2 Description of the Proposed Action and Alternatives

2.1 DEVELOPMENT OF THE PROPOSED ACTION AND ALTERNATIVES

2.1.1 Estimating a Benchmark Population Based on the Statement of Purpose

The size of the Bay-wide oyster population between 1920 and 1970 cited in the statement of purpose defined for this PEIS (Section 1.1.2) was never documented; therefore, the population during that time had to be estimated to establish a benchmark for evaluating the extent to which the proposed action or alternatives might be capable of meeting the stated goal. The numerous assumptions that were required to estimate the historical benchmark population, which are discussed below, illustrate the deficiencies in knowledge about the dynamics of the Eastern oyster population in Chesapeake Bay. The uncertainties created by those deficiencies are noted and their consequences are addressed in the analyses presented in Section 4.

Recorded commercial landings were the only historical data available from which to estimate the average abundance of oysters between 1920 and 1970; therefore, the size of the benchmark population had to be estimated in terms of the number of market-size oysters (more than 3 inches long). The average annual harvest between 1920 and 1970 was on the order of 35 million pounds (Figure 1-1), which is roughly equivalent to five million bushels. Applying the estimate of 275 market-size oysters per bushel used in the economics analyses for this PEIS (Appendix D), 5 million bushels would contain 1.4×10^9 market-size oysters.[1] No estimates of annual exploitation rates[2] are available for 1920 through 1970. Annual exploitation rates in Maryland from 1994 to 2007 have been estimated to range from 8% to 18% (Table 7 in Attachment 7 of Appendix A). As discussed in Section 4.1.4, oyster populations are unlikely to be able to sustain harvest rates greater than about 20% per year (E. Powell, Rutgers University, pers. comm.). If historical exploitation rates between 1920 and 1970 ranged from 8% to the 20% considered to be the maximum sustainable range, the number of market-size oysters in any given year needed to support an average annual harvest of 5 million bushels over several decades would range between 6.9×10^9 and 1.7×10^{10}. The midpoint of this range (i.e., 12 billion market-size oysters), therefore, affords a roughly estimated goal that is consistent with the statement of purpose defined for this PEIS. The outcomes of the proposed action and alternatives were evaluated against that benchmark.

[1] The number of oysters in a bushel varies depending on the size distribution of the oysters being harvested. It also differs between Maryland and Virginia: a "Virginia bushel" is 7% larger in volume than a "Maryland bushel." The value of 275 oysters per bushel was used as the standard unit in all analyses reported in this Draft PEIS.

[2] The term "annual exploitation rate" refers to the percentage of the population of market-size oysters that is removed from the population in a year.

Many analyses in Section 4 (Environmental Consequences) as well as the estimated size of the oyster population shown in Figure 1-3, are reported in terms of the projected biomass of the total oyster population; however, the benchmark goal could not be expressed in those terms for two reasons. First, it is not possible to estimate the number of oysters smaller than market size that would be required to maintain a population of 12 billion market-size oysters. When conditions favor settlement and survival of oyster spat, even a small number of oysters can quickly increase into a large population because of the species' enormous reproductive potential (Section 1.3.1); furthermore, in the absence of virulent diseases, oysters are long-lived. A single year of very successful spawning, therefore, could result in a large number of market-size oysters being available to harvesters for several years if the intensity of fishing effort remained fairly constant, while during those same years the number of small oysters might decrease as a result of poor spawning conditions (i.e., large volume of fresh-water inflow). Second, the benchmark estimate of 12 billion market-size oysters, which was calculated using exploitation rates and annual harvests, is based on the premise that landings from 1920 to 1970 all were from public bars open to oystering. This assumption probably was true for harvests from Maryland but is not likely to have been true for harvests from Virginia. About two-thirds of Virginia's oyster harvest historically has been supported by private investment on leased grounds (J. Wesson, VMRC, pers. comm.). This system of aquaculture produces landings that would not occur independently of the manipulation of shell and seed by growers and, therefore, that are not totally dependent on the health and status of the wild oyster stock. Depending on the proportion of harvest between 1920 and 1970 that was supported by private investment in Virginia, which is unknown, the size of the wild stock required to support average annual landings of 5 million bushels over several decades could be considerably smaller than the estimated benchmark of 12 billion market-size oysters.

In fact, if taken to its logical conclusion, expanding aquaculture to produce 5 million bushels of oysters a year could achieve one element of the stated goal in the absence of any wild stock in the Bay. The statement of need for the actions being evaluated in this PEIS clearly states, however, that "a need exists to restore the ecological role of oysters in the Bay and the economic benefits…." Although large-scale aquaculture of oysters in Chesapeake Bay probably would produce local ecological benefits (e.g., improvements in water quality), cultivated oysters would not be capable of providing the magnitude and kinds of ecological services throughout the Bay that a fully restored stock of wild oysters would produce (Sections 4.2.5 and 4.2.6). The analyses presented in Section 4.1 illustrate a potential contradiction inherent in the statement of purpose between the goals of restoring the ecological services of an abundant wild stock of oysters and restoring the economic contributions of the oyster fishery when the proposed action or alternatives are considered individually as potential means of reaching those goals. The combinations of alternatives developed by the lead agencies when the Draft PEIS was near completion, all of which include aquaculture of one or both species of oysters (E.4.9), provide a possible approach for resolving that contradiction.

2.1.2 Defining the Proposed Action

Maryland and Virginia proposed to introduce the disease-resistant Suminoe oyster into the Bay because oyster diseases appear to be a major factor inhibiting the recovery of the Eastern oyster population (Section 1.4). Proponents of the proposed action reasoned that introducing a disease-resistant oyster might be a cost-effective means of restoring the Bay's oyster population if the species is able to survive, reproduce, and colonize the large portions of the Bay where the Eastern oyster is currently depleted. A population capable of sustaining itself in Chesapeake Bay could supplement the stock of Eastern oysters that is being augmented (i.e., by planting seed oysters) through current restoration programs and also might increase the amount of shell in the Bay. Introducing a nonnative species, however, might also result in introducing devastating new diseases to which native organisms might be vulnerable. The wording of the proposed action developed by the PDT with public input obtained during scoping accounts for that concern as follows:

The State of Maryland and Commonwealth of Virginia propose to introduce the nonnative Suminoe oyster into the tidal waters of Maryland and Virginia for the purpose of establishing a naturalized, reproducing, and self-sustaining population of this Asian species. Diploid Suminoe oysters would be propagated from existing third or later generations of the Oregon stock of this species, in accordance with the ICES Code of Practices on the Introductions and Transfers of Marine Organisms 1994 (ICES 1995). Diploid Suminoe oysters produced in hatcheries would be deployed first on State-designated sanctuaries (separate from native oyster restoration projects), where harvesting would be prohibited permanently, then on harvest reserves and special management areas, where selective harvesting would be allowed. The States further propose to continue efforts to restore the native Eastern oyster throughout the Chesapeake Bay by using the best available restoration strategies and stock assessment techniques, including maintaining and expanding the existing network of sanctuaries and harvest reserves, enhancing the brood stock, and supplementing natural recruitment of the species with hatchery-produced spat.

The use of the Oregon stock and ICES protocols to introduce the Suminoe oyster were proposed to minimize the risk of introducing new diseases (Section 4.1.1 and Appendix B - Section 4.2.3). DNR, VMRC, and PRFC developed a representative plan for implementing the proposed action to serve as input to analyses for the Draft PEIS; that plan is described in detail in Section 4.1.1. The representative implementation plan was designed to be reasonably realistic, but not to be a specific recommendation for an introduction, if that is selected as the preferred alternative. The plan simply represents the kinds of actions that might be taken to implement the broad programmatic proposal being evaluated. The agencies did not consider cost specifically when developing the representative implementation plan. The kind and level of effort included in the plan represent realistic expectations of increases in funding that the agencies believe might be available. The scope of the representative introduction plan was intended to be sufficient to produce a significant increase in the oyster population, and that potential outcome is investigated in this Draft PEIS. The PDT intended the cost of the representative introduction plan to be estimated as part of the economic analysis of the proposed action.

2.1.3 Defining the Alternatives

The PDT defined the alternatives to the proposed action after extensive discussion and debate. Alternative 1 is the “no action” alternative. All environmental impact statements must include a “no action” alternative to represent the baseline conditions against which to evaluate the proposed action and other alternatives. The “no action” alternative for this PEIS is simply a continuation of oyster restoration programs at the level of effort during 2004.[3] The expected outcomes of continuing restoration programs at the 2004 level, therefore, provide the benchmark for comparison with the outcomes of the proposed action and all other alternatives.

The PDT defined the seven additional alternatives described in the Notice of Intent to represent a variety of distinct strategies for attempting to achieve the stated purpose for action. They reasoned that considering a wide range of alternatives would increase the likelihood that analyses might reveal clear differences in outcomes. The alternatives represent the major approaches being advocated by different agencies or stakeholders in Chesapeake Bay oyster restoration. The scope of the alternatives is appropriately broad because this is a Programmatic EIS. Each of the broadly defined strategies for restoring oysters could be implemented in a variety of ways. PEIS analyses are not intended or designed to identify optimal implementation plans; however, as described earlier, a reasonable representative implementation plan was identified for each alternative to provide a basis for evaluating the potential outcomes of the alternatives. The PDT chose to define two somewhat different approaches for implementing Alternative 2 to reflect the range of current hypotheses about how best to distribute effort to increase the population of the native oyster (Section 2.2.2).

As in the case of the proposed action, the PDT did not consider cost while developing the alternatives. Each alternative and its representative implementation plan were developed based on knowledge of past and current oyster management and restoration programs in the Bay and on actions and programs that the PDT believes could reasonably be expected to be feasible for implementation in the future. Estimating the cost of implementing the alternatives according to the representative plans was among the analyses performed to prepare this Draft PEIS (Section 4.6.2). The estimated costs differ substantially. The outcome of an alternative probably would change if the level of effort and amount of funding were significantly different than is described for the representative plans, but such relationships were not investigated for the individual alternatives evaluated in this Draft PEIS.

Alternative 8 in this PEIS is called "Combination of Alternatives." The lead agencies defined combinations of alternatives near the completion of this Draft PEIS. Based on the analyses of the individual alternatives available at that time, several combinations were defined to explore how the distinctly different approaches represented by the individual alternatives might be combined to improve the likelihood of achieving oyster restoration goals. Analyses of Alternative 8 are based on the outcomes of the analyses of the individual alternatives.

After initial evaluations and analyses, the PDT concluded that two of the eight alternatives listed in the Notice of Intent, Alternatives 6 and 7, did not merit detailed analysis in this Draft PEIS. The basis for those decisions is presented in Section 2.3.

---

[3] PEIS preparation began in 2004.

2.2 ALTERNATIVES EVALUATED IN THE PEIS

2.2.1 Alternative 1: No Action

Alternative 1 is: ***No Action—Not taking the proposed action: Continue Maryland's present oyster restoration and repletion programs, and Virginia's oyster restoration program under current program and resource management policies and available funding using the best available restoration strategies and stock assessment techniques.***

This alternative maintains the status quo and assumes that funding and resources for oyster restoration programs would continue as they were during 2004. Details of the States' restoration activities during 2004 are presented in Attachment 5 of Appendix A. One element of those activities, the dredged-shell planting component of Maryland's repletion program, ended in 2006. Maryland has designed and will be implementing a "shell reclamation" program that involves retrieving previously planted shell that has since been covered with silt and replanting it on other bars. That effort is expected to allow the State to continue rehabilitating habitat at the level achieved previously with the dredged-shell program. Maryland also is applying for a new permit to resume the dredged-shell program. If the State obtains that permit, dredging might provide shell resources that would allow for an increase in the level of habitat restoration; however, analyses for Alternative 1 assumed that habitat rehabilitation efforts will be maintained at the 2004 level into the future.

2.2.2 Alternative 2: Enhance Efforts to Restore the Native Oyster

Alternative 2 is: ***Expand Native Oyster Restoration Program: Expand, improve, and accelerate Maryland's oyster restoration and repletion programs, and Virginia's oyster restoration program in collaboration with Federal and private partners. This work would include but would not be limited to an assessment of clutch limitations and long-term solutions for this problem and the development, production, and deployment of large quantities of disease resistant strain(s) of C. virginica (Eastern oyster) for brood stock enhancement***.

Alternative 2 was intended to provide a basis for investigating if increasing oyster restoration activities significantly beyond the level during 2004 would result in a substantial increase in the oyster population. As described in Section 4.1.3 and Attachment 5 of Appendix A, this alternative includes roughly doubling the number of acres of habitat to be rehabilitated over a 10-year period and increasing the number of seed oysters to be planted by a factor of 4.5 over 10 years. The method of rehabilitation would be the same as is being used currently: placing thin layers of clean shell on selected bars.

In developing Alternative 2, the PDT determined that two different approaches for implementing this increased effort should be considered. The 2004 Chesapeake Bay OMP recommends that Maryland focus most of its effort in low-salinity areas where disease pressure is low, and the survival rate is maximized, but the rate of reproduction is low. Some stakeholders believe that increasing restoration on sanctuaries in areas of moderate and high salinity would produce better outcomes because the rate of reproduction is greater in saltier areas and because oysters that survive and reproduce in high-salinity areas, where disease pressure is great, might contribute to the development of disease resistance within the population. Alternative 2a, consequently, would focus enhanced restoration efforts in areas of low salinity, whereas Alternative 2b would shift a significant portion of effort into areas of moderate and high salinity. Whereas all of the seed would be planted in low-salinity areas (<10 ppt) under Alternative 2a, only 55% of the sites that would be seeded in Alternative 2b would be in low-salinity areas.

During development of the Draft PEIS, peer reviewers noted that the results of restoration programs might be enhanced if all restoration resources (i.e., shell and seed) were deployed only on "best bars" in order to ensure the greatest return in oyster abundance for investments in restoration. DNR compiled statistics based on the findings of its oyster bar surveys conducted from 2003 to 2007 to identify and rank the best bars in Maryland waters. The metrics used to rank the productivity of bars included consistency of spat set, mortality rate, and number of oysters in a sample (C. Judy, DNR, pers. comm.). DNR considers these data in selecting bars for current restoration efforts, and they were used to select the bars included in the representative implementation plans for Alternatives 2a and 2b. Virginia has used similar information in planning its current and future restoration programs (J. Wesson, VMRC, pers. comm.). No data are available from which to determine if increases in the number of oysters in the Bay since 1994 would have been greater than those shown in Figure 1-3 if all restoration resources had been deployed on the highest ranked best bars (e.g., if all shell and seed were allocated to only the top 10 bars instead of being distributed over the top 20). The best-bar approach probably would result in greater oyster abundance on the best bars, but would contribute to Bay-wide restoration only if those best bars served as "impact bars" that could generate increases in the number of oysters consistently over time on bars far afield from the enhanced bars (C. Judy, DNR, pers. comm.). Detecting any beneficial far-field effects that could be attributed specifically to best-bar enhancements probably would be difficult; consequently, many years would be required to achieve a reliable test of the efficacy of the best-bar approach. Both Maryland and Virginia are considering best bars in their current and future implementation plans, and that concept is inherent in the representative implementation plans defined for Alternative 2.

Although the implementation plan for this enhanced restoration alternative includes a substantial increase in the amount of habitat to be rehabilitated, all of the rehabilitation is anticipated to be of the same kind as in 2004 (Attachment 5 of Appendix A). Another approach for increasing the amount of suitable habitat for oyster settlement and growth is to enhance existing oyster bars in ways that would mimic the three-dimensional characteristics of historical oyster reefs. Section 1.3.1 summarizes recent and continuing efforts to construct three-dimensional reefs in Chesapeake Bay and the outcomes of those efforts. 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. Constructed three-dimensional reefs have produced localized increases in oyster populations at specific sites. Mann and Powell (2007) suggested, however, that the potentially feasible scope of development of three-dimensional reefs is not likely to be sufficient to counteract the effect of the continuing loss of hard-bottom habitat throughout the Bay. The continuing loss of hard-bottom habitat is highlighted as a major obstacle to oyster restoration throughout this Draft PEIS; however, no attempt was made to determine the level of habitat alteration that might be required to restore the oyster population to the benchmark goal for the actions evaluated in this Draft PEIS.

This alternative calls for deploying disease-resistant strains of the Eastern oyster to enhance the wild brood stock in the Bay. Potential use of those strains was investigated in conducting preliminary analyses for this Draft PEIS. A general consensus among oyster researchers that using disease-resistant oysters produced in hatcheries to supplement the wild brood stock is inadvisable because of the potential for adverse genetic consequences (Section 4.1.3) resulted in dismissing that element of the alternative during initial stages of analysis. Analyses for Alternative 2 assume the use of offspring of the brood stock of wild Eastern oysters spawned in hatcheries each year in Maryland and Virginia.

2.2.3 Alternative 3: Harvest Moratorium

Alternative 3 is: ***Harvest Moratorium: Implement a temporary harvest moratorium on native oysters and an oyster industry compensation (buy-out) program in Maryland and Virginia or a program under which displaced oystermen are offered on-water work in a restoration program.***

The premise of this alternative is that if harvest is a major factor precluding recovery of the stock of Eastern oysters in the Bay, eliminating harvest for some period of time might allow the stock to rebuild to a level that would provide significant ecological services and also support a sustainable harvest in the future. The lead agencies did not specify how long the temporary moratorium might be in effect or the level of stock restoration at which harvesting might be allowed to resume. The representative implementation plan for this alternative (Section 4.1.4) assumes that a moratorium would be in place for 10 years, which was adopted as a reasonable milestone for comparing the outcomes of the alternatives. The representative implementation plan also assumes that the cost of an industry-compensation program would be no more than the income that watermen earn from their oyster harvests and that current restoration programs would continue as described for Alternative 1. Alternative 3, therefore, is similar to Alternative 1, except that harvest of wild oysters would cease for an assumed period of 10 years. One important point reflected in the evaluation of this alternative (Section 4.1.4) is that most of the oyster population that is influenced by current restoration and management is on sanctuaries and harvest reserves, where harvest is prohibited or significantly restricted. Only the portion of the Bay-wide oyster population that is on unrestricted bars that are exposed to harvest would be affected by a moratorium.

During development of the alternatives, the members of the PDT discussed the potential benefits of different strategies for managing the oyster harvest as an element of the analysis of Alternative 3. Initial Draft PEIS analyses established that the kinds of evaluations of management actions that might be possible probably would be insensitive to differences in outcomes among harvest-management strategies; therefore, no such evaluations were conducted.

2.2.4 Alternative 4: Cultivate Eastern Oysters

Alternative 4 is: ***Aquaculture: Establish and/or expand State-assisted, managed or regulated aquaculture operations in Maryland and Virginia using the native oyster species.***

After considering several possible approaches for developing a representative implementation plan for this alternative, the PDT concluded that economic feasibility should be the primary consideration. An economic demand model developed for use in analyses for this Draft PEIS (Appendix D) was used to explore how the value of oyster harvests would change in response to changes in the number of oysters entering the market. Additional analyses presented in Appendix D evaluated the economic viability of aquaculture operations as a function of the price paid for the oysters produced. As described in Section 4.1.5, outputs of those analyses were used to determine the maximum number of oysters that could be produced annually in an economically viable (i.e., profitable) aquaculture industry in the Chesapeake Bay area. Analyses of the environmental consequences of this alternative assumed the existence of the maximum viable aquaculture industry. Section 4.1.5 identifies the numerous factors that could preclude the development of the maximum industry but does not estimate the probability of attaining that level. Assuming the maximum industry as a basis for evaluating the consequences of Alternative 4 is a conservative approach because it resulted in characterizing the greatest potential benefits and the worst potential adverse effects.

Information about current aquaculture operations in Maryland and Virginia supplied by operators, managers, and regulators of those operations was used to construct a representation of where and how large-scale aquaculture might become established in the Bay (Section 4.1.5 and Appendix C). The representative plan considers using both diploid and triploid Eastern oysters because triploids of both species grow faster than diploids. The term “State-assisted” was assumed to involve technical support, not financial incentives. The economic analyses assumed that private investors would establish and expand aquaculture operations if they were profitable. In considering this alternative at the programmatic level, the lead agencies chose not to evaluate the efficiency or cost of different methods of oyster aquaculture currently being used in Chesapeake Bay or elsewhere in North America or the world. Analyses designed to identify the economically optimal methods of cultivating oysters in Chesapeake Bay might be appropriate for developing a specific implementation plan, if aquaculture is ultimately adopted as the preferred alternative.

2.2.5 Alternative 5: Cultivate a Nonnative Oyster

Alternative 5 is: ***Aquaculture: Establish State-assisted, managed or regulated aquaculture operations in Maryland and Virginia using suitable triploid, nonnative oyster species.***

This alternative specifies the use of a triploid nonnative species but is not limited to the Suminoe oyster. Some initial studies indicated that the Suminoe oyster survives better and grows faster in Chesapeake Bay than the Eastern oyster does and, therefore, is a good candidate for aquaculture in the Bay. Several oyster growers in Virginia who participated in field trials with triploid Suminoe oysters found such operations to be profitable (Section 4.6.2.6); therefore, the PDT included this alternative in this Draft PEIS to provide a basis for comparing the pros and cons of aquaculture using the native oyster with those of using a nonnative oyster. A review of studies of nonnative species other than the Suminoe oyster that have been considered for use in aquaculture in Chesapeake Bay was performed as a preliminary assessment of Alternative 6. Based on that review, which is described in Section 2.3.1, the Suminoe oyster was determined to be the only nonnative species considered to date that has suitable environmental tolerances and could be economically viable for aquaculture in the Bay, and for which available information would support an acceptable level of analysis of the potential environmental consequences of growing the species in Chesapeake Bay. Evaluations for this alternative, therefore, considered only the use of triploid Suminoe oysters in nonnative aquaculture.

The alternative specifies the use of triploids for two reasons. First and most importantly, many stakeholders are concerned that using a nonnative species in aquaculture could result in accidentally introducing a potentially reproductive population into the Bay, as has occurred elsewhere throughout the world (e.g., the invasion of the Wadden Sea in the Netherlands by Pacific oysters brought to the area for use in aquaculture). Genetically altered triploid oysters generally are almost completely sterile and, therefore, are believed to be unlikely to contribute to an accidental introduction. The probability that producing and using triploid Suminoe oysters in aquaculture would result in an unintended introduction of reproductively capable diploids is explored in detail in Section 4.3 of Appendix B and discussed in Section 4.1.6 of this Draft PEIS. Second, triploids of any species grow faster than diploids of the same species because their energy is devoted to growth instead of to reproduction; therefore, using triploids enhances the potential production of an operation.

Producing triploid oyster spat and constructing and operating the biosecure facilities that would be required to cultivate a nonnative species and minimize the risk of an unintentional introduction are likely to cost more than producing diploid spat and building and operating hatcheries that do not require biosecurity measures. Furthermore, evaluations of this alternative assume that nonnative triploids would be contained in bags or cages when deployed to further reduce the risk of releasing them into the Bay. Section 4.6.2.6 discusses the economic consequences of those factors for aquaculture production of triploid Suminoe oysters.

The same approach used to define a representative implementation plan for Alternative 4 was used in developing the plan for this alternative. The discussion presented in Section 4.6.2.6 addresses the fact that Suminoe oysters may have different economic value than Eastern oysters, depending on the composition of the oyster market, and that the differing value could influence how these two aquaculture alternatives might evolve over time. Oysters for the half-shell market draw higher prices than oysters for the shucking market, and some attributes of the Suminoe oyster appear to make it less suitable for the half-shell market than the Eastern oyster. That issue and its implications for the success of aquaculture operations using triploid Suminoe oysters are discussed in the economic analyses presented in Section 4.6.2.6. As it was for Alternative 4, the representative implementation plan for this alternative was developed assuming that methods of cultivation to be used in the future would be the same as those currently in use in Chesapeake Bay. The analysis of this alternative was not designed or intended to identify the economically optimal methods of cultivating triploid Suminoe oysters in Chesapeake Bay.

2.2.6 Alternative 8: Combination of Alternatives

This alternative includes three combinations of oyster restoration activities included among those evaluated in this Draft PEIS. The combinations, which were defined by the lead agencies after analyses of the proposed action and other alternatives were near completion, arose from the recognition that a combination of those actions would have the greatest potential to restore the economic, cultural, and ecological benefits of oysters in Chesapeake Bay. The combinations are presented to provide stakeholders with the opportunity to consider and comment on an effort that would include the most promising elements of the proposed action and other alternatives. In considering the potential benefits and risks of each of these combinations, the lead agencies recognized that financial and physical constraints (e.g. oyster hatchery capacity, shell resources) might require some activities included as part of a combination to be implemented on smaller scales than were considered in evaluating the individual alternatives and the proposed action. The lead agencies will identify management actions that would best meet restoration objectives of the States of Maryland and Virginia after stakeholders have had an opportunity to review and comment on the proposed action and individual alternatives and the following combinations of alternatives:

- **Combination 8a –** Eastern oyster only
  - Alternative 2: Enhance efforts to restore Eastern oysters
  - Alternative 3: Impose a temporary harvest moratorium and a compensation program for the oyster industries
  - Alternative 4: Cultivate Eastern oysters

- **Combination 8b –** Eastern oyster and triploid Suminoe oysters
  - Alternative 2: Enhance efforts to restore Eastern oysters
  - Alternative 3: Impose a temporary harvest moratorium and a compensation program for the oyster industries
  - Alternative 4: Cultivate Eastern oysters
  - Alternative 5: Cultivate triploid Suminoe oysters

- **Combination 8c –** Eastern oyster and both diploid and triploid Suminoe oysters.
  - Proposed action: Introduce diploid Suminoe oyster and continue native oyster restoration
  - Alternative 2: Enhance efforts to restore native oysters
  - Alternative 3: Impose a temporary harvest moratorium and a compensation program for the oyster industries
  - Alternative 4: Cultivate Eastern oysters
  - Alternative 5: Cultivate triploid Suminoe oysters

Table 2-1 is an overview of the definition of the proposed action and alternatives considered in this Draft PEIS.

2.3 ALTERNATIVES CONSIDERED BUT ELIMINATED FROM DETAILED ANALYSIS

2.3.1 Alternative 6: Introduce Another Nonnative Oyster Species

Alternative 6 is: ***Introduce and propagate in the State sponsored, managed or regulated oyster restoration programs in Maryland and Virginia, a disease resistant oyster species other than C. ariakensis, or an alternative strain of C. ariakensis, from waters outside the United States in accordance with the ICES 1994 Code of Practices on the Introductions and Transfers of Marine Organisms.***

Table 2-1. Overview of proposed action and alternatives evaluated in the Draft PEIS for Oyster Restoration in Chesapeake Bay; Xs indicate expected conditions for each of the alternatives.

Alternative # / Description	**Funding for Effort to Restore the Native Oyster**		**Harvest Restrictions***		**Aquaculture**		**Deployment of Nonnative Oyster**		
	Status Quo	**High**	**As Is**	**Moratorium**	**As Is**	**Increased**	**None**	**Diploid (Fertile)**	**Triploid (Sterile)**
Proposed Action – Introduce Suminoe Oyster and Continue Effort to Restore Eastern Oyster	X		X		X			X	
1 – No Action	X		X		X		X		
2a – Enhance Native Restoration (100% in low salinity)		X	X		X		X		
2b – Enhance Native Restoration (55% in low salinity)		X	X		X		X		
3 – Harvest Moratorium	X			X	X		X		
4 – Cultivate Eastern Oysters	X		X			X	X		
5 – Cultivate a Nonnative Oyster	X		X			X			X
8a – Combination (Alts. 2, 3, and 4)		X		X		X	X		
8b – Combination (Alts. 2, 3, 4, and 5)		X		X		X			X
8c – Combination (PA and Alts. 2, 3, 4, and 5)		X		X		X		X	X

* For evaluations of the proposed action and alternatives, harvest restrictions were limited to either “as is” or “moratorium.” Implementation of the proposed action, any alternative, or any combination of alternatives is likely to involve regulatory changes other than those presented in this table.

The suitability of nonnative oyster species other than the Suminoe oyster for propagation in the Chesapeake Bay was reviewed in two studies. Mann et al. (1991) reviewed ranges of temperature and salinity for growth of larvae and adults and for optimal spawning of various species of oysters of the genera *Crassostrea* and *Ostrea*. Carriker and Gaffney (1996) reviewed the native ranges and areas of successful naturalization of several species of oysters as well as the maximum sizes they attain. Results of these two studies are summarized in Table 2-2.

Of the species examined by Mann et al. (1991), only the Pacific oyster (*C. gigas*)[4] has growth and spawning ranges similar to those of the Eastern oyster. *O. edulis* has a similar temperature range for growth but a very narrow temperature range for spawning. All other species seem to prefer temperature and salinity in higher ranges than those that are optimal for the Eastern oyster. The Pacific oyster accounts for 80% of the world's commercial oyster harvest (Ayer 1991). The Pacific oyster has been introduced successfully in many areas of the world including France, Oregon and Washington (United States), Western Canada, Australia, and New Zealand (Shatkin 1997). The Pacific oyster is more tolerant of Dermo and MSX than the Eastern oyster (Calvo et al. 1999; Gottlieb and Schweighofer 1996; Mann et al. 1991; Barber and Mann 1994) and can co-exist with the Eastern oyster, as observed in British Columbia (Bourne 1979).

Of the species reviewed, only the Pacific oyster has been studied in the Bay and other East Coast waters. Several studies examined the potential for survival and growth of Pacific oysters in Chesapeake Bay and North Carolina. Barber and Mann (1994) compared the growth and survival of Eastern and Pacific oysters in the presence of the parasite that causes Dermo by holding specimens in quarantined flumes that received water from the York River, Virginia. Although many Pacific oysters in that study accumulated parasites within their tissue (i.e., high prevalence), the rate of mortality due to Dermo disease was not great (i.e., low disease intensity). In contrast, Eastern oysters in the study showed high parasite prevalence and high intensity of Dermo disease. Mortality was great among Pacific oysters in the experiment, but the researchers attributed it to an extended period of exposure to salinity less than 20 ppt. The prevalence of the Dermo parasite in Pacific oysters was not high during the episode of mortality. Calvo et al. (1999) determined that triploid Pacific oysters "out-performed" triploid Eastern oysters only at salinities greater than 25 ppt in the Virginia portion of Chesapeake Bay. At salinities less than 15 ppt, Eastern oysters grew significantly faster and experienced less mortality than Pacific oysters. At medium salinities (15-25 ppt), the rates of growth and mortality of Eastern and Pacific oysters were not significantly different. At low and medium salinities, Pacific oysters in the study showed heavy infestations of the parasite *Polydora*, which produces mud-filled blisters on the inner surfaces of the shell. The Pacific oyster was deemed a poor candidate for aquaculture in Chesapeake Bay because of its relatively poor performance at low salinity and greater susceptibility to mud blisters (NRC 2004). At sites in North Carolina with salinities of 25 to 36 ppt, rates of growth and mortality among Pacific oysters were significantly greater than those among Eastern oysters; however, Eastern oysters "out-performed" Pacific oysters in areas with salinities between 15 and 25 ppt (Grabowski et al. 2004).

[4] The Pacific oyster is sometimes called the Japanese oyster.

Table 2-2. Comparison of environmental preferences and tolerances of nonnative oysters considered for use in Chesapeake Bay

General Characteristics				Adults				Larvae	
				Temp. (°C)		Salinity (ppt)		Temp. (C)	Salinity (ppt)
Species	**Native Range**	**Introduced**	**Max. Size (cm)**	**Growth**	**Spawning**	**Growth**	**Spawning**		
Crassostrea angulata	Southern Europe, Portugal	France	18	20-30	7-40 (30-40)*	21-43	< 32		21-43 (28-35)
C. gasar	Central Western Africa, Senegal to Angola		large	25-30	5-34	14-20			
C. gigas	Indo-West Pacific to Pakistan to Japan, Korea, Philippine Islands; Borneo, and Sumatra; along the Chinese coast	Western Coasts of Canada, U.S., Mexico; Chile, Korea, Taiwan, New Zealand, Australia, coastal European countries	40-45	3-35 (11-34)	16-30 (20-25)	10-42 (35)	10-30 (20-30)	18-35 (30)	19-35
C. gryphoides	NW coast of India		17	19-33	27-31	4-40 (30-40)	13-29		
C. iredalei	Philippines, Southwest Asia		Large	30-33	< 45	> 15			
C. madrasensis	India, China, Pakistan		21	26 (30)	1-40 (8-25)	17-35 (20-35)			
C. rhizophore	Gulf of Mexico, Caribbean, Brazil	Maine, Eastern Canada. Japan	15			22-40 (26-37)		< 30 (25)	20-40 (28)
Ostrea edulis (= *O. taurica*)	From Norway and British Isles to Morocco; Mediterranean, Black, Aegean, and Marble Seas		11	3-28	17-18				

* Values in parentheses are average ranges. For example, *C. angulata* can spawn at temperatures ranging from 7°C to 40°C, but the average temperature for spawning is between 30°C and 40°C.

Anecdotal evidence of several unsuccessful attempts to introduce the Pacific oyster into Chesapeake Bay and surrounding areas has been recorded (NRC 2004). In the early 1930s, a couple of bushels of Pacific oysters were planted in Barnegat Bay (Andrews 1980). Those oysters failed to grow and died within two years, possibly due to low salinity (12-20 ppt) and insufficient DO (NRC 2004). A couple of trays of Pacific oysters were kept in Rehoboth Bay for several years without significant mortality or successful reproduction (Andrews 1980). During the 1970s, a Maryland seafood dealer obtained some Pacific oysters from the West Coast and planted them in the Maryland portion of Chesapeake Bay (Andrews 1980). The oysters were recovered by scuba divers, and a law specifically prohibiting the introduction of Pacific oysters was passed to discourage similar attempts. Carlton (1992) reported that sometime between 1988 and 1990, thousands of bushels of Pacific oysters were introduced illegally into the Chesapeake Bay; however, no population appears to have become established as a result of that introduction. Based this information and the findings of the reviews summarized above, it was concluded that no nonnative oyster considered to date other than the Suminoe oyster appears to have significant potential for successful reproduction or propagation in Chesapeake Bay.

Alternative 6 also refers to introducing a strain of the Suminoe oyster other than the Oregon stock. Proponents of this suggestion reasoned that reduced genetic variability in the Oregon stock could limit the ability of Suminoe oysters descended from that stock to survive and propagate in a new environment. Studies using molecular techniques have shown that all current hatchery stocks of the Suminoe oyster in the United States have reduced genetic variability compared to wild populations and little differentiation from each other (Cordes and Reece 2007). Many generations of inbreeding within a small starting population can limit the genetic diversity of the population, which can reduce its resilience to selective pressures such as disease, predators, and extreme weather. In a genetically diverse population, if a strong selective pressure kills a large portion of the population, some genetic variants will be able to withstand the selective pressure and continue to produce offspring. The more genetically varied the population is, the greater the variety of selective pressures it can withstand. Introducing a strain of Suminoe oysters obtained from a population outside the United States that has greater genetic variability than the Oregon stock, therefore, might increase the likelihood of establishing a self-sustaining population in Chesapeake Bay.

Researchers at VIMS have imported other strains of the Suminoe oyster from the Yellow River estuary (Northern China *ariakensis*) and from the Guanxi Province (Southern China *ariakensis*) for comparative studies (NRC 2004). Some researchers, including Zhou and Allen (2003), have observed that the taxonomy of *C. ariakensis* has been confused in Asia with several other *Crassostrea* species. Zhang et al. (2005) recently provided more precise taxonomic clarification of *C. ariakensis* in its native range as well as in hatcheries in the United States. Oyster samples were taken from northern and southern China, from southern Japan, from four groups of *C. ariakensis* at the VIMS hatchery, and from oysters at the Taylor Hatchery in Washington State. Significant genetic variation was found between the oysters from northern and southern China. The southern oysters that were thought to be *C. ariakensis* were re-classified as *C. hongkongensis* based on genetic evidence; the northern oysters were determined to be *C. ariakensis*. The VIMS Aquatic Genetics and Breeding Technology Center currently maintains two other strains of the Suminoe oyster besides the Oregon stock (which has been labeled WCA). One was imported from the Yellow River area, labeled NCA for northern China *ariakensis*. The NCA are genetically very similar to the WCA, which originated from Japan, and the two have been cross-bred. The offspring were labeled WNA. WNA is not another strain, but rather, is a derivative with genetic characteristics of the two parent populations. One additional strain was obtained from southern China and has been labeled SCA. SCA are genetically distinct from either NCA or WCA, are kept separately, and have not been hybridized. All tests of the Suminoe oyster in the Chesapeake Bay area, both in the lab and in the field, have used WCA (i.e., the Oregon stock) to ensure consistency over all studies and all study years. The WNA population is likely to offer greater genetic diversity than the WCA strain; however, no field or comparative studies using the hybrid have been conducted to date. As a result, no information is available for use in assessing the merits of an introduction using the WNA strain.

This alternative was dismissed from detailed analysis in this Draft PEIS due to the lack of information about a suitable alternative nonnative species and the lack of information about the probable behavior of other strains of the Suminoe oyster in Chesapeake Bay.

2.3.2 Alternative 7: Introduce the Suminoe Oyster and Discontinue Efforts to Restore the Eastern Oyster

The Notice of Intent presented Alternative 7 as the "combination of alternatives." Following scoping meetings and further discussion among the lead agencies and other members of the PDT, one additional alternative was created, and the "combination of alternatives" became Alternative 8. Alternative 7 as defined after scoping is: ***Introduce the oyster species, Crassostrea ariakensis, into the tidal waters of Maryland and Virginia for the purpose of establishing a naturalized, reproducing, and self-sustaining population of this oyster species. Diploid C. ariakensis would be propagated from existing 3rd or later generation of the Oregon stock of this species, in accordance with the International Council for the Exploration of the Sea's (ICES) 2003 Code of Practices on the Introductions and Transfers of Marine Organisms. Deployment of diploid C. ariakensis from hatcheries is proposed to occur first on State designated sanctuaries where harvesting would be prohibited permanently, and then on harvest reserve and special management areas where only selective harvesting would be allowed***.

Biologically, this alternative is similar to the proposed action, except that any benefits (or costs) of current restoration activities for the Eastern oyster would not be realized. Section 2.1.2 noted that a population of Suminoe oysters capable of sustaining itself in the Bay would significantly supplement the Eastern oyster population being augmented (i.e., by planting seed oysters) through restoration programs. The concept underlying Alternative 7 was that if the introduction of the Suminoe oyster were to result in an oyster population that grows and disperses throughout the Bay, the need for efforts to restore the Eastern oyster might decrease, potentially resulting in significant cost savings.

When considered individually, the potential outcomes of the proposed action and Alternative 1 suggested that the size of the total Bay-wide oyster population expected to result from implementing Alternative 7 would be similar to the population that might result from implementing the proposed action, although some geographical differences in any changes in oyster abundance are possible. Preliminary economic analysis of costs of the proposed action and Alternative 7 revealed that costs for Alternative 7 were only about 2% less than costs for the proposed action (Appendix D, p. 15). The primary explanation for the minimal savings is that the representative implementation plans for both strategies include habitat rehabilitation only for the continuing effort to restore the Eastern oyster; Suminoe oyster seed would be planted in areas that are assumed not to need rehabilitation. Assuming that the environmental consequences of this alternative would not differ significantly from those of the proposed action and that the difference in cost between them would be minimal, this alternative was dismissed from detailed analysis in this Draft PEIS.