimated.

4.6.2.6 Alternative 5: Cultivate a Nonnative Oyster

Section 4.1.6 indicates that the Suminoe oyster is the only nonnative species that appears to be feasible for this alternative. The economic analyses presented here are based largely on available information from pilot studies involving cultivation of triploid Suminoe oysters in the Chesapeake Bay.

Implementation Costs – As indicated for Alternative 4, the level and nature of State assistance would determine the public costs of this alternative. The kinds of business-development actions being considered were discussed for Alternative 4. For this alternative, hatcheries with quarantine facilities would be required to produce triploid Suminoe oyster spat. Such facilities would be more costly than hatcheries for the Eastern oyster, but insufficient information about hatchery production costs precluded a quantitative analysis of the difference[16]. Qualitatively, both capital and operational costs would be higher for a biosecure hatchery facility. As for Alternative 4, government agencies would incur some increased costs to manage and regulate the industry for activities such as water quality monitoring and permit processing; however, the magnitude of such costs could not be estimated.

Fishery Benefits – To evaluate this alternative, the wild fishery was assumed to continue as in Alternative 1. Cultivated Suminoe oysters would supplement the local production of native oysters from Chesapeake Bay. Based on the analysis presented in Appendix D4, a private aquaculture industry based on triploid Suminoe oysters could produce about 780,000 bushels for the half-shell market supplied by about 223 "representative sized" aquaculture firms producing about 3,500 bushels each to be sold at about $0.16 per oyster, assuming the quality of the product were sufficient for that market. In recent years, 15% to 35% of triploid Suminoe oysters raised in the Bay have gone into the half-shell market, and larger percentages have gone into that market from coastal bay producers (A.J. Erskine, Cowart Seafood Corporation, pers. comm.). A net present value for the full industry over the 10-year assessment period for the PEIS was estimated in the manner described for Alternative 4. Assuming that the maximum industry would develop gradually, starting with 10 firms and building to 223 firms at year 10[17], 30 firms a year were added to the analysis in years 2 through 5, 20 firms in years 6 through 9, and 13 firms in year 10. Firms in year 1 would contribute $126,000 each to the net present value, and firms added in subsequent years would contribute less (Table 4-23). The overall net present value of the industry would be $16 million, with a one-standard-deviation range of $9 million to $23 million (Appendix D). Based on the data available, the results of the analyses conducted suggest that the

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[16] Triploid Suminoe oysters used in all VSC trials and studies in the Bay have been produced by a State institution (VIMS) that conducts a wide range of shellfish studies; estimates of costs specifically for triploid production cannot be easily partitioned from overall facility costs and are unlikely to be representative of commercial production costs.

[17] This number of firms is greater than the number of firms for Eastern oyster aquaculture as a result of differences in production costs between the two species.

triploid Suminoe oyster could support more firms and create more employment opportunities for watermen and others than the Eastern oyster (Alternative 4). Considering the potential industry from the perspective of an individual oyster-producing operation, however, the analyses presented in Appendix D indicate that the probability of economic success is greater for an operation using triploid Suminoe oysters at a lower per-oyster output price than for an operation using triploid Eastern oysters (Figure 4-19). This illustrates an economic advantage of using triploid Suminoe oysters; however, uncertainty about the suitability of Suminoe oysters for the half-shell market may negate this advantage (Appendix D2).

Table 4-23. A scenario for growth and estimated net present value (NPV) of a triploid Suminoe oyster aquaculture industry for the 10-year PEIS assessment period.

Year	**New Firms**	**NPV**	**Total NPV**	**Min**	**Max**
1	10	$126,000	$1,260,000	$730,800	$1,789,200
2	30	$123,000	$3,690,000	$2,140,200	$5,239,800
3	30	$112,000	$3,360,000	$1,948,800	$4,771,200
4	30	$107,000	$3,210,000	$1,861,800	$4,558,200
5	30	$79,000	$2,370,000	$1,374,600	$3,365,400
6	20	$61,000	$1,220,000	$707,600	$1,732,400
7	20	$36,000	$720,000	$417,600	$1,022,400
8	20	$18,000	$360,000	$208,800	$511,200
9	20	$0	$0	$-	$-
10	13	$0	$0	$-	$-
TOTAL	223		$16,190,000	$ 9,390,200	$ 22,989,800

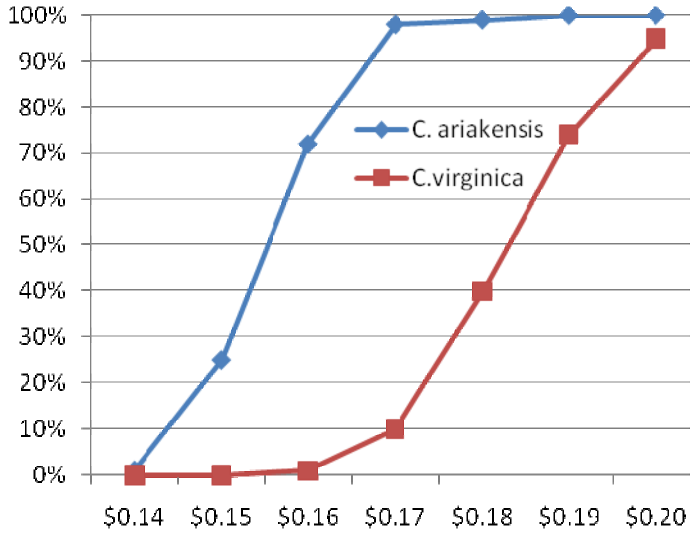

Figure 4-19. Probability of economic success for intensive aquaculture of triploid Suminoe oysters (*C. ariakensis)* and triploid Eastern oysters (C. *virginica)* at different output prices.

Caveats and uncertainties similar to those described for the economic evaluation of Alternative 4 apply for Alternative 5. Recent experience with cultivated triploid Suminoe oysters suggests that they are more appropriate for the shucked market than the half-shell market because of their short shelf life but that they would still bring a higher price than shucked Eastern oysters due to significantly greater yields (A. Erskine, Bevans Oyster Company, pers. comm.). The ability of a large-scale production industry for shucked Suminoe oysters to compete with the high-yielding Pacific oyster, for which production costs are smaller than for triploid Suminoe oysters, is unknown. Suminoe oysters produced in extensive, unconfined aquaculture operations probably would have signficantly lower production costs than those grown in confined operations and, thus, would compete better against shucked Pacific oysters imported from the West Coast. Unconfined cultivation of triploid Suminoe oysters may be possible if regulatory agencies conclude that the risk of an unintended introducton of diploids (Section 4.1.6) is acceptable. Due to the restricted nature of the VSC trials, no data are available to support an analysis of production costs for extensive, unconfined cultivation of Suminoe oysters in Chesapeake Bay.

The issue of biosecurity of the Suminoe oyster brood stock to minimize the risk of introducing a reproducing population into the Bay may also have an impact on seed costs. Hatchery production costs of seed will be higher with required hatchery biosecurity than without. However, in the absence of an extensive analysis of hatchery production operations and costs, it is not possible to quantify what these additional costs would be. Clearly, scale of operation will be an important factor in whether the additional costs add significantly to the price per seed charged to aquaculturists. To demonstrate the sensitivity of aquaculture production of Suminoe oysters to higher seed costs, Monte Carlo simulations were run for Suminoe oyster aquaculture operations at output prices of $0.18 and $0.17 an oyster while varying the expected hatchery cost from the $1.50 per thousand used in previous calculations to $3.00 per thousand. The results of the probability of financial survival of the modeled aquaculture firm are shown in Figure 4-20.

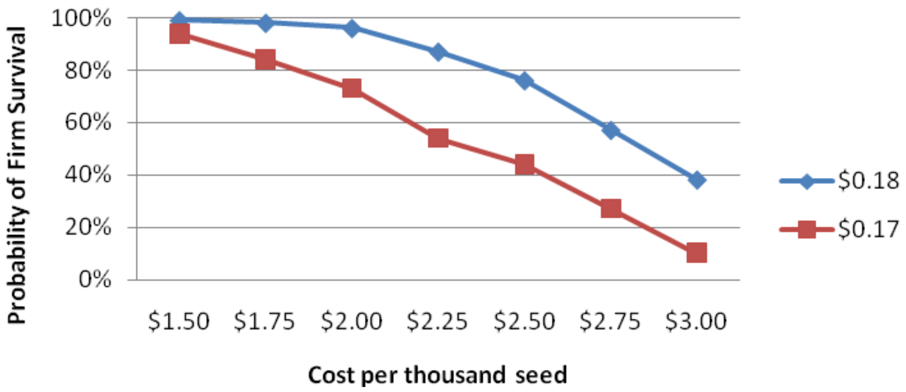

Figure 4-20. Firm survival for Suminoe oyster aquaculture production when expected seed costs vary from $1.50-$3.00 per thousand.

Increases in seed costs would lower the probability of survival of firms and, thus, would result in the need for a higher output price to ensure the firms' success. From the oyster demand model, this would lead to a prediction of less production and fewer firms than predicted at the $1.50 per thousand price for seed.

Indirect Benefits – Although achievement of a slightly larger aquaculture industry in Chesapeake Bay is projected for Alternative 5 than for Alternative 4, the kinds of indirect benefits expected would be similar. One difference, however, is that cultivated Suminoe oysters might filter more water than cultivated Eastern oysters over the same amount of time in order to support their faster growth. This increased filtration rate might enhance ecological benefits on a local scale. Suminoe oysters probably would be cultivated using only confined methods, such as floats, bags or off-bottom cages; therefore, the potential benefit to hard-bottom habitat from on-bottom aquaculture of Eastern oysters would not be realized, and this alternative definitely would adversely affect boating and fishing (Section 4.7) and result in negative indirect effects. The magnitude of those effects cannot be estimated.

4.6.2.7 Alternative 8: Combination of Alternatives

The combinations of alternatives were established by the lead agencies after most of the analyses for the PEIS were completed. As a result, no specific economic assessment of the combinations is available, and conclusions regarding economics are severely constrained by a lack of data. Some conclusions can be drawn based on the individual economic analyses of the proposed action and alternatives.

Implementation Costs – Average annual implementation costs were estimated for the proposed action ($25.8 million), Alternative 2 ($40.4 million), and Alternative 3 ($1.05) but not for Alternatives 4 and 5. Assuming no cost savings associated with implementing combinations of alternatives, the minimum annual average implementation cost for Combinations 8a and 8b would exceed $41 million, and the minimum annual implementation cost for Combination 8c would exceed $67 million.

Fishery and Processor Benefits **–** The fishery and processor benefits of the combinations cannot be estimated for several reasons. First, no quantitative projections were possible for some of the actions included in the combinations (e.g., proposed action and harvest moratorium). Perhaps more importantly, the demand model used in most of the analyses in this section suggests that as the supply of oysters on the market increases, the price would decrease. If the combinations of alternatives resulted in significant increases in oyster production, the economics of both culture and harvest could change in unpredictable ways. Although the total increase in oysters in the Bay may result in substantial ecological benefits, a great increase in the number of oysters that reach the market may not have a commensurate economic benefit.

Indirect Benefits – Significant increases in oyster abundance could improve water quality and habitat in ways that could contribute economic benefits associated with larger populations of other important commercial and recreational species in Chesapeake Bay and improve water clarity, which could lead to higher values for other forms of recreation (e.g., swimming and boating) and higher values for waterfront property. Given the results of the ERA, enhancements in ecological services are potentially greatest under Combination 8c and least under Combination 8a. Estimating the economic benefits related to the ecological services provided by oyster populations would require quantifying ecological changes related to increasing oyster populations. These changes could not be quantified; therefore, the indirect economic benefits of these combinations of alternatives cannot be estimated.

4.7 VISUAL, AESTHETIC, AND RECREATIONAL RESOURCES

Chesapeake Bay's diverse visual, aesthetic, and recreational resources were described in detail in Section 3.7. In addition to the Bay's natural beauty, many consider traditional water-front communities to be of particular aesthetic value. The historic watermen's communities along the Chesapeake's western and eastern shores offer an aesthetic charm and have contributed greatly to tourism in these areas. The Bay supports a very significant recreational fishery. There is no recreational oystering in the Bay, although many owners of shoreline property participate in oyster rearing programs coordinated by the Chesapeake Bay Foundation. Boating on Chesapeake Bay is a popular recreational activity and an important component of the economies of Maryland and Virginia. Waterfowl hunting is a popular sporting tradition in near-shore areas throughout the region. Recreational swimming is a popular summertime activity in the Chesapeake Bay region, where not impaired by stinging sea nettles. Wildlife viewing is a popular activity in the forests, marshes, and waterways of the area. The eastern shore of the Bay is an important stopover for migratory shorebirds and has many nationally recognized areas for wildlife viewing.

The consequences of the proposed action and the alternatives for visual, aesthetic, and recreational resources were addressed primarily by evaluating how the oyster and ecosystem outcomes described in Sections 4.1 and 4.2 might influence human perception and use of Chesapeake Bay. Descriptions of the consequences are all qualitative, primarily reflecting the likelihood that a particular resource would be positively or negatively affected; the potential magnitude of the effect is discussed when possible.

4.7.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

This alternative calls for continuing current efforts to restore the Eastern oyster and undertaking an intensive program to introduce the Suminoe oyster. If new hatcheries are required to implement this alternative, they would most likely be located near the shoreline. Constructing hatcheries in natural, undeveloped shoreline locations could adversely affect visual aesthetics, but only to a small degree. Based on characteristics of the University of Maryland's hatchery at Horn Point, a large-scale hatchery might occupy about five acres of land.

Implementing this alternative would cause minor, temporary negative effects on visual and aesthetic resources during the brief periods when oyster spat are planted and shell or other substrate is replenished. Spat are generally planted during the spring and takes four to six weeks. Shell planting or work on substrate generally occurs during the summer and may take six to eight weeks. Effects would be the result of movements and activity of relatively large boats and barges involved in those operations. Such operations could interfere with recreational boating and fishing, but only briefly at individual locations designated for restoration and introduction.

A successful introduction of the Suminoe oyster that results in significant increases in oyster abundance could provide a visual benefit if it is accompanied by an increase in the activity of skipjacks and watermen. Increases in harvest could help to support shucking houses, where oysters are removed from their shells for market, and other shoreline facilities, thus preserving scenic, fisheries-related shoreline facilities. An increase in oysters and hard-bottom habitat would benefit not only oystering, but also recreational fishing for reef-oriented fish, as discussed in Section 4.1.1. There would be little to no effect on recreational swimming because Suminoe oysters are not expected to become established in intertidal areas (Section 4.2.2.1 of Appendix B). Waterfowl hunting might benefit from any increases in bottom-feeding diving ducks resulting from an increased oyster stock. There might be a minor disruption of wildlife viewing during the brief periods when spat and shell planting activities are taking place. An unsuccessful Suminoe oyster introduction program would not result in any of these potential benefits occurring.

4.7.2 Alternative 1: No Action

Alternative 1 would be expected to result in an increase in oyster abundance in low-salinity areas in Maryland, decreases in higher salinity areas, and an overall Bay-wide decrease (Section 4.1.2). Implementing this alternative would cause minor, temporary negative effects on visual and aesthetic resources during the brief periods when oyster spat are planted and shell or other substrate is replenished. The effects would be less than those expected for the proposed action. Spat are generally planted during the spring and takes four to six weeks. Shell planting or work on substrate generally occurs during the summer and may take six to eight weeks. Effects would be the result of movements and activity of relatively large boats and barges involved in those operations. Such operations could interfere with recreational boating and fishing, but only briefly at individual locations designated for restoration. Changes of this magnitude would be expected to have little effect on visual and aesthetic resources. There would be no effect on recreational boating, swimming, or wildlife viewing. Predicted declines in the oyster population under current programs could reduce the opportunities for fishing and waterfowl hunting associated with oyster reefs. A continued decline in the number of watermen, as suggested in Section 4.6.1, would result in a loss of visual resources, such as working oystermen and skipjacks on the Bay.

4.7.3 Alternative 2: Enhance Restoration

The Bay-wide oyster population under this alternative is anticipated to experience greater increases than under Alternative 1, with the largest increases occurring in low-salinity zones but some increase in mesohaline zones. Implementing this alternative would cause minor, temporary negative effects on visual and aesthetic resources during the brief periods when oyster spat are planted and shell or other substrate is replenished. The effects would be greater than expected for Alternative 1. Spat are generally planted during the spring over a period of four to six weeks. Shell planting or work on substrate generally occurs during the summer and may take six to eight weeks. Effects would be the result of movements and activity of relatively large boats and barges involved in those operations. Such operations could interfere with recreational boating and fishing, but only briefly at individual locations designated for restoration.

Increases in oysters and hard-bottom habitat would provide little enhancement of visual resources such as working watermen and skipjacks because most of the increased oyster stock would be on sanctuaries and reserves. Increases in those locations could result in local enhancement of recreational fishing for reef-oriented fish. Waterfowl hunting might benefit from any increase in numbers of bottom-feeding diving ducks. There may be minor disruption of wildlife viewing during the brief periods when restoration activities are taking place.

4.7.4 Alternative 3: Harvest Moratorium

A harvest moratorium would result in the elimination of working watermen and skipjacks as elements of oystering activity and, therefore, would decrease visual and aesthetic resources. Elimination of harvest might indirectly adversely affect scenic shoreline support facilities (e.g., shucking houses), although most of those operations currently import most of their oysters (Section 4.6.2.2). The limited increases in oysters and hard-bottom habitat expected to result from imposing a moratorium could provide limited local enhancement of recreational fishing for reef-oriented fish. Elimination of working watermen might reduce conflicts with recreational boaters and fishermen. Waterfowl hunting might be enhanced as a result of any increases in the numbers of bottom-feeding diving ducks in response to an increased oyster stock. Implementing this alternative would cause minor, temporary negative effects on visual and aesthetic resources associated with restoration activities, which would continue during the moratorium. Spat are generally planted during the spring, which takes four to six weeks. Shell planting or work on substrate generally occurs during the summer and may take six to eight weeks. Effects would be the result of movements and activity of relatively large boats and barges involved in those operations. Such operations could interfere with recreational boating and fishing, but only briefly at individual locations designated for restoration.

4.7.5 Alternative 4: Cultivate Eastern Oysters

Implementing Alternative 4 could adversely affect visual and aesthetic resources, depending on the manner in which oysters are cultivated. On-bottom culture of the Eastern oyster would have no direct effect on visual and aesthetic resources; however, if additional hatcheries and shoreline support facilities are needed (e.g., new docks), constructing those facilities could adversely affect scenic shorelines. Off-bottom cultivation techniques would cause the greatest aesthetic and visual effects. The locations of off-bottom cages must be marked with buoys. Floats used for culturing oysters in near-surface waters would occupy considerable areas. Both buoys and floats could have significant adverse visual effects (Section 4.1.5) and could interfere with recreational boating and fishing, depending on their location and concentration. Oysters produced under this alternative would produce little if any aesthetic benefits through associated ecological services, except through potential effects on local water quality. A concentration of cultured oysters would offer increased filtration capacity and potential for indirect effects associated with water quality improvements. The magnitude of this effect would depend on the concentration of cultured oysters and the hydrodynamics of the culture site.

This alternative could benefit recreational fishing if on-bottom culture is employed because it would enhance hard-bottom habitat for fish. Oysters in off-bottom cages may provide some temporary habitat, food, or both for species such as reef-oriented fish; however, such benefits would be temporary because the cages or cultured habitat would be disturbed periodically for harvest. The buoys and floats in off-bottom culture probably would be located in near-shore environments; consequently, opportunities for swimming might decrease. These facilities and floats might also adversely affect wildlife viewing and waterfowl hunting (e.g., by disrupting existing blinds and the placement of decoys). Regular boating activity required to maintain aquaculture operations could increase noise and decrease visual aesthetics of waterways and also interfere with waterfowl hunting.

4.7.6 Alternative 5: Cultivate a Nonnative Oyster

Operations to cultivate a nonnative species of oyster would have to be confined, requiring the use of off-bottom cages, on-bottom bags, suspended bags, or floats. Off-bottom cages and bags would all be marked with buoys. Oysters in off-bottom cages may provide some temporary habitat, food or both for species such as reef-oriented fish, and thus enhance recreational fishing. Such benefits would be temporary because the cages would be disturbed periodically for harvest. Oysters produced under this alternative would produce little if any aesthetic benefits through associated ecological services, except through potential effects on local water quality. A concentration of cultured oysters would offer increased filtration capacity and potential for indirect effects associated with water quality improvements, such as increases in SAV. The magnitude of these effects would depend on the concentration of cultured oysters and the hydrodynamics of the culture site.

Alternative 5 would have potential adverse effects on visual and aesthetic resources related to the construction of shoreline hatcheries, docks and other associated shoreline facilities. The greatest potential impact on visual and aesthetic resources would be from the presence of buoys or floats. Access to fishing areas probably would be constrained where floats or buoys are deployed, and those also could interfere with recreational boating. Opportunities for swimming might decrease because floats and other aquaculture facilities would be located in near-shore environments. These facilities and floats might also adversely affect wildlife viewing and waterfowl hunting (e.g., by disrupting existing blinds and the placement of decoys). Regular boating activity required for maintenance of aquaculture operations could increase noise and decrease visual aesthetics of waterways and also interfere with waterfowl hunting.

4.7.7 Alternative 8: Combination of Alternatives

Full implementation of any of the three combinations would require significant increases in spat production (for both seed planting and aquaculture activities), seed planting, and oyster bar rehabilitation. If new hatcheries were required to produce the additional spat, they probably would be located near the shoreline. Constructing hatcheries in natural, undeveloped shoreline areas could adversely affect visual aesthetics, but only to a small degree. Any of the three combinations probably would cause minor, temporary negative effects on visual and aesthetic resources during periods when oyster spat are planted, and shell or other substrate is replenished. Effects of planting shell and seed include movements of relatively large boats and barges involved in those operations. This could interfere with recreational boating and fishing, but only briefly at individual locations designated for restoration and introduction.

Expanded cultivation of oysters could adversely affect visual and aesthetic resources, depending on the mode of cultivation. On-bottom cultivation of Eastern oysters under Combination 8a would have no direct effect on visual or aesthetic resources. Operations to cultivate the Eastern oyster as well as triploid Suminoe oysters under Combinations 8b and 8c would require the use of off-bottom cages, on-bottom bags, suspended bags, or floats. Using off -bottom techniques for cultivation oysters (Eastern or Suminoe) would require marking the locations of cages or floats. Off-bottom aquaculture could have significant adverse visual effects and could interfere with recreational boating and fishing; diminish opportunities for swimming; adversely affect wildlife viewing and waterfowl hunting; increase noise; and decrease the visual aesthetics of waterways. It would produce little if any aesthetic benefits through associated ecological services, except through potential positive effects on local water quality.

The benefits of increases in oyster abundance as a result of implementing any of the combinations would include visual benefits related to increases in the activity of skipjacks and watermen. If fisheries resumed when the moratorium was lifted, resumption would help to support shucking houses and other shoreline facilities, provide potential benefits to recreational anglers and waterfowl hunters as a result of increased abundance of some species of fish and ducks, and create aesthetic benefits associated with local or tributary level improvements in water quality.

4.8 HISTORIC AND ARCHEOLOGICAL RESOURCES

The NEPA requirement to consider effects on historic and archeological resources is explained in Section 3.8, and the kinds of resources that might be affected are described in Section 3.8.3. The historical context of the Chesapeake Bay is summarized in Appendix F. The proposed action and alternatives could affect these recourses throughout the entire historical range of the Eastern oyster in the Chesapeake Bay as well as in the Bay's tributaries and along its shorelines. To date, no comprehensive survey of historic and archaeological resources of the Bay's shoreline or floor has been attempted. Sites are most commonly recorded as the result of small, isolated surveys and reports by local informants. Information about the distribution of known sites, therefore, is biased and is not necessarily useful for predicting the location of other potential resources. Consequently, predicting the effects of the proposed action and alternatives is challenging.

While developing the Draft Chesapeake Bay Special Resource Study, the National Park Service (NPS) identified six kinds of historic and archaeological resources associated with the Bay that are believed to contribute to the national significance of the region: (1) water-oriented settlement sites, (2) Chesapeake Bay vessels, (3) water-based transportation routes, (4) waterman fishing areas, (5) Bay-oriented agricultural landscapes, and (6) water-connected military sites. Examples of all six kinds have been identified and documented as archaeological sites in Maryland and Virginia.

Currently, 806 submerged sites are recorded in Chesapeake Bay and its tidal regions, although as many as 5,000 are thought to exist (S. Langley, pers. comm., May 9, 2007). Site data available for this PEIS did not include information about setting, distribution, or frequency of sites, which are details that would be required for any site-specific NEPA assessment.

Surveys probably will be required if implementing an alternative would involve disturbing previously undisturbed areas that could harbor submerged and partially submerged prehistoric and historic resources spanning thousands of years of Chesapeake culture and history. Investigations to be carried out prior to disturbing the shoreline or bottom should include site searches at MHT and VDHR to determine if previously recorded resources lie within the targeted areas; terrestrial and underwater archaeological surveys to discover if unrecorded sites exist in the targeted areas; and potentially, NRHP evaluation and data recovery at any sites that might be adversely affected by the action.

Although several of the assessments of the proposed action and alternatives presented in this PEIS are based on assessment scenarios that define specific locations and activities, those assessment scenarios were developed only for the purpose of framing assessments; they do not represent recommendations or actual plans for implementing any of the alternatives. Assessments of potential effects on historic and archaeological resources are inherently site specific and cannot be performed comprehensively for an area as expansive as the whole of Chesapeake Bay; therefore, this description focuses on the potential modes of effect that might occur under each alternative and how they might differ among the alternatives. The potential effects of rehabilitating existing oyster bars, constructing on-shore support facilities (e.g., hatcheries), harvesting, and increasing Bay traffic are considered specifically. As noted in Section 3.8, dredging for shell to replenish existing oyster bars, an activity that has significant potential to adversely affect underwater cultural resources, has ceased in Maryland and was not considered in this evaluation of the potential effects of the proposed action or alternatives on historic and archaeological resources there. Some dredging of buried shell does occur in Virginia, but on a limited scale.

4.8.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

According to the proposed action, Suminoe oyster spat would be planted on existing bars, and limited shell replenishment programs would continue at existing oyster bars (Section 4.1.2 and Attachment 5 of Appendix A). Some additional on-shore support facilities (e.g., a new hatchery) might be required, harvest would continue, and there might be some increase in boat traffic, both by oystermen as and by agencies conducting the introduction and restoration programs.

Oyster bar rehabilitation according to the current level of effort to restore the Eastern oyster has minimal potential to affect historic and archaeological resources. Existing oyster reefs can be considered part of a traditional cultural landscape associated with resources in the region. Under the proposed action, the only program that would alter or affect non-oyster bottom in the Bay would be the limited shell-dredging done by the State of Virginia, which because of its small scale, would have little potential to adverse affect historical resources. All other activities expected under the proposed action would involve areas that have been harvested previously, they present little potential to affect historic and archaeological resources. Placing non-shell substrates on existing oyster bars would have no effect, and collecting such substrates from outside the Bay proper would not be likely affect historic or archaeological resources. A natural oyster reef may cover and essentially cap underlying resources. Enhancing such cover through replenishment might actually offer some level of protection from disturbance for underlying historic and archaeological resources.

Any new shoreline facilities required under the proposed action (e.g., a new hatchery) would have the potential, albeit small, to affect historic and archaeological resources. A hatchery might occupy approximately five acres of shoreline, and any other support facilities (e.g., docks, ramps, outbuildings) would have moderate potential to affect terrestrial and intertidal resources. A variety of resources have been documented along virtually the entire shoreline of the Bay. Four of the six kinds of resources identified by the NPS (2003) are well represented among shoreline resources. Recorded water-oriented settlement sites include prehistoric shell middens, lithic scatters, temporary camps, and permanent villages as well as historical artifact scatters/middens, dwellings and industrial sites typical of maritime communities. Bay-oriented agricultural landscapes are recognized on the shoreline primarily as historic farmsteads and middens. Archaeological sites associated with water-based transportation have also been recorded along the Bay shoreline. This class of resources encompasses dams, canals, fords, and wharfs. Water-connected military sites on the shoreline include earthworks and forts primarily associated with the War of 1812 and the Civil War. Although some sites have been identified as specifically associated with waterman fishing areas (e.g., fish weirs on streams), resources of this kind are likely to be encompassed within other, more general categories. Chesapeake Bay vessels are not found commonly along the shoreline. An archaeological survey of all shoreline areas that would be altered as a result of constructing any shoreline facilities would be required to avoid or define a plan to mitigate potential effects.

Because all areas in which oyster harvesting might occur under the proposed action are existing oyster bars where harvesting has occurred traditionally, the potential to affect underwater archeological resources is minimal. Dredging for oysters would have the greatest potential effect because it could disturb any underlying and adjacent archaeological resources; however, oyster dredging practices disturb only the top two to three inches of shell. Diver harvesting would have the least potential effect. Although boat traffic on and around the Bay might increase (Section 4.7.1), increased traffic by itself is not likely to affect archaeological sites directly. Increasing traffic, however, increases the chance that previously unknown archaeological sites will be encountered. Greatly increased boat traffic could increase wave action, which might contribute to cumulative disturbance of submerged and shoreline resources; however, the level of increase expected to result from implementing the proposed action probably would be insufficient to produce this effect.

4.8.2 Alternative 1: No Action

The modes of potential effect associated with Alternative 1 would be the same as described for the proposed action. The potential magnitude of effect, however, would be much less because the scale of spat planting and shell replenishment would be substantially less, and no new shoreline facilities would be needed. Historic and archaeological resources might be affected indirectly as a result of a decline in oystering under Alternative 1 (Section 4.6.1). Oyster-related shoreline facilities that may be historically significant (e.g., docks or buildings) could be subject to the threat of demolition and replacement with structures perceived to be of higher value. Overall, negligible effects on historic and archaeological resources would be expected.

4.8.3 Alternative 2: Enhance Restoration

The modes of potential effect associated with Alternative 2 would be the same as under the proposed action and Alternative 1. The magnitude of effect would be somewhat greater than for Alternative 1. If managers assumptions regarding sufficient current hatchery capacity are correct, no new shoreline facilities would be required (Section 4.1.3). Although spat planting and shell replenishment actions would be greater than under Alternative 1, they would occur only on existing oyster bars. Overall, negligible effects on historic and archaeological resources would be expected.

4.8.4 Alternative 3: Harvest Moratorium

If a harvest moratorium is imposed, the degree of disturbance of the bottom due to harvest activities would be reduced significantly compared to levels expected for the proposed action and all other alternatives. Similarly, boating activity by watermen would decrease. Eliminating the oyster industry, however, could contribute to exposing shoreline structures of historical significance to the threat of demolition, depending on the extent to which they rely on Chesapeake Bay oysters, as discussed for Alternative 1. With that exception, the overall effects on historic and archaeological resources would be the least under this alternative.

4.8.5 Alternative 4: Cultivate Eastern Oysters

Aquaculture alternatives have the greatest potential to adversely affect historic and archaeological resources. Although the modes of affect would the same as for the proposed action and all the other alternatives, the potential magnitude of effects would be greater, depending on the ultimate size of the aquaculture industry, the method of aquaculture employed, its location, and the density of culture activities.

A significant proportion of on-bottom cultivation of Eastern oysters probably would occur on existing oyster bars because regulatory constraints and costs would be less than for creating new hard bottom. Using existing oyster bars would pose no greater threat to historic and archaeological resources than implementing Alternative 1 (i.e., No Action). The assessment scenario for the aquaculture alternatives (Section 3.0 of Appendix C) identifies nine locations, six in Virginia and three in Maryland, as candidates for large-scale aquaculture operations. If those areas are typical of locations where aquaculture might be expanded (i.e., tributaries rich in natural resources), they are also examples of ideal locations for sites of prehistoric resource extraction and later, permanent settlements. Prehistoric sites representing a range of time periods have been recorded along these river corridors and the Bay. Europeans settled in similar areas early on to take advantage of fertile land and access to water. Historically, these river corridors all were navigable to the fall line, so the potential for finding shipwrecks exists not only in the deep waters of the Chesapeake, but also within the river corridors. The potential is great for a wide range of resources representing all six of the kinds identified by the NPS to exist in many possible aquaculture locations. Submerged resources would be affected only if off-bottom aquaculture methods (e.g., floats, off-bottom cages) were employed or if shell or other hard materials were deposited to support on-bottom operations. In such cases, anchors or other mooring structures, disturbances of the bottom when equipment is deployed or retrieved, or placement of new hard substrate could affect submerged resources. Expanding the aquaculture industry might require constructing more extensive shoreline facilities (e.g., hatcheries, docks) than would be needed to implement the other alternatives. Expanding aquaculture would entail more extensive boat traffic, creating the potential for greater wave action and cumulative disturbance of submerged or shoreline resources. Overall, potential effects on historic and archaeological resources expected under Alternative 4 would be greater than under the proposed action or the other non-aquaculture alternatives.

4.8.6 Alternative 5: Cultivate a Nonnative Oyster

Although the magnitude of effects due to implementing Alternative 4 may be greater than under the effects of implementing Alternative 5, the potential modes of effect associated with cultivating triploid Suminoe oysters would be the same as for Alternative 4, except that no on-bottom culture would be permitted. Although off-bottom cages must be deployed over hard bottom, they can be deployed over any hard substrate, not just beds of oyster shell. Similarly, floats or suspended bags could be anchored in areas other than existing oyster beds. This alternative, therefore, has greater potential to disturb previously undisturbed Bay bottom and greater potential to affect submerged resources than Alternative 4. The potential to affect shoreline and terrestrial resources may be greater than for Alternative 4 if new hatcheries are required to produce triploid Suminoe oysters. This alternative probably has the greatest potential of all the actions considered to adversely affect historic and archaeological resources; nevertheless, potential effects could be mitigated readily by evaluating candidate sites thoroughly and selecting those that avoid effects.

4.8.7 Alternative 8: Combination of Alternatives

All three combinations include expanded cultivation of the Eastern oyster, which is the action with the greatest potential to adversely affect historic and archeological resources in the Bay. The assessment scenario for the aquaculture alternatives identified nine locations as candidates for large-scale aquaculture operations. These areas were ideal locations for sites of prehistoric resource extraction and later, permanent settlements.

Including cultivation of triploid Suminoe oysters in Combinations 8b and 8c may reduce the spatial extent of aquaculture areas to less than the area required for Combination 8a but could require constructing new shoreline hatcheries, which would increase the potential for adverse effects. An archaeological survey of all shoreline areas that would be altered as a result of constructing any shoreline facilities would be required. Given that all planting and restoration activities involve areas that have been harvested previously, these activities would present little potential to affect historic and archaeological resources.

Oyster harvesting under the combinations of alternatives would resume only after the temporary moratorium was lifted. Fisheries probably would resume in traditional harvest areas and, therefore, would have minimal potential to affecting underwater archeological resources. Dredging for oysters would have the greatest potential effect; however, it would disturb only the top two to three inches of shell. Implementing any of the combinations might result in increased boat traffic from restoration activities as well as aquaculture maintenance, which could increase wave action. Increased wave action might contribute to cumulative disturbance of submerged and shoreline resources; however, the level of increase expected to result from the combinations probably would be insignificant.

4.9 WETLANDS

Wetlands are important ecological resources that improve and maintain water quality, reduce flood damage, and provide habitat for a wide variety of plants and animals, including many threatened and endangered species. Section 3.9 presents a summary characterization of Chesapeake Bay's wetlands. The potentially affected ecosystem components and mechanisms of effect of the proposed action and alternatives within estuarine wetlands in the Bay region are as described in Sections 4.1, 4.2, and 4.3 of this PEIS. In nearly all cases, effects would be indirect because oysters are not common members of wetlands biological communities in Chesapeake Bay; therefore, the magnitude of effects would be minimal in all cases.

4.9.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

The increase in oyster reef that might result if the proposed action were successful could have some beneficial effect on wetlands by reducing the erosive force of wave action at the margins of wetlands. Local improvements in water clarity due to increased filtering by an abundant local oyster population could enhance the establishment and survival of SAV beds and provide ancillary benefits for wetlands plants (e.g., decreased shoreline erosion). An unsuccessful introduction would not result in any such benefits.

4.9.2 Alternative 1: No Action

Changes in Bay-wide oyster abundance projected for this alternative would be too limited to have any effect on wetlands.

4.9.3 Alternative 2: Enhance Restoration

Changes in Bay-wide oyster abundance projected for this alternative would likely be too limited to have any effect on wetlands. The larger increase in oyster abundance expected in low-salinity areas could have some local beneficial effect by reducing the erosive force of wave action at the margins of wetlands, if three-dimensional oyster reefs were to become established. Water clarity could improve in local areas of high oyster abundance due to increased oyster filtering, which could enhance the establishment and survival of SAV beds and provide ancillary benefits for wetlands plants.

4.9.4 Alternative 3: Harvest Moratorium

Changes in Bay-wide oyster abundance projected for this alternative would likely be too limited to have any effect on wetlands. The larger increase in oyster abundance expected in low-salinity areas could have some local beneficial effect by reducing the erosive force of wave action at the margins of wetlands, if three-dimensional oyster reefs were to become established. Water clarity could improve in local areas of high oyster abundance due to increased oyster filtering, which could enhance the establishment and survival of SAV beds and provide ancillary benefits for wetlands plants.

4.9.5 Alternative 4: Cultivate Eastern Oysters

Implementing Alternative 4 could affect wetlands adversely, if it requires construction of any shoreline facilities (e.g., hatcheries, boat docks). If on-bottom culture is pursued, no significant indirect effects on wetlands would be likely. Deployment of floats for culturing oysters near the surface could contribute to dampening wave action in restricted water bodies, which could reduce shoreline erosion of wetlands. Oysters produced in aquaculture operations would contribute little if any wetlands benefits through associated ecological services, except for potential local improvements in water clarity due to enhanced water filtration in the vicinity of an operation.

4.9.6 Alternative 5: Cultivate a Nonnative Oyster

Effects of this alternative would be the same as for Alternative 4, except that confined culture would be required. The use of off-bottom cages would be unlikely to result in any indirect effects on wetlands. If floats are used, they could contribute to dampening wave action in restricted water bodies, which could reduce shoreline erosion of wetlands. Oysters produced in aquaculture operations would contribute little if any wetlands benefits through associated ecological services, except for potential local improvements in water clarity due to enhanced water filtration in the vicinity of an operation. Given the faster growth rates of the Suminoe oyster, the local improvement in water clarity might be greater under this alternative than under Alternative 4, given the same concentration of oysters.

4.9.7 Alternative 8: Combination of Alternatives

Increases in oyster reefs resulting from implementing an of the three combinations of alternatives could have beneficial effects on wetlands by reducing the erosive force of wave action. Ancillary benefits for wetlands due to the establishment and survival of SAV beds could also accrue as a result of local improvements in water clarity resulting from increased oyster abundance. Although on-bottom aquaculture probably would not result in significant indirect effects on wetlands, deployment of floats for culturing oysters near the surface could contribute to dampening wave action in restricted water bodies, which would reduce shoreline erosion. Given that the potential for positively affecting wetlands is related to increased oyster abundance, either directly through dampening of wave action or indirectly through improvements in water clarity, potential beneficial effects would be least significant under Combination 8a and most significant under Combination 8c.

4.10 SANCTUARIES AND REFUGES

Section 3.10 describes sanctuaries and refuges in Chesapeake Bay. These preserved natural areas are diverse and encompass a wide variety of kinds of terrestrial and wetlands habitat. Table 3-7 lists the components of the National Estuarine Research Reserve System

(NERRS) located in Maryland and Virginia, and Figure 3-5 shows the locations of the components. Table 3-8 lists the National Wildlife Refuges (NWR) in Maryland and Virginia that encompass estuarine habitat suitable for oysters, and Figure 3-6 shows the locations of those refuges. The mechanisms of effect and potentially affected ecosystem components within the refuges are as described in Sections 4.1, 4.2, and 4.3 of this PEIS. The distribution of existing oyster habitat throughout the Bay is not particularly concentrated in the vicinity of any sanctuary or refuge; therefore, the indirect effects of a change in the Bay-wide population of oysters would be dispersed and probably would be minimal at any single location.

4.10.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

The proposed action would have no effect on NERRS sites at Otter Point, Jug Bay, Sweet Hall Marsh, and Taskinas Creek because oysters would not become established in those freshwater habitats. The proposed action could benefit the NERRS sites at Monie Bay, the Catlett Islands, and the Goodwin Islands by enhancing ecological services associated with oysters. Increases in oyster abundance in all salinity zones probably would provide some minimal local improvements in water quality and clarity, as well as increased food and habitat that could benefit other species at these sites. Refuges in higher salinity areas, such as Blackwater, Martin, and Plum Tree Island, could experience some positive effects due to the projected increase in oysters in those high-salinity zones. An unsuccessful introduction would not result in any of these potential beneficial effects.

4.10.2 Alternative 1: No Action

Changes in Bay-wide oyster abundance projected for this alternative would be too limited to have any effect on sanctuaries and refuges.

4.10.3 Alternative 2: Enhance Restoration

The increase in oyster abundance projected for this alternative would be greatest in low-salinity zones in Maryland. Eastern Neck NWR, therefore, might experience positive indirect effects related a reduction in the erosive force of wave action associated with the presence of oyster reef and small local improvements in water clarity due to increased filtering by oysters. Such effects are likely to be dispersed and, therefore, to be minimal at any single location.

4.10.4 Alternative 3: Harvest Moratorium

The increase in oyster abundance projected for this alternative would be greatest in low-salinity zones in Maryland. Eastern Neck NWR, therefore, might experience positive indirect effects related to a reduction in the erosive force of wave action associated with the presence of oyster reef and small local improvements in water clarity due to increased filtering by oysters. Such effects are likely to be dispersed and, therefore, to be minimal at any single location.

4.10.5 Alternative 4: Cultivate Eastern Oysters

An assessment scenario for distribution for a large-scale aquaculture industry for oysters in Chesapeake Bay was developed to facilitate the assessment of the effects of this alternative (Appendix C). This assessment scenario assumes that most production would occur in Virginia waters. Activities associated with implementing this alternative that might influence sanctuaries and refuges (e.g., regular boat traffic for maintaining aquaculture equipment, which could disturb wildlife) would have to occur in close proximity to a refuge or sanctuary to exert any influence. It seems unlikely that either Maryland or Virginia would permit concentrated aquaculture operations to be established in the vicinity of sanctuaries and refuges; consequently, this alternative would be unlikely to affect sanctuaries and refuges.

4.10.6 Alternative 5: Cultivate a Nonnative Oyster

The same assessment scenario used for Alternative 4 was assumed for this alternative. Activities associated with implementing Alternative 5 that might influence sanctuaries and refuges would have to occur in close proximity to a refuge or sanctuary to exert influence. It seems unlikely that either Maryland or Virginia would permit concentrated aquaculture operations to be established in the vicinity of sanctuaries and refuges; consequently, this alternative would be unlikely to affect sanctuaries and refuges.

4.10.7 Alternative 8: Combination of Alternatives

If the proposed introduction of the Suminoe oyster were successful, Combination 8c could offer the greatest benefit to several NERRS sites by enhancing ecological services associated with oysters. Implementing Combination 8a or 8b is expected to result in increasing oyster abundance in low-salinity waters; consequently, NERRS sites in those regions might experience positive indirect effects related to a reduction in wave action associated with the presence of oyster reefs and small local improvements in water clarity due to increased filtering by oysters. Aquaculture included in any of the combinations would not be likely to have an effect because it probably would not be permitted in the vicinity of sanctuaries and refuges.

4.11 ENVIRONMENTAL JUSTICE

NEPA requires Federal agencies to include an assessment of potential effects on minority and low-income communities among their analyses of proposed Federal actions. Agencies are responsible for identifying and addressing, as appropriate, any disproportionately great and adverse effects of such proposed actions on the health of minority and low-income populations and their environments. Results from recent anthropological fieldwork, which included participant observation and informal and formal interviews, suggest that no low-income or minority populations currently are significantly involved in harvesting oysters from the Bay. Processing operations employ immigrant Hispanic workers to shuck oysters, but shucking houses in the Bay region depend heavily on imported oysters. Although significant numbers of African-Americans historically were employed as commercial watermen and in shucking houses, today the few African-American watermen employed in the oyster industry are socially and economically similar to other watermen. Based on a review of written sources and Web sites and informal discussions at a Native American Festival on the Eastern Shore, Native Americans do not appear to be significantly involved in oystering or the oyster industry in the Bay region (Section 3.11). The effect of changes in Chesapeake Bay oyster harvests under any alternative, therefore, would be either minimal or beneficial.

4.11.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

The oyster population and harvest in the Bay could increase substantially under the proposed action if the proposed introduction of the Suminoe oyster were successful. To the extent that minorities or low-income individuals are involved in oystering or in other components of the oyster industry, they would be positively affected by such an increase. An expansion of oystering and ancillary business could provide additional employment opportunities for low-income and minority populations in areas of Maryland and Virginia where such activities are concentrated. Improvements in water quality and habitat under this alternative would benefit all residents of the Bay area, regardless of minority or economic status. Such potential benefits would not be realized if an introduction were unsuccessful, and consequences would then be similar to those under Alternative 1.

4.11.2 Alternative 1: No Action

Although the oyster population could increase modestly under this alternative, a decline in oystering would be likely(Section 4.6.1). Such a decline could adversely affect any low-income and minority individuals presently involved in the industry; however, those demographic groups are not currently involved to a significant level, and they would not be disproportionately affected.

4.11.3 Alternative 2: Enhance Restoration

The regional increase in oyster populations that may occur under this alternative would not minimize the decline in oystering anticipated under Alternative 1 because most of the increase would occur on bars that are protected from harvesting. Any positive effect on low-income and minority individuals presently involved in the industry would be limited. Improvements in water quality and habitat under this alternative would benefit all residents of the Bay area, regardless of minority or economic status.

4.11.4 Alternative 3: Harvest Moratorium

A moratorium would affect watermen who harvest oysters but would not affect Hispanics employed in shucking houses because a significant proportion of the oysters currently being processed are imported from outside Chesapeake Bay. Recent surveys suggest that no low-income or minority populations are significantly involved in harvesting oysters from the Bay. This alternative, therefore, would not affect low-income or minority populations disproportionately. Improvements in water quality and habitat under this alternative would benefit all residents of the Bay area, regardless of minority or economic status.

4.11.5 Alternative 4: Cultivate Eastern Oysters

Expanding aquaculture in the Bay using to the estimated maximum economically viable size would increase potential employment opportunities for low-income or minority populations in locations in which such an industry develops. If the assessment scenario established for PEIS analyses were to be realized, such opportunities would be greater in Virginia than in Maryland. Although shucking operations currently rely on immigrant Hispanic workers, a large increase in the oyster industry could increase employment opportunities for low-income or minority workers in other demographic groups both in aquaculture operations and in processing operations. Improvements in water quality and habitat under this alternative would be local and limited; to the extent that they occurred they would benefit all demographic groups, regardless of minority or economic status.

4.11.6 Alternative 5: Cultivate a Nonnative Oyster

Expanding aquaculture using the Suminoe oyster to the estimated maximum economically viable level of production (Appendix D) would have the same effect on low-income or minority workers as would expanded aquaculture using the Eastern oyster. Employment opportunities for low-income and minority populations could increase in locations in which such an industry developed. If the assessment scenario established for PEIS analyses were to be realized, such opportunities would be greater in Virginia than in Maryland. Although shucking operations currently rely on immigrant Hispanic workers, a large increase in the oyster industry could increase employment opportunities for low-income or minority workers in other demographic groups both in aquaculture operations and in processing operations. The level of increase in employment opportunities under this alternative might be less than under Alternative 4 because the spatial extent of aquaculture using the Suminoe oyster may be less than for Eastern oysters. Improvements in water quality and habitat under this alternative would be local and limited; to the extent that they occur, they would benefit all demographic groups, regardless of minority or economic status.

4.11.7 Alternative 8: Combination of Alternatives

No low-income or minority populations currently are significantly involved in harvesting oysters in Chesapeake Bay. Migrant Hispanic workers are employed in the oyster processing industry, which depends largely on oysters imported from outside the Bay region. Changes in harvest or processing volumes under any of the combinations would not influence environmental justice. To the extent that a significant expansion of aquaculture, which is included in all three combinations, would result in increases in oyster harvesting or production, that increase could create opportunities for greater participation by low-income or minority populations .

4.12 AIR QUALITY

Pollution in the air can affect the water quality and living resources of Chesapeake Bay, as described in Section 3.12. EPA has rated Washington, D.C., Northern Virginia, and several Maryland counties as severe non-attainment areas for ozone. Maryland, Virginia, and the District are listed as maintenance areas for carbon monoxide. Air quality effects attributable to the proposed action or any of the alternatives would result from the use of trucks, boats and other types of equipment. The proposed action and alternatives may differ in the level of usage of such equipment. The implementation plans developed for analysis of the potential outcomes of the proposed action and alternatives are merely representative and speculative; therefore, the numbers of vehicles and boats and the frequency of usage of those vehicles that might result from implementing any of the alternatives and the emissions that would be attributable to them cannot be estimated. Given the relatively small scale of the oyster industry throughout the Chesapeake Bay region, the emissions attributable specifically to any of the actions would be likely to fall below the threshold at which a Clean Air Act conformity statement is required. For example, in a severe non-attainment area, any action that results in emissions of nitrogen oxides less than 25 tons per year would not require such a statement. In the absence of quantitative emissions data, the assessments presented here can only characterize potential relative differences among the alternatives in the amounts of resultant air emissions.

4.12.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

Boat activity required for the introduction, restoration, and harvest activities included in the proposed action could contribute temporarily to greater air emissions in local areas (e.g., at a particular bar when boats, barges, and equipment are being used to plant spat or shell). The magnitude of these emissions probably would be small in relation to the emissions of other mobile sources on water and land (e.g., large freighters and automobiles) and stationary sources in the region. Sustained operations at one site, however, could result in temporary and local elevation of some air contaminants. Although it cannot be quantified, considering the kinds and amounts of emissions from trucks and boats that might be involved in implementing the proposed action suggests that the resulting increase in emissions would be below the threshold that requires a Clean Air Act conformity statement.

4.12.2 Alternative 1: No Action

The air quality effects attributable to this alternative would be emissions from the operation of boats being used by watermen and from the operation of larger boats and dredging equipment that might be used in repletion activities. Emissions under this alternative would be lower than those expected to result from implementing the proposed action and all alternatives except Alternative 3. Although it cannot be quantified, considering the kinds and amounts of emissions from trucks and boats that might be involved in implementing Alternative 1 suggests that any resulting increase in emissions would be below the threshold that requires a Clean Air Act conformity statement.

4.12.3 Alternative 2: Enhance Restoration

The increases in boat activity for increased repletion and restoration programs and potentially greater boating by watermen to harvest oysters would result in somewhat greater air emissions than expected for Alternative 1. Although it cannot be quantified, considering the kinds and amounts of emissions from trucks and boats that might be involved in implementing Alternative 2 suggests that the resulting increase in emissions would be below the threshold that requires a Clean Air Act conformity statement.

4.12.4 Alternative 3: Harvest Moratorium

Alternative 3 could result in a very slight decrease in air emissions as a result of less boat activity by watermen, unless State or Federal agencies fund some kind of on-water work for watermen to compensate for the loss of oystering income. In that case, there would be no net change in the level of emissions expected under Alternative 1. Although it cannot be quantified, considering the kinds and amounts of emissions from trucks and boats that might be involved in implementing Alternative 3 suggests that the resulting increase in emissions would be below the threshold that requires a Clean Air Act conformity statement.

4.12.5 Alternative 4: Cultivate Eastern Oysters

A slight local increase in emissions could occur in the vicinity of concentrated aquaculture operations as a result of an increase in boat and truck traffic needed to deploy, maintain, harvest, and transport oysters. The rate of growth of the aquaculture industry and the location of its development cannot be predicted; therefore, the location and amounts of emissions increases are not predictable. Although it cannot be quantified, considering the kinds and amounts of emissions from trucks and boats that might be involved in implementing Alternative 4 suggests that the resulting increase in emissions would be below the threshold that requires a Clean Air Act conformity statement.

4.12.6 Alternative 5: Cultivate a Nonnative Oyster

A slight local decrease in air quality could occur in the vicinity of concentrated aquaculture operations as a result of an increase in air emissions from boat and truck traffic needed to deploy, maintain, harvest, and transport oysters. The rate of growth of the aquaculture industry and the location of its development cannot be predicted; therefore, the location and amounts of emissions increases are not predictable. Although it be cannot quantified, considering the kinds and amounts of emissions from trucks and boats that might be involved in implementing Alternative 5 suggests that the resulting increase in emissions would be below the threshold that requires a Clean Air Act conformity statement.

4.12.7 Alternative 8: Combination of Alternatives

Increase in emissions for the proposed action and each of the individual alternatives are considered to be unlikely to result in an increase in emissions that would exceed the threshold that requires a Clean Air Act conformity statement. The effects on air quality of a combination of alternatives would be additive and, therefore, would increase total emissions. Given the kinds and amounts of emissions expected from truck and boats, the combination of alternatives still would appear to be unlikely to produce emissions that would exceed the regulatory threshold for a conformity statement.

4.13 PUBLIC SAFETY AND FOULING

Oyster restoration in the Bay has limited potential to affect public safety. Implementing the proposed action or alternatives probably would not affect typical public safety factors such as emergency services, law enforcement, and fire protection. Potential public safety issues identified in Section 3.13 that might be influenced by increasing the abundance of oysters and oyster habitat in the Bay include the possibility of creating new navigational hazards; an increase in human health risk from consuming oysters that might contain contaminants; an increase in species associated with oysters that can be considered hazardous to man, such as stinging sea nettles; the increased potential for boating accidents due the increased activity of watermen, restoration activities, or both; and the possibility that Suminoe oysters would foul natural and artificial substrates.

4.13.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

The proposed action probably would have only a minimal effect on typical public safety factors such as emergency services, law enforcement, and fire protection. Increased boating activity (e.g., barges) associated with planting oyster spat and shell would increase the chance of accidents between working boats and recreational boaters; however, the expected increase in such activities is unlikely to be sufficient to create significant additional risk.

As discussed in Section 4.2.1, the Suminoe oyster is capable of building reefs and providing ecological services similar to those provided by the Eastern oyster. If a population of Suminoe oysters becomes established, grows rapidly in the Bay, and creates three-dimensional oyster reefs, new reefs in shallow waters could create navigational hazards for recreational boaters. Uncertainty about whether the projected rate of population growth would actually occur is high, and uncertainty about whether the Suminoe oyster would create reefs in Chesapeake Bay is moderate. The likelihood that implementing the proposed action would pose a threat to the safety of recreational boaters, therefore, is uncertain. An unsuccessful Suminoe oyster introduction would pose no threat to recreational boating.

Rates of uptake and depuration of waterborne pathogens by the Suminoe oyster in the Bay differ according to the pathogen.

Oysters filter enormous volumes of water and can bioaccumulate toxins in their body tissues to concentrations considered dangerous for humans. If Suminoe oysters were to concentrate toxins or contaminants to a greater concentration than Eastern oysters typically do, introducing them to the Bay and into seafood markets in the region could increase the risk to human health. In one study, depuration rates for triploid Suminoe oysters were evaluated by growing them in marine tanks spiked with 1.0×10^5 transmissive stages of several human pathogens, including *Cryptosporidium parvum* oocysts, *Giardia lamblia* cysts, and microsporidian spores (*Encephalitozoon intestinalis, Encephalitozoon hellem*, and *Enterocytozoon bieneusi*). These are waterborne pathogens of the human intestine that can sicken healthy people and kill people whose immune systems are suppressed (Graczyk et al. 1997; Weber et al. 2004). Depuration rates were slowest at medium salinities (12 ppt) compared to low (8 ppt) and high (20 ppt) salinities. Eastern oysters also retain waterborne pathogens (Fayer et al. 1998), but the residence time of *C. parvum* oocysts in the triploid Suminoe oysters (33 days) was almost 5 times longer than in Eastern oysters (7 days).

A laboratory study by Bean et al. (2006) exposed Suminoe and Eastern oysters to *E. coli* cells and monitored for the presence of naturally occurring *Vibrio* species. This study found that Eastern oysters bioaccumulated nearly an order of magnitude more *E. coli* than Suminoe oysters after 4 hours. Suminoe oysters depurated *E. coli* significantly faster than Eastern oysters. Post-harvest decay rates of another pathogen, *Vibrio* sp., were significantly lower in Suminoe oysters than in Eastern oysters. Reece and Kator (2006) carried out a series of studies to examine the uptake and elimination of indicators of fecal contamination and pathogens as well as *Vibrio* bacteria species in both Eastern and Suminoe oysters. Triploid Suminoe and Eastern oysters were exposed to water from a sewage treatment plant that was naturally contaminated with fecal material. Uptake of some contaminant indicators by Suminoe oysters was approximately twice that of Eastern oysters. In one experiment, 62.5% (5 of 8) of Suminoe oysters were positive for indicators of fecal contamination, whereas 0% of Eastern oysters were positive 14 days following exposure. In oysters collected at various locations in Maryland and Virginia, the bacterium *Vibrio vulnificus* was found in Suminoe oysters (100%, 56 of 56) as well as Eastern oysters (95%, 53 of 56) collected in Maryland and Virginia. The bacterium *V. parahaemolyticus* was detected in 69.0% (20 of 29) of Suminoe oysters and in 65.8% (25 of 38) of Eastern oysters. No consistent differences were found between the species when they were monitored in the lab to characterize elimination rates.

Suminoe oysters appear to bioaccumulate zinc faster than Eastern oysters, although no rigorous studies of that phenomenon have been conducted (C. Mitchelmore, UMCES, CBL, pers. comm.). If species differences of this nature are documented for contaminants that pose a threat to human health and for the parameters used to close waters to shellfish harvesting (e.g., coliform bacteria), the criteria for safely harvesting Suminoe oysters might have to be revised to more restrictive levels than are in effect presently for harvesting Eastern oysters. Such management changes would not preclude the harvest and sale of a well-monitored population of Suminoe oysters.

A substantial increase in the Bay-wide oyster population resulting from implementing the proposed action could produce an increase in the area of shell-covered hard bottom that provides habitat for reproduction of stinging sea nettles. The resulting increased abundance of nettles would be more a nuisance to swimmers than a threat to their safety. Even though the nettle's sting can cause discomfort, it is not potent enough to kill a person, except by allergic reaction

Because oysters settle on hard surfaces, they have the potential to be fouling organisms, (i.e., to settle and grow on surfaces where their presence may inconvenience people or impair the function of the surface). Concern about the Suminoe oyster becoming a fouling organism is high because of the problems caused by other nonnative species, such as the zebra mussel and a small clam, *Corbicula*. These species have grown in massive aggregations on manmade structures such as intakes for drinking water supplies and for cooling water at power plants, clogging the structures and significantly reducing flow through them. Such intakes usually have high water flow, which ensures great availability of food for filter feeders; therefore, they support maximum population growth. Suminoe oysters cannot survive in fresh water; consequently, they will not foul drinking water intakes in Chesapeake Bay. Many steam electric-generating stations on Chesapeake Bay, however, are located in oligohaline and mesohaline areas in which Suminoe oysters might thrive. If an increased oyster population results in significant fouling of cooling water intakes at power plants, it could affect their capability to generate electricity for residents of the Bay watershed. Also, if Suminoe oysters preferentially settle on hard structures other than oyster shell, they could create a nuisance by fouling surfaces such as boat hulls or pier pilings. A review of literature about fouling by other oyster species throughout the world is useful for evaluating the potential for the Suminoe oyster to become a fouling organism.

Although rare, fouling by oysters has been reported in some locations. For example, Indian backwater oysters (*Crassostrea madrasensis*) routinely clog coolant pipes at the Madras nuclear power station in India and must be removed by chemical treatment (Masilamoni et al. 1997; Rajagopal et al. 2003). Nonnative Pacific oysters, which were introduced into the North Sea unintentionally during the 1960s, have become a fouling nuisance recently at several power plants in the Wadden Sea, Netherlands (Jenner et al. 2004). A secondary problem may occur where oysters live near intakes or are chemically controlled if the shells of dead oysters are swept into power plants. The Brunswick nuclear power plant in North Carolina was closed temporarily in 1981 when shells of Eastern oysters growing on a water intake pipe were swept into the plant and caused a baffle to fail (U.S. Nuclear Regulatory Commission 1981). Shells of oysters killed by chemical treatment also sometimes detach and clog tubes or sieves at power stations in Western Europe (Jenner et al. 1998).

Despite these examples, severe fouling of power plants by oysters appears to be uncommon. Oysters occur in waters used to cool power plants along coasts worldwide, yet a search of the scientific literature using several computerized databases (i.e., Aquatic Sciences and Fisheries Abstracts, BIOSIS, Science Citation Index, and Web of Science) and a general search of the World Wide Web using Google revealed only a few examples of severe fouling. A similar search revealed thousands of references to fouling damage caused by other invasive mollusks, such as the zebra mussel. In Chesapeake Bay, Eastern oysters have been found occasionally on power plant intake structures in Maryland but have never caused a significant fouling problem, even during years of high spatfall (T. Ringger, Constellation Energy Group, pers. comm.).

The conditions that promote fouling by oysters have not been investigated systematically but appear to be related to habitat characteristics that support productive populations very near water intakes. A suite of environmental parameters including salinity, temperature, dissolved oxygen, food, sediment, and pollutant levels influences the survival and reproduction of oysters. None of these factors is characteristically unsuitable for oysters near most power plants; however, the fact that oysters often are found in small numbers but do not usually proliferate in intakes (e.g., Jenner et al. 1998) suggests that one or more limiting factors make the habitat marginal. That is, survival is possible but growth and reproduction may be limited because the habitat near power plants is, for some reason, at the edge of most oyster species' ecological niches. Local demographics are particularly important for oyster colonization because adults do not move after cementing themselves to the substrate (Yonge and Thompson 1976). Oysters must be available from a nearby population to colonize any water intake, and no barriers that would prevent larvae from surviving can separate the source population from the intake. Pacific oysters that are fouling intakes at power plants in the Wadden Sea (Jenner et al. 2004) probably come from productive populations on nearby mussel beds and sea walls (Reise 1998; Wehrmann et al. 2000). Some of the reported cases of biofouling by oysters may be explained by unique conditions that promoted oyster colonization and survival nearby. For example, Moazzam and Rizvi (1983; cited in Zhou and Allen 2003) suggested that the jinjiang oyster (*C. rivularis*) occurs in the cooling system of a power plant in Pakistan because manmade structures around the plant created habitat that is similar to the species' natural backwater environment. These examples demonstrate that oysters have the potential to create a fouling problem under certain conditions.

Oyster species that prefer shallow habitat may be more likely to cause fouling problems than those that prefer deeper areas farther from the shore. European flat oysters (*Ostrea edulus*), which occurred in the subtidal zone, did not cause fouling problems in the Wadden Sea, even before their population declined during the 1960s. Furthermore, no cases of fouling by oysters of the genus *Ostrea* have been reported world-wide. Pacific oysters (*C. gigas*), which now cause fouling in the Wadden Sea, occupy shallower subtidal and intertidal areas (Reise 1998). Other species that have been reported to cause fouling, such as Indian backwater oysters and jinjiang oysters, also tend to use shallow subtidal areas (Rajagopal et al. 2003; Zhou and Allen 2003). Eastern oyster reefs occurred historically in both intertidal and subtidal areas (Kennedy and Sanford 1999) but have not generally caused serious fouling problems. Pacific oysters have not been reported to cause serious fouling problems in their native range. A preference for inshore areas closer to intake and effluent pipes probably increases the likelihood that a species would cause fouling problems, but the effect is apparently overwhelmed by other factors that control fouling in most areas.

Regarding the proposed action, the key question is whether the Suminoe oyster would pose a greater risk of fouling than the native Eastern oyster. Results of studies of the substrate preferences of Suminoe and Eastern oysters are discussed in Section 4.1.1. In laboratory studies, both species showed a 1- to 2.5-times greater preference for natural substrates such as shell and granite than for manmade substrates such as PVC, fiberglass, and steel. The absence of sediment and the presence of a biofilm on a natural substrate at least doubled the rate of settlement for both species in most instances. Suminoe oysters appear to be 2 to10 times more likely than Eastern oysters to settle on manmade substrates (e.g., PVC and fiberglass); therefore, Suminoe oysters might adhere to surfaces like boat bottoms more frequently than the native species. This suggests some chance that the Suminoe oyster would cause fouling; however, the species' strong preference for natural substrates suggests that it is unlikely to become a significant fouling nuisance. There are no records of the Suminoe oyster causing fouling problems in its native range.

> The Suminoe oyster's strong preference for setting on natural substrates suggests that it is unlikely to become a significant fouling

4.13.2 Alternative 1: No Action

No effects on public safety and fouling have resulted from the current restoration programs, which would continue under this alternative. The one incident described in Section 3.13, in which the construction of an artificial reef in Maryland resulted in creation of a hazard for recreational boating was not specifically part of standard oyster habitat rehabilitation program.

4.13.3 Alternative 2: Enhance Restoration

Implementing this alternative would have no effect on typical public safety factors such as emergency services, law enforcement, and fire protection. Boating activity (e.g., barges) associated with planting spat and shell would increase the potential for accidents between working boats and recreational boaters, and the level of activity would be somewhat greater than under Alternative 1. The increase in working activity, however, would be insufficient to create significant additional risk. Implementing this alternative would not increase risks for human health or fouling. The oyster population growth projected for this alternative would be unlikely to result in the creation of new three-dimensional reefs that would pose hazards for recreational boating.

4.13.4 Alternative 3: Harvest Moratorium

Implementing this alternative would have no effect on typical public safety factors such as emergency services, law enforcement, and fire protection. The absence of the oyster harvest would slightly reduce the potential for accidents between working boats and recreational boaters. Implementing this alternative would not increase risks for human health or fouling. The oyster population growth projected for this alternative would be unlikely to result in the creation of new three-dimensional reefs that would pose hazards for recreational boating.

4.13.5 Alternative 4: Cultivate Eastern Oysters

The demand for typical public safety support such as emergency services, law enforcement, and fire protection might increase if a large-scale aquaculture industry develops and that industry requires a significant expansion of infrastructure and an increase in the number of employees involved in the business. Increased boat and truck activity for deploying, maintaining, harvesting, and transporting cultivated oysters might increase the risk of accidents. Implementing this alternative would not increase risks for human health or fouling. If off-bottom culture methods (e.g., floats) are employed, surface structures could increase the risk of boating accidents. On-bottom culture would increase the amount of hard substrate, which might contribute to an increase in stinging sea nettles.

4.13.6 Alternative 5: Cultivate a Nonnative Oyster

Implementing this alternative might affect typical public safety factors such as emergency services, law enforcement, and fire protection if a large-scale aquaculture industry develops and that industry requires significant infrastructure and a large number of employees. Increased boat and truck activity for deploying, maintaining, harvesting, and transporting cultivated oysters might increase the risk of accidents. Although Suminoe oysters may bioaccumulate and retain some contaminants that pose risks for human health to greater a degree than Eastern oysters do, the potential for increased risk is likely to be small because both Virginia and Maryland require routine water quality monitoring at aquaculture operations, and oysters cultured in contaminated waters must be depurated and tested before being sold.

Regulations governing the cultivation and sale of Suminoe oysters might have to be modified to ensure minimal risk. Implementing this alternative would require using confined, off-bottom culture methods (e.g., floats, off-bottom cages) to minimize the risk of an unintentional introduction; structures associated with those methods would increase the risk of boating accidents. Despite the use of confined methods, cultivating triploid Suminoe oysters could result in the establishment of a diploid population at large in the Bay (Section 4.1.6); however, an extended period of time probably would be required to develop any substantial population. If such a population were to become established, its presence would create a slight risk of fouling, as discussed for the proposed action (Section 4.13.1)

4.13.7 Alternative 8: Combination of Alternatives

The magnitude of the increased in risks for public safety and fouling would differ among the three combinations. In general, the minimal risks described for the proposed action and alternatives individually would be additive in the combinations; therefore, levels that might constitute minimal risk individually might cumulatively rise to a level of significance. Cultivating triploid Suminoe oysters probably would require less area and less deployment of oysters than cultivating Eastern oyster, risks to public safety may be less under alternatives 8b and 8c than under 8a. Combination 8c, which includes introducing diploid Suminoe oysters, would pose the greatest risk for fouling. Combination 8b, which involves triploid Suminoe oysters, poses such a risk, but the time frame over which the risk would rise to significant levels would be much greater.

4.14 COMMERCIAL NAVIGATION

Major shipping ports in Chesapeake Bay are located in the lower Bay (Norfolk, Newport News, and Front Royal) and in the upper Bay (Port of Baltimore). Thousands of commercial ships travel throughout the length of the Chesapeake Bay each year, but their routes of movement are limited to dredged shipping channels where there is no oyster habitat. Oyster reefs, whether developed naturally or created artificially, could become navigation hazards for shallow-draft commercial vessels transiting small inlets and tributaries in the Bay.

4.14.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

Boating activity (e.g., barges) associated with planting oyster spat and shell might create the potential for accidents with commercial ships. Planting activities, however, would occur almost entirely outside of commercial shipping lanes, even the small tributary routes, and the increase in such activities would be insufficient to create significant additional risk.

If a population of Suminoe oysters becomes established, grows rapidly in the Bay, and creates three-dimensional oyster reefs, new reefs in shallow waters could create navigational hazards for any shallow-draft commercial vessels that transit small inlets and tributaries in the Bay (e.g., small fuel tankers delivering to Bay island communities). Uncertainty about whether the projected rate of population growth would actually occur is high, and uncertainty about whether the Suminoe oyster would create reefs in Chesapeake Bay is moderate. The likelihood that implementing the proposed action would pose a threat to the safety of shallow-draft commercial vessels, therefore, is uncertain. The risk of new disease organisms discharged into the Bay from ballast water becoming established because of the presence of the Suminoe oyster is considered minimal (Section 4.2.3 of Appendix B).

4.14.2 Alternative 1: No Action

There are no records documenting any effects of current oyster restoration programs of the type that would continue under this alternative on commercial navigation.

4.14.3 Alternative 2: Enhance Restoration

Boating activity (e.g., barges) associated with increased planting of oyster spat and shell might cause a slight increase in the risk of accidents between working vessels and commercial vessels. Planting activities would occur almost entirely out of commercial shipping lanes, even the small tributary routes, and the increase in such activities would not be insufficient to create significant additional risk. The growth of the oyster population projected for this alternative would be unlikely to result in creation of three-dimensional reefs that would pose a threat to commercial navigation.

4.14.4 Alternative 3: Harvest Moratorium

A slight decrease in boating activity associated with cessation of the oyster harvest would slightly decrease the risk of accidents between working vessels and commercial vessels. The growth of the oyster population projected for this alternative would be unlikely to result in creation of three-dimensional reefs that would pose a threat to commercial navigation.

4.14.5 Alternative 4: Cultivate Eastern Oysters

Implementing Alternative 4 would have no effect on commercial navigation to and from the Port of Baltimore or Virginia. Aquaculture facilities and activities could pose navigation hazards for shallow-draft commercial vessels transiting small inlets and tributaries in the Bay, depending on the sites of new or expanded aquaculture operations.

4.14.6 Alternative 5: Cultivate a Nonnative Oyster

Implementing Alternative 5 would have no effect on commercial navigation to and from the Port of Baltimore or Virginia. Confined aquaculture of triploid Suminoe oysters in cages near the bottom or in surface floats could pose navigation hazards for shallow-draft commercial vessels transiting small inlets and tributaries in the Bay.

4.14.7 Alternative 8: Combination of Alternatives

The minimal potential for conflicts with commercial navigation expected to result from implementing the proposed action or alternatives individually suggests that none of the combinations of alternatives would result in any significant risk for commercial navigation.

4.15 POTENTIALLY AFFECTED RESOURCES OUTSIDE OF CHESAPEAKE BAY

4.15.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

Once a nonnative species has been introduced, the possibility that the species would spread beyond the point of entry is a concern. The ability of a nonnative oyster to spread would depend upon many factors including the availability of habitat, hydrodynamic patterns, settlement behaviors, and the species' range of tolerance for chemical, physical, and biological variables. According to the NRC (2004), if a reproductively viable population of the Suminoe oyster becomes established in the Chesapeake Bay, it is highly likely that the species would spread beyond the Bay. Modes of dispersal include natural mechanisms of larval dispersal, ship traffic, and deliberate translocation by humans.

Transport of Suminoe oysters by means of larval transport would be influenced by hydrodynamic regimes (advection and turbulence) and species-specific vertical swimming behavior (North et al. 2006). Laboratory studies have demonstrated that Suminoe oyster larvae tend to swim toward the bottom and remain there, where, in the Bay, they would be subjected to more landward water flows (Newell et al. 2005) and more up-Bay bottom flows. A coupled hydrodynamic and larval transport model predicted that Suminoe oyster larvae are more likely to be retained within the basin in which they are produced than to be transported to a different basin due to their vertical position in the water column and the typical patterns of flow within the Bay (North et al. 2006). Such behavior may reduce the probability of Suminoe oyster larvae being transported out of the Bay; however, the model developed by North et al. (2006) was not designed to quantify such probabilities.

Humans could also disperse Suminoe oysters to other estuaries. Suminoe oysters could be transported unintentionally as fouling organisms on the hulls of boats or as larvae in ballast water. Interested parties also could purposefully transport Suminoe oysters or larvae to other estuaries. This scenario of a "rogue" introduction would be particularly likely if the Suminoe oyster were to become established rapidly and increase throughout the Bay.

The rate and direction of dispersal would depend on many environmental factors, both physical and biological. Available research and discussions with researchers suggest that the Suminoe oyster is more likely to succeed in areas to the north of Chesapeake Bay than in areas to the south due, in part, to the distribution of suitable environments for settlement and growth. Intertidal environments, which do not appear to be favorable for Suminoe oysters, constitute much of the oyster habitat south of Chesapeake Bay. North of the Bay, Eastern oysters are found predominantly in subtidal areas, which appear to be more suitable habitat for Suminoe oysters. Researchers have suggested that the Suminoe oyster's ability to thrive in polyhaline waters along the coast may be limited by disease because of the species' vulnerability to *Bonamia* at high salinities.

Once it entered Atlantic coastal waters, the potential range of the Suminoe oyster would be a function of its environmental tolerances and habitat requirements. Scarpa et al. (2008)

showed that in a subtropical environment (17-29ºC and salinity 27-35 ppt), 1- to 2-year old diploid Suminoe oysters (2004 cohort) had an instantaneous growth rate similar to Eastern oysters from January through March but in December, instantaneous growth rate of Eastern oysters was about 3 times greater than for Suminoe oysters. The authors do not offer an explanation for this difference. Absolute mortality rates for the 2004 cohort were greater for Suminoe oysters (100%) than for Eastern oysters (72.6%) after 8 months; similar relative patterns were observed for the 2006 cohort. Although the data are limited, they suggest that Suminoe oysters may not compete strongly with Eastern oysters in subtropical areas of the United States. Preliminary evidence has indicated that the Suminoe oyster and the Eastern oyster are both capable of growing and spawning within a wide range of salinity (5 to 35 ppt). An early study (Langdon and Robinson 1996) found a strong relationship between salinity and the success of settlement among Suminoe oyster larvae (i.e., no successful settlement at 35 ppt, 3% success at 30 ppt, 11% success at 25 ppt, 23% success at 20 ppt, and 27% at 15 ppt). More recent studies of the effect of salinity on larval settlement (Zohar et al. 2006) were unsuccessful and provided no additional information. If the rate of successful settlement of Suminoe oyster larvae is low at high salinities, that response would contribute to constraining the species' spread and slowing the rate of dispersal out of the Bay. Minimum temperatures in the Suminoe oyster's native range drop to about 14ºC. Eastern oysters can be found in waters as cold as -2ºC. The higher minimum temperature in the Suminoe oyster's native range suggests that low temperatures might limit the northern expansion of the Suminoe oyster along the Atlantic coast; however, triploid and diploid Suminoe oysters used in experiments in the Bay have been maintained at temperatures as low as 2ºC (Newel et al 2007b; Calvo et al 2001; Paynter et al. 2007).

The areas outside Chesapeake Bay into which the Suminoe oyster might expand include most of the areas that currently support the Eastern oyster. Eastern oysters occur in every major bay system along the Atlantic coast from the Gulf of St. Lawrence, Canada, through the Gulf of Mexico, and into the West Indies (Figure 3-8). The native range of the Suminoe oyster spans a broad range from Korea to Vietnam (41 N to 20 N); the latitude of its native range corresponds to the area between Connecticut and the Yucatan Peninsula, Mexico.

The likelihood that Suminoe oysters would compete with Eastern oysters in areas outside of Chesapeake Bay would be a function of the nonnative species' ability to become established in existing oyster habitat and to develop reefs. At low numbers of adults within an area (relative to the Eastern oyster), Suminoe oysters would be at a competitive disadvantage due to the phenomenon of gamete sink (Section 4.2.2.3 of Appendix B). The ERA concludes overall that although the two oyster species would compete, they would be able to co-exist in suitable environments. The form of that coexistence could range widely from single species only in some locations, mixed-species reefs with one dominant species, or mixed-species reefs with both species abundant (Section 4.2.1 of Appendix B). For the purpose of this assessment, the Suminoe oyster is assumed to be established in Chesapeake Bay and to expand outside the Bay into all suitable habitats along the coast. Suminoe oysters would interact with potential receptor species that represent the components of other coastal ecosystems in the same ways that they interact with representatives of comparable components of the ecosystem of Chesapeake Bay. The kinds of interactions expected are described in the ERA (Sections 2.3 and 2.4 of Appendix B) and summarized in Table 4-1.

Direct mechanisms of effect are those in which a receptor is affected directly by the size (abundance or biomass), spatial distribution, or characteristics of the oyster population. Direct receptors compete for the same space of food as oysters or depend on oysters or oyster reefs for successful completion of their life cycles. Direct receptors can be categorized by their ecological roles. Indirect receptors are species that do not compete directly with oysters for food, but might be affected if one or more of their forage species was influenced by changes in oyster populations. Species connected by more than one trophic link are considered to be affected through indirect mechanisms. The types of interactions and effects summarized here are described in more detail in Section 2.3 and 2.4 of the ERA (Appendix B).

Benthic Hard-bottom Receptors – The Eastern oyster is an important component of hard-bottom habitats throughout the mid-Atlantic, Gulf of Maine, Southeast, and Gulf of Mexico and, therefore, is an appropriate representative species for hard-bottom habitats in all four geographic regions. The risk that the Suminoe oyster would interact and compete with the Eastern oyster is moderate to high (Section 4.2.2 of Appendix B). The Eastern oyster may have an ecological advantage at the northern and southern extents of its range. In areas where habitat is suitable for both species, the two species could occur together because they are likely to be able to co-exist within a reef. Because of they grow faster, Suminoe oysters could produce shell for colonization by spat of both species, as they do in their native range. In subtropical and temperate-subtropical regions of the Southeast and Gulf of Mexico, hard-bottom communities also include hard corals, soft corals, and sponges (Danek and Lewbel 1983, etc.). Functioning hard-bottom reefs provide and maintain habitat for numerous other epifaunal species, including barnacles, mussels, encrusting bryozoans, and sponges. To the extent that Suminoe oysters populate and are able to sustain themselves in those environments, they could contribute substrate for other hard-bottom species; however, the oysters' own requirement for hard substrate for settling could also result in some competition with these other epifaunal species. Competition of this nature has been recorded for the Pacific oyster, in some locations to which it is not native, such as the Wadden Sea. There, the introduced oyster has shown a tendency to settle on native mussel shells, and the oyster population has expanded to overwhelm beds of the native mussel. The Pacific oyster appears to have a particular combination of characteristics that enhances its potential to become an invasive nuisance in some environments (e.g., the tendency to settle on the shells of other shellfish species and prosper in intertidal areas; hard shell that is resistant to predators). The Suminoe oyster shares some but not all of these characteristics (e.g., it is not expected to form large reef systems outside of historical hard-bottom areas that would overtake intertidal areas, other soft-bottom habitat, or SAV habitats; its thin shell makes it more vulnerable to predation) suggesting that it is less likely to develop in a similar manner (Section 4.2.4 of Appendix B).

Benthic Soft-bottom Receptors – Two species of soft-bottom benthos that are considered receptor species in Chesapeake Bay are found throughout the other major regions of the eastern United States: the hard clam (*M. mercenaria*), found in higher salinities, and the Baltic clam (*M. balthica*), found in lower salinities. The two species occupy different salinity regimes that cover the range of salinities in which both species of oysters occur. Both soft-bottom receptors are filter-feeding infauna (i.e., species that live completely or mostly buried within the bottom sediment). In the Gulf of Maine, the Atlantic bay scallop (*Argopecten irradians*) is a comparable, representative soft-bottom species for high-salinity areas; however, the extent to which the habitats of the scallop and oyster overlap would be minimal. The major potential mechanism for the Suminoe oyster to interact with benthic soft-bottom species is through competition for food and space. Suminoe oysters are unlikely to compete for space with soft-bottom receptors because Suminoe oysters prefer to settle and grow on existing oyster shell and other hard substrate. Competition for food between oysters and clams or other filter feeders could result in a reduction in the abundance of clams or scallops, at least on a local level, if a substantial population of Suminoe oysters becomes established in any restricted location. The likelihood that oyster populations of such size would develop is not known.

Predatory Macrobenthic Invertebrates – As in the Chesapeake Bay, the blue crab is a common oyster predator throughout the mid-Atlantic, Southeast, Gulf of Maine, and Gulf of Mexico regions. Blue crabs are opportunistic predators, exploiting prey species of the most common sizes in each of the habitats they visit. Although adult oysters are too large for blue crabs to open and prey upon, crabs feed readily and opportunistically on juvenile oysters. Oysters attain a partial refuge from predation at low densities, but predation by blue crabs might increase with increasing oyster abundance. Given the thinner shell of the Suminoe oyster, predation by blue crabs and other invertebrates with shell-crushing capability (e.g., lobsters in northern waters) could constrain its expansion through coastal waters. Conversely, an expanding population of Suminoe oysters could provide more food for such predators. Changes in the community structure and population density of predators and prey species resulting from complex interactions with introduced species can have cascading trophic effects that can alter the structure of an ecosystem. In addition to increasing the food supply for crabs and other oyster predators, an increasing oyster population might indirectly enhance some species by increasing the availability of refuge habitat, such as for juvenile crabs. An increase in the abundance of SAV resulting from increased filtration of water in confined estuaries by an expanding stock of Suminoe oysters could enhance the populations of species such as the blue crab by enhancing SAV growth (through improved water clarity).

Planktivorous Fish – Planktivorous fish consume small organisms that drift or swim in the water column, collectively called plankton, and are preyed upon by larger fishes. As such, they are an important part of coastal and estuarine food chains. Both of the planktivorous fish species designated as receptor species in the Bay, Atlantic menhaden and Bay anchovy, and closely related species (e.g., Gulf menhaden) have coastal ranges overlapping that of the oyster. Because oysters also feed on some types of plankton, planktivorous fish might interact with oysters through competition for food. Competition may be direct, such as in the case of menhaden that feed on phytoplankton, or indirect, such as in the case of the Bay anchovy that feed on zooplankton which, in turn, feed on phytoplankton. If the population of Suminoe oysters in any restricted location were to be sufficient to reduce phytoplankton availability, that reduction in food resources could adversely affect growth, reproduction, and survival of planktivorous fishes. However, in most environments food is not a limiting factor for plankton feeders and this type of interaction would be unlikely to occur.

Reef-Associated Fish – Oyster bars and reefs provide habitat for a wide range of fish species, many of which are important in commercial and recreational fisheries throughout coastal waters. Although some tropical fish reside on reefs throughout their life cycles, most temperate species may occupy this habitat during only a portion of their life cycle. The naked goby, a receptor species for this ecosystem component in the Bay, is considered an exclusively reef-dwelling species and occurs in the mid-Atlantic, Southeast, and Gulf of Mexico regions. Oyster habitat provides a refuge from predation as well as feeding and reproduction sites for the species. Black sea bass, another receptor species for reef habitat in the Chesapeake Bay, is found throughout coastal waters of the mid-Atlantic and Southeast regions. Other reef-oriented species common in Chesapeake Bay, such as the Atlantic croaker, are also found throughout the mid-Atlantic, Southeast, and the Gulf. Such species use oyster habitat for refuge, reproduction, and foraging. All species that either depend on or are associated with oyster bar and reef habitat would benefit from any increase in such habitat that might result from the growth of a population or Suminoe oysters in coastal waters. For example, Rodney and Paynter (2006) compared macrofaunal assemblages on restored and non-restored oyster reefs in mesohaline regions of Chesapeake Bay and found that densities of demersal fish, primarily naked goby, were four times greater on the restored reefs than on the unrestored reefs. They also found that densities of fish prey species were much greater on restored reefs, 20 times greater than on unrestored reefs for amphipods, for example.

Piscivorous Fish – Piscivorous fish are members of the fish community that feed on other species of fish. Several piscivorous species in coastal waters are among the most sought-after species in recreational and commercial fisheries, including striped bass and bluefish, the two receptor species considered for Chesapeake Bay. Changes in oyster populations in coastal waters could affect piscivorous fish indirectly through the food chain, through negative effects on planktivorous forage species, and positive effects on reef-oriented or dependent species. Effects of this kind would be likely only in relatively confined waters where a large population of Suminoe oysters might become established.

Other Receptors – Most of the receptor species designated for other ecosystem components in the ERA have wide distributions that overlap oyster distributions in coastal waters (e.g., bald eagle, turtle species). The kinds of effects discussed in the ERA and in Section 4.2.1 would be typical of those expected in coastal waters if the Suminoe oyster were to expand its range and prosper in those waters. For the most part, an increase in oysters would have a positive influence on most receptors. The magnitude of effects would be a function of the amount of oysters, the density in which they occur, and the hydrodynamics of their location. Effects would be greatest in restricted waters, such as small, semi-confined embayments that might support a large population of oysters. They would be least along open coastal waters, where sparse oyster populations might be dispersed across extensive hard substrate, such as coastal stone shorelines.

Potential consequences of the development of a population of Suminoe oysters in coastal waters for other elements of the affected environment would be similar to the kinds of effects described for Chesapeake Bay. The length of time before any effects would be realized would be great because the rate of colonization and expansion in coastal waters is likely to be slow. For the most part, the establishment and growth of such a population would be likely to result in ecological benefits because the Suminoe oyster appears to offer ecological services quite similar to those provide by the Eastern oyster. A major of concern of many stakeholders is the extent to which a very successful population of Suminoe oysters might become a nuisance species through fouling of a wide range of substrates and surfaces that Eastern oysters do not populate currently. This concern is based on events in other locations, such as the Wadden Sea, where the Pacific oyster has become established, overtaken native mussel beds, and created large intertidal reefs that have adversely affected human activities along the shore. If the Suminoe oyster were to become a nuisance species, which seems unlikely (Section 4.13.1), its presence could have negative social and economic consequences; however, establishment of a population of Suminoe oysters that exhibits greater growth and productivity than the population of Eastern oysters in coastal waters could enhance coastal oyster fisheries and provide economic benefits.

4.15.2 Alternative 1: No Action

This alternative would have no effect on resources located outside Chesapeake Bay.

4.15.3 Alternative 2: Enhance Restoration

This alternative would have no effect on resources located outside Chesapeake Bay.

4.15.4 Alternative 3: Harvest Moratorium

This alternative would have no effect on resources located outside Chesapeake Bay.

4.15.5 Alternative 4: Cultivate Eastern Oysters

This alternative would have no effect on resources located outside Chesapeake Bay.

4.15.6 Alternative 5: Cultivate a Nonnative Oyster

Effects on resources outside Chesapeake Bay would be possible under this alternative only if a self-sustaining population of the Suminoe oyster were to result from large-scale aquaculture operations using triploid Suminoe oysters. The probability of such an outcome is discussed in detail in Section 4.3 of Appendix B and summarized in Section 4.1.6. The probability of a diploid population becoming established under the aquaculture assessment scenario defined for the PEIS could not be determined conclusively because of the variety of pathways of possible introduction of the species and limitations of the data available for the evaluation; however, the rate of expansion within the Bay of a population introduced in this manner would be expected to be very slow. Consequently, the rate at which expansion would extend to coastal waters also would be slow. If a large population were to become established, the likelihood of its expansion outside the Bay would be the same as for the proposed action, as would the ecological consequences of such an expansion.

4.15.7 Alternative 8: Combination of Alternatives

Only Combinations 8b and 8c involve the use of the Suminoe oyster and would pose any risk of affecting resources outside Chesapeake Bay. The risk would be greater under Combination 8c, which includes an introduction of diploid Suminoe oysters, and would be as described for the proposed action (4.15.1). Risk would be less under Combination 8b, and the same as described for Alternative 5 (4.15.6).

4.16 CUMULATIVE IMPACTS

In regulations implementing the procedural provisions of NEPA (40 CFR 1500-1508), CEQ defines cumulative effects as follows (CEQ 1997a):

> "…the impact on the environment which results from the incremental impact of the action when added to other past, present and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions…" (40 CFR 1508.7)

If the actions evaluated in this PEIS achieve their purpose as stated in Section 1, they would affect the entire Chesapeake Bay. Addressing all the "…past, present and reasonably foreseeable future actions…." that may affect the Chesapeake Bay is beyond the scope of any one PEIS. Such actions are addressed in other major programs, in particular the Chesapeake Bay Program (CBP) (www.chesapeakebay.net). Since its inception in 1983, the CBP has documented the major problems facing the Chesapeake Bay and the actions needed to resolve those problems. An overview of past, current and future stressors drawn from the CBP web page provides a context for addressing the cumulative effects of oyster restoration.

The major pollutants affecting the Bay are excess nutrients, which come from agriculture, urban/suburban runoff, vehicle emissions, and many other sources. Excess nutrients fuel the growth of algae blooms, which block sunlight that underwater grasses need to grow. When algae die, they are decomposed in a process that depletes the water of oxygen, which all aquatic animals need to survive. Other major stressors on the Bay include erosion, chemical contaminants, air pollution, and landscape changes. Natural factors can have a great direct influence on the Chesapeake Bay ecosystem and also on the magnitude and scope of the effects of human activities. Total river flow into the Bay can vary dramatically from year to year, causing large fluctuations in salinity that affect the Bay's biological communities, and oysters in particular, dramatically. Droughts result in high salinity throughout much of the Bay, which contribute to the range expansion and increase in severity of diseases that affect the Eastern oyster population (Section 1.2.1). In wet years, when precipitation is frequent and heavy, normally brackish regions of the Bay can become fresh and cause mortality of oysters and other animals and plants that cannot survive in fresh waters. Some scientists contend that extremes of precipitation will become more frequent in the future due to climate change. Climate change and variability have caused water temperatures in the Bay to exhibit greater extremes during the 20th century than during the previous 2,000 years. Sea-level rise related to climate change is contributing to the loss of vital coastal wetlands. The amounts of pollutants entering the Bay continue to exceed target levels established by the CBP to restore the Bay's water quality. The human population in the Bay watershed is now growing by about 130,000 residents annually. The cumulative impact of centuries of population growth (currently nearly 17 million) and landscape change has taken its toll.

Historical over-harvest compounded by the effects of poor water quality and disease has resulted in the current low abundance of oysters (Section 1.1.1) in the Bay. Excess suspended sediment is one of the largest contributors to the Bay's impaired water quality. The culprits are the tiny clay- and silt-sized fractions of sediment. These particles frequently are suspended in the water because of their size and can be carried long distances during storms. In excess, these smaller grains of sediment cloud the water, reducing the amount of sunlight that reaches submerged grasses. Without enough sunlight, these underwater grasses are not able to grow and provide habitat for young fish and blue crabs. The excess suspended sediment can carry chemical contaminants that may affect fish and other living things in the Bay, as well as humans and animals that swim in it. When it settles to the bottom, the excess sediment also covers and degrades hard-bottom habitat that is essential for the growth of the oyster population and the well being of other aquatic organisms that require that kind of habitat.

4.16.1 Proposed Action: Introduce the Suminoe Oyster and Continue Efforts to Restore the Eastern Oyster

The proposed action has the potential to substantially increase oyster abundance in the Bay, although many factors could preclude that potential from being realized (Section 4.1.1). The failure of proposed action to create a self-sustaining and abundant population of Suminoe oysters in Chesapeake Bay could contribute to an overall failure to reverse the cumulative effects of all other stressors on the Bay's oyster population and ecosystem and could have a negative economic consequence on other programs for managing natural resources by consuming financial resources that might otherwise have been available to those programs. If the proposed action were successful and the Suminoe oyster became abundant and widespread, it could contribute to local, small-scale improvements in water quality through filtering of plankton and other suspended solids from the water column. The increased population of oysters could help counteract the effects of nutrient and sediment runoff resulting from further development throughout the watershed; however, unless state and local municipalities take significant actions to control pollution, nutrient and sediment runoff could continue to increase, counteracting any beneficial effects of increased oyster abundance. If a population of Suminoe oysters were to become established in the Bay, it could contribute to the development of oyster reefs that would help to counteract the loss of hard-bottom habitat in the Bay and, in turn, contribute to enhancing populations of species that depend on such habitat (Section 4.2.1). If a population of Suminoe oysters were to grow in the Bay, it could reverse the decline in the Bay's oyster fishery, create a means of sustaining the watermen's culture (Section 4.6.1), and counteract the consequences of declines in other exploited species, such as the blue crab. If the species were to become very abundant, however, increased harvest could result in reduced prices and unintended negative economic consequences (Section 4.6.2; Appendix D).

Introducing this nonnative species could add to the multiple stressors that have contributed to the decline of the Eastern oyster in the Bay, although the interactions between the species might have both positive and negative consequences (Section 4.1.1). An established and self-sustaining population of Suminoe oysters in the Bay would also alter the natural biodiversity of the Chesapeake Bay ecosystem. The Bay's biodiversity has been subject to significant alteration from many unintentional introductions of nonnative species, such as those resulting from releases of ballast water.

4.16.2 Alternative 1: No Action

Only small changes in the population of Eastern oysters were projected to result from continuing current restoration programs (Section 4.1.2), and continued decline of the oyster population is anticipated into the future. Changes in oyster populations under this alternative would not contribute to reversing the affects of watershed development and nutrient and sediment loading to the Bay and would not reverse the continuing loss of hard-bottom habitat in the Bay.

4.16.3 Alternative 2: Enhance Restoration

Increases in oyster populations in some sections of the Bay (e.g., oligohaline waters in Maryland; Section 4.1.3) could result in ecosystem changes that would counteract some of the cumulative effects of watershed development and pollutant loading to the Bay, although the effects are likely to be local, not Bay-wide. Much of the increase in the oyster population would be on protected bars, many of which are located in low-salinity areas where oyster spawning is very limited. The increases in oyster abundance on sanctuary bars in low-salinity areas would not contribute directly to reversing the adverse economic effects on watermen that have resulted from declines in oysters and other exploited species. To the extent that sanctuary bars that support healthy oyster populations could be established in high-salinity areas, spawn from sexually mature oysters on those bars might disperse and colonize bars where harvesting is permitted, if the spat were able survive and grow to legal size. This alternative might contribute to counteracting the cumulative impacts to Chesapeake Bay’s water quality to a limited extent and most likely only locally, not Bay-wide. The level of habitat rehabilitation anticipated under this alternative would not appear to be sufficient to counteract the continuing and long-term cumulative impacts of the factors causing loss of hard-bottom habitat throughout the Bay.

4.16.4 Alternative 3: Harvest Moratorium

Overharvest and destructive harvest methods clearly were major factors in reducing the Bay-wide oyster population historically (i.e., through about 1930, Figure 1-1); however, the consequences of harvest at current levels, with currently legal methods, and exploiting the existing depressed oyster stock appear to be less significant (Section 4.1.4). Terminating all oyster harvest Bay-wide would eliminate one of the cumulative stressors on the remnant Eastern oyster population, regardless of the magnitude of its specific effect Cessation of harvesting could allow oysters to develop resistance to Dermo and MSX more quickly than it would develop when large, old oysters are being harvested from exploitable bars. The rate at which disease resistance would develop with or without harvesting cannot be estimated, and the length of time it might take for the Bay-wide stock to become disease resistant if harvest was eliminated has not been determined. If development of disease resistance were to take an extended period of time, this alternative would not contribute to reversing the cumulative impact of all the factors contributing to loss of hard-bottom habitat throughout the Bay. Cessation of commercial oyster harvest, even only temporarily, would further exacerbate economic consequences for watermen faced with the declining numbers of species they exploit, and some watermen have indicated they would be unlikely to re-enter the fishery after a temporary moratorium (Section 4.6.1.4). A consequent decline in the community of watermen could contribute to more rapid socioeconomic changes in shoreline communities and facilities. Increases in oyster populations in some sections of the Bay in response to a harvest moratorium (Section 4.1.4) could result in local ecosystem changes that would counteract the cumulative effects of watershed development and pollutant loading to the Bay, although the effects are likely to be small because of the modest levels of increase expected.

4.16.5 Alternative 4: Cultivate Eastern Oysters

The development of a large and economically viable aquaculture industry in the Bay could contribute to revering the effects of watershed development and nutrient and sediment loading locally in the vicinity of operations, depending on the location and density of new or expanded aquaculture operations. If on-bottom culture were employed, it could contribute to local reversal of the continuing loss of hard-bottom habitat. Bar maintenance required to cultivate Eastern oysters on the bottom would contribute to maintaining the amounts of hard-bottom habitat available locally. If watermen were able to pursue aquaculture opportunities, this alternative could help reverse the economic stress within that community caused by the continuing decline in oysters and other exploited species. Expansion of the aquaculture industry could result in local shoreline development, possibly in currently under-developed locations that are particularly suited for aquaculture. Such development would further compound the shoreline development stressors affecting the watershed.

4.16.6 Alternative 5: Cultivate a Nonnative Oyster

Cumulative effects of this alternative initially would be similar to those described for Alternative 4. The development of a large and economically viable aquaculture industry in the Bay could contribute to reversing the effects of watershed development and nutrient and sediment loading locally, depending on the location and density of new or expanded aquaculture operations. The confined methods of cultivation expected to be required in this industry could contribute to stresses affecting some rare, threatened, and endangered species by interfering with their movements, foraging behavior, or both. If watermen were able to pursue aquaculture opportunities, this alternative could help reverse the economic stress within that community caused by the continuing decline in oysters and other exploited species. Expansion of the aquaculture industry could result in local shoreline development, possibly in currently under-developed locations that are particularly suited for aquaculture. Such development would further compound the shoreline development stressors affecting the Chesapeake Bay watershed.

One difference between Alternative 4 and Alternative 5 is that cultivating triploid Suminoe oysters poses the risk of unintentionally establishing a reproductive population in the Bay. The time required for a reproductive population be initiated, become established, become abundant, and spread throughout the Bay as a result of aquaculture operations using triploids would be much longer than expected under the proposed action. If and when such a widespread and abundant population developed, the effects would be as described in Section 4.1.1 for the proposed action.

4.16.7 Alternative 8: Combination of Alternatives

Combination 8a. – Eastern oyster only. - The potential contribution to cumulative impacts under this combination is less than under the other two. Increases in oyster populations in low-salinity sections of the Bay could result in local ecosystem changes that would counteract some of the cumulative effects of watershed development and pollutant loading to the Bay, although the effects are likely to be small. Much of the increase in the oyster population would be on bars protected from harvest; therefore, this alternative would not contribute to reversing the adverse economic effects on watermen that have resulted from declines in oysters and other exploited species. Cessation of commercial oyster harvest would further exacerbate economic consequences for watermen faced with the declining numbers of species they exploit. A consequent decline in the community of watermen could contribute to more rapid socioeconomic changes in shoreline communities and facilities.

Implementing enhanced Eastern oyster aquaculture could contribute to local reversal of the continuing loss of hard-bottom habitat, if on-bottom culture methods were used. If watermen were to pursue aquaculture opportunities, this alternative could help reverse the economic stress within that community caused by the continuing decline in oysters and other exploited species.

Combination 8b. – Native oyster and triploid Suminoe oysters. - Cumulative impacts of this combination are similar to those identified for combination 8a with one exception. Because triploid Suminoe oysters are resistant to MSX and Dermo, they could be cultivated over a larger portion of the Bay than the Eastern oyster. As a result, the cumulative economic benefits could be realized over a greater geographical area throughout the Bay than under combination 8a.

Combination 8c. – Native oyster and both diploid and triploid Suminoe oysters. - This combination of alternatives has the highest potential to increase oyster abundance because it includes the proposed action; however, many factors could preclude that potential from being realized. If the Suminoe oyster were to be successfully introduced into the Bay and become abundant and widespread and it could

- contribute to local improvements in water quality and help counteract the effects of factors such as watershed development and nutrient and sediment runoff;
- contribute to the development of oyster reefs that would help to counteract the loss of hard-bottom habitat;
- contribute to enhancing populations of species that depend on oyster reef habitat; and
- reverse the decline in the Bay's oyster fishery and create a means of sustaining the watermen's culture in the Bay, counteracting the consequences of declines in other exploited species, such as the blue crab.

Successful introduction of the Suminoe oyster also could have unintended negative consequences:

- adding to the multiple stressors that have contributed to the decline of the Eastern oyster in the Bay (e.g., diseases, habitat loss), although the interactions between the species might have both positive and negative consequences;
- altering the natural biodiversity of the Chesapeake Bay ecosystem, adding to the changes in biodiversity resulting from all of the previous intentional and unintentional introductions of nonnative species;
- reducing market prices for oysters and other negative economic consequences.