APPENDIX D

ECONOMIC ANALYSIS

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Note to Readers of Appendix D

Appendix D presents the methods for and results of analyses of the economics of the oyster restoration alternatives evaluated in the PEIS. The economics analyses were reviewed by a panel of resource economists, and this appendix represents the final, peer-reviewed version of the results. Reviewers' comments and the author's responses are available at http://www.nao.usace.army.mil/OysterEIS/PeerReviews/homepage.asp.

Although the OAP was not the designated peer-review group for the economics analyses, it was responsible for the overall peer review of the PEIS prior to its publication. In that capacity, the OAP reviewed all appendices to the pre-draft PEIS during its review of that document in the summer of 2008. That review was the first opportunity that members of the OAP had to see how the economic analyses were conducted and how ODM results were used in those analyses. The OAP concluded that PEIS analyses relied too heavily on ODM results, given the substantial uncertainties associated with ODM outcomes. ODM results were employed in the economic analyses presented in this appendix specifically for estimating the economic benefits of the alternatives for the fishery and processors (see the first two sections of this appendix - Final Draft Economic Analysis for Oyster Restoration Alternatives, and Economic Analysis of Alternatives: Projecting Oyster Harvests). Because of the OAP's concerns regarding use of the quantitative predictions of the ODM, the evaluations of economic benefits for the fishery and processors presented in this appendix are not presented in Section 4.6.2 of the Draft PEIS. An alternative approach for estimating fishery and processor benefits is described in that section, but only for Alternatives 1, 2, and 3. Fishery and processor benefits for the proposed action presented in this appendix were based on exploratory ODM runs that assumed a low mortality rate and a high growth rate expected for a Suminoe-like oyster and on assumptions regarding exploitation rates that are likely to be unrealistic. In acknowledgement of the large uncertainties regarding those exploratory ODM projections, those estimates of benefits are considered to be unreliable and are not presented in Section 4.6.2. No new estimates of the benefits of the proposed action were developed because no reliable method for projecting the size of an introduced oyster population is available at this time.

D1 FINAL DRAFT ECONOMIC ANALYSIS FOR OYSTER RESTORATION ALTERNATIVES

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Final Draft Economic Analysis for Oyster Restoration Alternatives

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Alternative 1--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.

Implementation Costs of Alternative 1

We use two approaches to estimate the costs of this alternative. First, since the alternative is based on actions in 2004, we use expenditure estimates from that period as one estimate. We follow that with an estimate that is based on a more detailed description of habitat rehabilitation and seeding costs.

The Maryland and Virginia oyster restoration programs are not static in either policy or available funding. Strategies have changed over time as information is gained on effective restoration techniques and for a variety of other reasons. Funding from state and federal sources also varies greatly from year to year. Table 1 shows how expenditures have varied from 1994-2006, both in their magnitude and use on harvest bars versus sanctuaries.

The reported state and federal expenditures for oyster restoration in 2004 totaled about $7.2 million dollars. It is assumed that these costs would be the same in each year of the ten-year time horizon chosen for analysis.

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

	MD		**Potomac**		**VA**		**Combined**	
Year	**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

To calculate the net present value equivalent of these expenditures, first the $7.2 million from 2004 is inflated to $7.9 million in 2007 dollars by applying the consumer price index available from the Bureau of Labor Statistics[1]. Next, we applied a real discount rate of 2.6% as specified by Office of Management and Budget[2] (OMB) for projects of 10 years to calculate the net present value of costs for the alternative. The net present value cost of implementing Alternative 1 based solely on reported state and federal expenditures is estimated at approximately $68.8 million.

This estimate is likely an underestimate of the total costs associated with the restoration activities since it reflects only the direct state and federal appropriations for oyster restoration. Extensive monitoring and management (Mon/Man) activities accompany these restoration efforts. Maryland DNR and PRFC estimated that these annual expenditures were $1.7 million, and $0.5 million, respectively. Since no estimate was available for Mon/Man for Virginia, we approximated these to constitute the same percentage of restoration outlays as they represent in Maryland and the Potomac, 30% of the restoration costs, or about $0.8 million. Additionally, the expenditure data does not include an estimate 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. OMB Circular A-76 contains guidance on the calculation of full project costs and recommends that 12% of the activity costs be used to calculate the overhead.[3] Adding annual Mon/Man and overhead charges brings the full estimate of the net present value based on state and federal agency expenditures to $101.7 million.

A second and more detailed analysis of potential expenditures was conducted by obtaining yearly bar by bar estimates of habitat rehabilitation and seeding costs based on the scenarios provided for the demographic model (see Appendix XX). Per acre cost estimates for habitat restoration and per unit seed planting costs were obtained from Maryland DNR, VMRC and the PRFC. In this more detailed analysis we also included estimates of monitoring and management costs (Mon/Man) and overhead charges as was done above.

Annual expenditures for implementation of Alternative 1 vary over the 10 years, but on average are estimated to be around $12 million. The net present value of the ten years of expenditures at the 2.6% discount rate is $106.4 million (Table 2). While slightly exceeding our estimate based on adjusted agency expenditures, we use this estimate based on bar by bar rehabilitation because we can consistently use this approach to generate cost estimates for the other alternatives.

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[1] http://www.bls.gov/cpi/home.htm
[2] http://www.whitehouse.gov/omb/circulars/a094/a94_appx-c.html
[3] http://www.whitehouse.gov/OMB/circulars/a076/a76_rev2003.pdf

Table 2. Estimate of ten-year net present value (2.6% discount rate) of costs for implementation of Alternative 1 ($millions).

	Habitat	Seed	Mon/Man	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

Benefits of Alternative 1

Fishery Benefits

The harvest of oysters under this alternative is estimated from the oyster demographic model. The model can be run with a variety of assumptions about what the harvest rate of the population will be. The demographic modeling team determined that a 40% rate of removal of market size oysters would be used throughout the analysis to predict industry harvest levels. We use the data based on the 50th percentile results of the demographic model runs to estimate Maryland and Virginia landing for this alternative (Table 3).

Table 3 summarizes the net returns to harvesting oysters in Maryland and Virginia 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 (CB) price is based on the price flexibility from the inverse demand model detailed in Appendix D.

Table 3. Annual landings, Chesapeake Bay price, gross revenues, harvest costs and net revenues based on 40% harvest of market oysters under Alternative 1.

Year	MD Landings[1]	VA Landings[1]	CB Price	Gross Revenues	Harvest Cost	Net Revenue
1	1,003,164	1,174,494	$4.28	$9,327,729	$6,999,614	$2,328,115
2	856,245	1,218,969	$4.29	$8,907,455	$6,670,333	$2,237,122
3	494,865	1,437,212	$4.30	$8,317,167	$6,210,247	$2,106,920
4	330,762	1,364,029	$4.33	$7,330,752	$5,447,543	$1,883,210
5	301,496	909,549	$4.37	$5,289,389	$3,892,646	$1,396,742
6	281,463	839,156	$4.38	$4,903,270	$3,601,988	$1,301,282
7	266,411	610,999	$4.40	$3,857,709	$2,820,247	$1,037,462
8	265,895	360,713	$4.42	$2,768,706	$2,014,099	$754,607
9	278,871	241,470	$4.43	$2,303,977	$1,672,525	$631,452
10	295,114	179,861	$4.43	$2,104,982	$1,526,705	$578,276

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

The net present value of this stream of net revenues using the 2.6% rate of discount is $12.8 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 20-42 full-time watermen equivalents over the ten 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.

We do not have comprehensive cost and returns data on oyster processing 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. In Lipton et al. (2006) we generated 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, we calculated the gross revenues for the wholesale value of the Chesapeake Bay harvest over the ten-year time horizon. For the ten year time horizon, wholesale prices were allowed to fluctuate in direct proportion to harvest prices derived from the inverse demand model. We also subtracted out the predicted harvest cost since we know this is what the processor or wholesaler will have to pay for these oysters. Table 4 gives the annual gross wholesale value and the value net of harvest cost for the wholesale industry. The estimate of the present value of revenues net of harvesting costs at the wholesale level for Maryland harvested oysters under Alternative 1 is $35.8 million. While these revenue estimates cannot be interpreted as a benefit, this figure is helpful for comparison with revenue estimates from the other alternatives.

Table 4. 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	$16,052,448	$9,327,729	$6,724,719
2	$15,329,183	$8,907,455	$6,421,728
3	$14,313,334	$8,317,167	$5,996,166
4	$12,615,775	$7,330,752	$5,285,022
5	$9,102,713	$5,289,389	$3,813,324
6	$8,438,226	$4,903,270	$3,534,956
7	$6,638,880	$3,857,709	$2,781,171
8	$4,764,773	$2,768,706	$1,996,067
9	$3,965,003	$2,303,977	$1,661,026
10	$3,622,544	$2,104,982	$1,517,562

Indirect Benefits

Lipton et al. (2006) discuss the indirect economic benefits associated with the oyster resource, particularly the economic value of ecological services. Some of the ecological services provided by oysters that may provide economic benefit include improved water quality and habitat functions leading to:

- Larger populations of, and potentially greater industry profits and consumer benefits from other important commercial species in Chesapeake Bay such as striped bass and blue crab

- Larger populations and potentially greater economic benefits from important Chesapeake Bay recreational species

- Improved water clarity leading to higher values for other forms of Chesapeake Bay recreation such as swimming and boating, and higher values for waterfront profit

Calculation of the economic benefits related to ecological services from oyster populations would require quantification of the ecological changes related to oyster populations. These quantifications have not been estimated for the alternatives, and thus, it is not possible to estimate the indirect economic benefits for each alternative. The Ecological Risk Assessment (ERA, see Appendix Y) uses a relative risk model (RRM) to assesses the relative positive and negative influences associated with changes in habitat, food, and water quality. 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 RRM does not predict the actual magnitudes of changes or risks such as the increase or decrease in abundance. Thus, the ERA can be used only as a general guide to the direction of change in potential indirect economic benefits from one alternative compared to another. Even then, caution must be taken in interpreting positive ecological interactions as indicators as positive economic benefits. In a complex ecosystem such as Chesapeake Bay what appears to be a positive ecological interaction between oyster abundance and other organisms can result in negative economic consequences.

The RRM for this alternative shows declining scores for all but the Maryland oligohaline region of Chesapeake Bay. Since these declines are occurring from an already significantly reduced ecological impact of oysters in the Bay, it is unlikely that this alternative will lead to additional declines in indirect economic value from the resource. It is also not anticipated that the increase in oyster biomass in the Maryland oligohaline will be significant enough to result in indirect economic benefit in this section of the Bay.

Alternative 2--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 not be limited to an assessment of cultch limitations and long-term solutions for this problem and the development, production, and deployment of large quantities of disease resistant strain(s) of C. Virginia (Eastern Oyster) for brood stock enhancement.

Costs of Alternative 2
Implementation of Alternative 2 requires a major increase in investment in the habitat rehabilitation and seeding program as outlined in [insert section]. The same cost factors for habitat and seed as were used to determine the detailed cost estimates for Alternative 1 are used to determine the detailed cost for Alternative 2. Implicitly this assumes that the analysis fails to capture any economies of scale that might accrue to this expanded effort. Conversely, we feel that monitoring and management costs will not increase in proportion to the overall habitat and seeding program, although we do believe they will increase. To represent the increase we estimate monitoring and management cost to be equal to those costs under Alternative 1 plus 10% of the incremental habitat and seed costs for Alternative 2.

Table 5. Estimate of ten-year net present value (2.6% discount rate) of costs for implementation of Alternative 2 ($millions).

	Habitat	Seed	Mon/Man	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

Benefits of Alternative 2

Fishery Benefits
The amount of oysters harvested under this alternative was based on results of the oyster demographic model (Table 6). Over the ten year period, oyster harvests increase by 69% compared to the no action alternative.

Table 6. Annual landings, Chesapeake Bay price, gross revenues, harvest costs and net revenues based on 40% harvest of market oysters under Alternative 2.

Year	MD Landings	VA Landings	CB Price	Gross Revenues	Harvest Cost	Net Revenue
1	1,003,164	1,174,494	$4.28	$9,327,729	$6,999,614	$2,328,115
2	856,750	1,222,990	$4.29	$8,926,063	$6,684,882	$2,241,181
3	495,587	1,471,666	$4.30	$8,462,561	$6,323,313	$2,139,248
4	396,463	1,387,207	$4.32	$7,701,380	$5,733,226	$1,968,154
5	555,747	925,579	$4.34	$6,434,979	$4,761,407	$1,673,573
6	732,897	834,952	$4.34	$6,799,014	$5,039,513	$1,759,501
7	995,410	594,351	$4.33	$6,891,000	$5,109,945	$1,781,055
8	1,442,841	365,357	$4.32	$7,803,418	$5,812,065	$1,991,353
9	2,477,660	255,357	$4.23	$11,574,258	$8,784,697	$2,789,561
10	4,113,489	196,947	$4.10	$17,661,994	$13,854,975	$3,807,019

The net present value of the increased oyster harvest under this alternative is $19.4 million, a 51% increase over Alternative 1. The increased harvestable population in this scenario can support from 33-71 full-time equivalent watermen. In contrast to Alternative 1, the number of watermen supported increases over the ten years. Near the end of the period, the significant increases in Maryland more than offset the industry decline in Virginia.

Processor Benefits/Consumer Benefits

We assume the same ratio of halfshell to shucked oysters in the wholesale marketplace as Alternative 1. We also assume that wholesale prices move in proportion to estimated harvest prices. The present value of wholesale revenues increases over alternative 1 by 58% to $56.8 million under Alternative 2. This represents an increase in revenues associated with locally caught oysters, but again, not necessarily a net increase in overall processed oyster production if it is simply replacing imported shellstock. However, if there are higher processor profits with locally produced oysters compared with imported shellstock, the increase in revenue net of harvest cost could serve as an indicator of processor benefits. Similarly, if consumers prefer local oysters to those produced from imported shellstock they will benefit in similar proportion.

Table 7. Estimated wholesale value for projected oyster harvest from Chesapeake Bay for Alternative 2.

Year	Gross Revenue	Oyster Cost	Revenue Net of Oyster Cost
1	$16,052,448	$9,327,729	$6,724,719
2	$15,361,205	$8,926,063	$6,435,143
3	$14,563,548	$8,462,561	$6,100,987
4	$13,253,601	$7,701,380	$5,552,222
5	$11,074,204	$6,434,979	$4,639,225
6	$11,700,686	$6,799,014	$4,901,672
7	$11,858,987	$6,891,000	$4,967,987
8	$13,429,202	$7,803,418	$5,625,785
9	$19,918,586	$11,574,258	$8,344,328
10	$30,395,206	$17,661,994	$12,733,212

Indirect Benefit

The overall RRM scores for this alternative are significantly higher in the Maryland oligohaline compared with Alternative 1, and positive in other areas except Virginia polyhaline. Because this alternative entails significantly more habitat rehabilitation than Alternative 1, it has significantly higher positive RRM for hard bottom habitat and reef associated fish. As discussed in Lipton et al. (2006) and analyzed in Hicks et al. (2004), recreational anglers show a preference for fishing on hard bottom habitat and 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 adding to 1,890 restored acres of oyster bottom 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. Since their analysis is dependent on the location of the restoration projects relative to fishing activity in Chesapeake Bay, the specific location of habitat restoration in Alternative 2 will provide different results; however, this does serve as a relative indicator of indirect benefits in the form of recreational fishing resulting from oyster habitat restoration.

Comparison of Alternatives 2a and 2b
As described in section{?}, Alternative 2 has two scenarios that differ based on the strategy of seeding in the sanctuary areas. The analysis above is based on the planting strategy for Alternative 2a. While a similar analysis was conducted for Alternative 2b, the difference in restoration costs between the two scenarios was extremely small. Fishery benefits also did not differ significantly between the two scenarios. Given the large uncertainties in economic data, these two alternatives are virtually indistinguishable from an economic perspective.

Alternative 3--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.

Costs of Alternative 3

For harvesters, foregone net income is a measure of the cost of imposing the moratorium. The foregone net income depends on which restoration scenario the moratorium is imposed upon. Under Alternative 1, the foregone net present value of net income is $12.8 million, but rises to $19.4 million under Alternative 2. A buy-out program that compensates watermen for foregone net income does not impact the estimate of costs; it simply shifts the costs of the moratorium from the watermen to the public sector. Hiring displaced watermen preferentially to conduct on-water restoration is also simply an income transfer from non-displaced watermen or other individuals and firms to displaced watermen.

Benefits of Alternative 3

Fishery Benefits
Since this alternative specifies the moratorium as temporary, benefits to the fishery can accrue once the moratorium has been lifted. The benefits would then be calculated as the increased profits to oystermen compared with Alternative 1. The increase in profits would be related to an increase in oyster biomass that would lower the cost because of an increase in individual fisherman catch per unit of effort. Given the small increase in oyster biomass predicted by the demographic model for the oyster moratorium and the need to discount the benefits that start to accrue in the years the fishery reopens to calculate their present value, it is unlikely that this alternative would result in significant positive net benefits to the fishery. To demonstrate, this we compared the demographic model estimate of market size oyster biomass in year 10 under this alternative compared with Alternative 1. Based on this analysis, if the fishery was opened in year 10, the increase in year 10 net revenues compared to Alternative 1 would be $175 thousand or $135 thousand in present value. The harvest industry would have foregone $12.8 million in present value net revenues to have obtained that increase when the fishery was opened. It would require running the demographic model beyond the ten year time horizon to

calculate further discounted increases in industry net revenues, but since fishing mortality will begin to accrue again, the small net income differential will dissipate.

Processor Benefits/Consumer Benefits

As was stated earlier, the bulk of oysters processed and sold in the region are already being provided by other producing areas. Therefore, it is anticipated that the total elimination of Chesapeake sourced harvest will have a relatively small impact on the small number of remaining processors in the region. A moratorium could have a larger impact on processors than anticipated if part of the decision to continue in business is an anticipation of increased harvests of Chesapeake Bay oysters in the near future. If processors view the moratorium as a long term closure of the fishery, that might alter business decisions based on near-term potential harvests.

Oyster consumers already have limited availability of Chesapeake Bay oysters. A harvest moratorium would have the greatest impact on consumers that specifically seek and prefer Chesapeake Bay oysters for purchase.

Indirect Benefit

According to the RRM, this alternative performs slightly better than Alternative 1 depending on the salinity zone, basically following the predicted oyster biomass. Thus, it is anticipated that this option will have indirect economic benefits similar to Alternative 1.

Alternative 4--Aquaculture:

Establish and/or expand State-assisted, managed or regulated aquaculture operations in Maryland and Virginia using the native oyster species.

Costs of Alternative 4

Private aquaculture of *C. virginica* exists in Chesapeake Bay, but is limited. Entrepreneurs are experimenting with a variety of off-bottom and on-bottom practices. Interest has arisen in production of triploid *C. virginica.* The analysis of Chesapeake Bay oyster aquaculture in Appendix X demonstrates that a variety of aquaculture alternatives are economically viable with the native oyster species at current high prices. Significant expansion of production from aquaculture will lead to lower prices, making the operations more risky and limiting the overall size of the industry. To determine the additional public costs of this alternative will require specifying what actions the states will undertake to expand aquaculture beyond what the market will allow. Some actions may have little or no public cost such as relaxing or streamlining regulatory constraints. Other actions such as direct subsidies, subsidization of seed production, low or no interest loans, can have substantial public costs associated with them.

Other than any subsidized costs mentioned above, expanded aquaculture will entail the private costs of oyster producers. As discussed in Appendix X, these costs will be borne if the price of oysters is sufficiently high enough to cover them and provide a return on investment and management. Any benefits discussed below are net of these estimated private costs.

Benefits of Alternative 4

Fishery Benefits

Under this alternative, it is assumed that the wild fishery will continue as in Alternative 1. Aquaculture will supplement this local production of oysters from Chesapeake Bay. Based on the analysis in Appendix X, we believe there is the potential for a private aquaculture industry based on *C. virginica* production of about 330,000 bushels per 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 *C. virginica* for the halfshell market. The Monte Carlo simulations used to simulate this operation show a great deal of uncertainty in economic performance. Over the ten years that the simulations are run, the total net present value of the individual firm is about $190,000, but the coefficient of variation of the net present value from the model runs is 42%. Note that the ten years that the model runs is not the same ten year time period of study of the EIS. These 94 firms would not appear overnight, but would gradually increase as industry support capacity such as hatchery production increases. Our analysis predicts the market equilibrium number of firms, but not the path in terms of how many firms will develop over ten years to achieve that equilibrium.

To make comparisons to the other alternatives, we assume that in the first year there are 10 firms corresponding to the participants in the Virginia Seafood Council trials. The number of firms is assumed to increase by 10 firms a year and 4 firms in the tenth year to achieve the predicted equilibrium of 94 firms by year 10 of the planning horizon. We then compute the net present value of the industry for the ten year time horizon corresponding to the period of analysis for the EIS. Thus, the first 10 firms are credited with $190,000 each and contribute $1.9 million. The firms that enter in the second year only contribute $179,000 each, with each subsequent’s year contributing less (Table 8). The net present values were calculated by running the Monte Carlo simulations for the shorter number of years. Since the software used requires a minimum of a five year time horizon, the net present value for firms in business 4 years or less was determined by examining the performance on the firms in business longer. First, the net present value was determined to be zero for firms in business 2 years or less. Net present value for four year firms was 50% of five year firms, and for three year firms it was 25% of five year firms. The minimum and maximum values in Table 8 correspond to the range of 1 standard deviation from the predicted value. Under this scenario, it is predicted that an expanded C. virginica aquaculture industry will contribute about $8 million in net present value, but the amount could range from $6-$15 million.

Table 8. A scenario of *Crassostrea virginica* industry growth and estimated net present value for the ten year planning horizon.

Year	New Firms	Firm NPV	Industry 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 aquaculture production discussed above is based on fairly intensive aquaculture production because that is where most of the data has been collected. The potential exists for a viable extensive *C. virginica* production industry based on triploid or fast-growing strains of oysters. As this technology develops, it has the potential to supplement or compete with intensive 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. Data to further analyze extensive aquaculture production was not available at the time of the writing of this EIS.

Indirect Benefits

The relative risk model shows that given the scale of oyster aquaculture anticipated in Chesapeake Bay there may be very limited ecological effects. Thus, we do not expect any significant indirect effects arising from this aquaculture alternative.

Alternative 5-- Aquaculture:

Establish State-assisted managed or regulated aquaculture operations in Maryland and Virginia using suitable triploid, nonnative oyster species.

Costs of Alternative 5

As in Alternative 4, the level and nature of state assistance will determine the public costs of this alternative. The private costs are included in the discussion of net economic benefits to the industry.

Benefits of Alternative 5

Fishery Benefits

Under this alternative, it is assumed that the wild fishery will continue as in Alternative 1. Aquaculture will supplement this local production of oysters from Chesapeake Bay. Based on the analysis in Appendix D, we believe there is the potential for a private aquaculture industry based on *C. ariakensis* of 780,000 bushels supplied by about 223 of our "representative size"aquaculture firms producing about 3,500 bushels sold at about $0.16 per oyster. Over the ten years that the simulations are run, the total net present value of the individual firm is about $122,000, less than in Alternative 4. The coefficient of variation of the net present value from the model runs is 69%. The larger industry and aggregate production compared to Alternative 4 lowers the net benefit per firm and increases the variability of that benefit in Alternative 5 In general, more producers are made better off in Alternative 5 compared with Alternative 4, but the individual producer in Alternative 4 is better off than an equivalent producer in Alternative 5.

A net present value for the full industry over the 10 year time horizon of the EIS was estimated in a manner similar to Alternative 4. We started with 10 firms and built to 223firms by adding 30 firms a year in years 2-5, 20 firms in years 6-9 and 10 firms in year 10. Firms in year 1 contribute $126,000 each to the net present value, with later firms contributing less (Table 9). The overall industry net present value is $15 million with a one standard deviation range of $9 - $23 million. Thus, the aquaculture industry based on *C. ariakensis* will have a greater expected economic benefit than the one based on *C. virignica*. The *C. ariakensis* based industry will support more firms, and thus create more employment opportunities for watermen and others.

Table 9. A scenario of *Crassostrea virginica* industry growth and estimated net present value for the ten year planning horizon.

Year	New Firms	Firm NPV	Industry 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

One has to note, however, the large uncertainty in the range of outcomes. Similar caveats and uncertainties from Alternative 4 apply to Alternative 5 as well. Based on recent experience with *C. ariakensis*, it may be used more as a shucked oyster, maintaining a higher price compared to *C. virginica* in that market due to significantly higher shucking yields. What is unknown is how a much larger scale shucked production of *C. ariakensis* produced in higher cost intensive systems can compete with also high yielding *C. gigas* that is mainly produced in lower cost extensive production systems. *C.ariakensis* produced in a more extensive aquaculture operations should have signficantly lower production costs than intensive operations, and thus, be more competitive with shucked *C. gigas* that is imported to the region from the west coast. Due to the restricted nature of the Virginia Seafood Council trials, no data on production costs for *C. ariakensis* in Chesapeake Bay is available for analysis.

Indirect Benefits

Although this alternative anticipates a slightly larger scale oyster aquaculture industry in Chesapeake Bay compared with Alternative 4, the relative risk model still shows very limited ecological effects. Thus, we do not expect any significant indirect effects arising from this aquaculture alternative.

Alternative 6—Introduce and Propagate an Alternative Oyster Species (Other than *C.ariakensis*) or an Alternative Strain of *C. ariakensis*

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 U.S. in accordance with the ICES 1994 Code of Practices on the Introductions and Transfers of Marine Organisms.

No economic analysis was conducted regarding this alternative.

Alternative 7 -- Introduction of Diploid *Crassostrea ariakensis* And Discontinuation of *Crassostrea virginica* Restoration Programs:

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.

Costs of Alternative 7

Using the same approach as for Alternatives 1 and 2, we calculate the habitat restoration, seeding, monitoring, management and overhead costs for planting C. ariakensis seed over the 10 year period.

Table 10. Estimate of ten-year net present value (2.6% discount rate) of costs for implementation of Alternative 7 ($millions).

	Habitat	Seed	Mon/Man	Overhead	TOTAL
MD	$29.8	$93.0	$22.3	$17.4	$162.5
VA	$53.3	$15.0	$11.4	$9.6	$89.3
PRFC	$3.1	$2.2	$0.6	$0.7	$6.6
TOTAL	$86.2	$110.2	$34.3	$27.7	$258.4

Harvest Benefits of Alternative 7
The harvest benefits from this alternative cannot be quantified without the quantitative estimates from the oyster demographic model. However the model can be used to simulate an expected harvest for an oyster that has a growth, reproductive and mortality rate as specified. Using the 40% harvest rate to be consistent with comparison to the other alternatives, this simulated oyster would result in a ten-year harvest that is about 40% higher than Alternative 1 and 8% higher compared with Alternative 2. The difference between the alternatives is limited by the fact that there would be no harvest due to the priority creation of sanctuaries in Alternative 7 during the first two years, while harvest occurs in those years for Alternatives 1 and 2. Since all the simulations were run for an additional year, it is interesting to compare the projected harvests in year 11. For Alternative 1, year 11 harvests fall to less than 500,000 pounds, but rise to about 5.7 million pounds in Alternative 2. In contrast, the simulated harvests in Alternative 7 would exceed the estimated maximum economically sustainable harvest for Chesapeake Bay.

For illustrative purposes, we used the same methodology to calculate the net present value of the simulated oyster harvest as in the other alternatives. Price was adjusted with harvest to reflect own price flexibility which resulted in a significant lowering of net present value with the assumed higher harvest. Because oysters would be denser in this alternative, we lowered the harvest cost from $0.075 per oyster, the mid-range of the Wieland (2006) estimate to $0.05, the lower value of the range. The net present value for the ten-year period for oyster harvest net revenues under these assumptions is $45.1 million. What happens beyond the ten-year planning horizon would be critical to determining the commercial net benefits of this alternative. For example, if harvests can be sustained at the maximum economically feasible level with little or no additional implementation costs, a longer time horizon for analysis might yield positive net benefits. This would also depend on adopting a management regime for oyster harvests that prevents economic overfishing and the dissipation of positive net revenues.

Processor benefits were also calculated in the same manner as the other alternatives. Net present value of processor revenue net of the cost of oysters to the processor was $94.9 million.

Indirect Benefits
See discussion for the Proposed Action

Proposed Action

Costs of Proposed Alternative
The implementation cost for the Proposed Alternative is not simply the addition of Alternative 1 and Alternative 7. Areas for habitat rehabilitation are limited as are the areas to receive seed. Hatchery capacity is also a limiting factor. Thus, the total cost of implementing the Proposed Alternative differs in the net present value compared with Alternative 7 by only an additional $5.8 million (Table 7).

Table 11. Estimate of ten-year net present value (2.6% discount rate) of costs for implementation of the Proposed Alternative ($millions).

	Habitat	Seed	Mon/Man	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

Benefits of Proposed Alternative

Fishery Benefits

As in the analysis of Alternative 7, we are limited in estimating the fishery benefits by the limitations of the demographic modeling in regard to *C. ariakensis* populations. For comparison purposes, and using the same assumptions for calculation of fishing benefits, we calculated a potential net present value of fishing over the ten year time frame for the Proposed Action. We used a fishing cost of $0.075 per oyster for the first two years of the analysis since only *C. virginica* would be harvested in those years. For years 3-10, the fishing cost was lowered to $0.05 per oyster to be consistent with the analysis of Alternative 7. The net present value of fishing benefits increases to $56.4 million for the Proposed Action if the introduced oyster performs as anticipated. Net present value of processor revenues net of oyster costs was $127.6 million for this alternative. Continued production of native oysters during the first two years account for most of the difference between this alternative and alternative 7.

Indirect Benefits

As discussed in Alternative 2, the most likely indirect benefit to be impacted by oyster restoration is recreational fishing over hard bottom reefs. For this alternative, the relative risk model predicts significant beneficial interactions with hard bottom habitat in all the salinity regimes in the Bay where restoration activities will occur. Similarly, reef associated fish will benefit. Together, these indicate that the Proposed Action may lead to benefits for recreational fishermen throughout Chesapeake Bay. These benefits would be due to greater availability of preferred fishing grounds and potentially higher catch rates due to the aggregating function of fish reefs or higher levels of fish populations. According to Marine Recreational Fishery Statistics Survey data[4], over 6 million recreational fishing trips were taken in Chesapeake Bay in 2006. Improved recreational fishing due to restored hard bottom oyster reefs could increase the average value of those fishing trips, although we do not attempt to quantify this.

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

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D2 FOR ECONOMIC ANALYSIS OF ALTERNATIVES: PROJECTING OYSTER HARVESTS

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The purpose of this background report is to provide the detail used in developing reasonable estimates of the size and nature of the oyster harvesting industry, both aquaculture and public fishery, that will emerge following implementation of the different alternatives being considered for the EIS. The results draw on the economic analysis documents that were developed as supporting material for the EIS (Lipton, et al. 2006; Lipton 2008) and the corresponding peer review comments relevant to those documents (Anderson 2007) along with the manuscript by Dedah et al. (2007) included with those comments.

The analysis that follows acknowledges the great deal of uncertainty regarding oyster markets under all the scenarios considered. The approach taken here is to develop simple and logical approaches based on existing data and studies, reflecting the large uncertainties that exist in making these types of predictions.

1) **What is the projected demand for Chesapeake Bay oysters? Will prices go up, down or remain the same when Chesapeake oyster production is expanded? What is our best estimate of what those prices will be at different levels of Chesapeake production? How will demand differ between *C. virginica* and *C. ariakensis*?**

Background

Oysters are produced all over the world and in all regions of the United States. The market is complex with a variety of species being produced. *Crassostrea virginica* and *Crassostrea gigas* are the two major species marketed in the United States, with the latter mainly being produced on the Pacific coast. Final preparation and consumption of oysters include, raw on the halfshell, cooked and prepared on the halfshell (e.g. Oysters Rockefeller), steamed or roasted in the shell, and oysters which are shucked at a processing plant and packed into pint or gallon containers and then subsequently prepared for consumption as items such as fried oysters, oyster stews, as an ingredient in stuffings, and other culinary delights.

Any comprehensive study of the oyster market would begin with determining the prices and quantities of these products that form the oyster market. We are unaware of any modern comprehensive set of data on prices and quantities of final consumption of oyster products. For example, we do not have any data on the prices and consumption of raw oysters. As presented in Lipton, Kirkley and Murray (2006), there is information on wholesale prices of oysters sold as shellstock and shucked oysters sold by the gallon, but there is no contemporaneous quantity information that can be used for modeling demand at the retail or wholesale level.

The best source of data on oyster production and prices is at the harvest level. Data is readily available monthly by state and species. Thus, oysters that are sold to the final consumer in a variety of forms at different price levels are represented by a single oyster harvest price estimate. This creates a lot of error in our measurement of oyster price, and particular in any demand model that attempts to relate oyster harvest levels and prices. With these data limitations we felt it was appropriate to take a simple approach to addressing the above questions.

Analysis

In the initial analysis Lipton, Kirkley and Murray (2006) (LKM) used a simple reduced form inverse demand model that treats Chesapeake Bay price as an endogenous variable that is regressed on annual production from the Chesapeake region and all other producing regions of the country. Oyster quantities are assume to be exogenous is this model. The justification for the assumption of exogeneity is that the abundance of oysters in a year is largely determined by uncontrollable natural factors. From a statistical viewpoint, the model performed well, predicting 80% of the variability in Chesapeake Bay oyster price. The peer review comments expressed concern about this approach and provided a copy of a paper presented at the Southeastern Region Agriculture Economics meeting (Dedah et al. 2007) that also uses inverse demand, but the different regions of the country are modeled in separate regressions that are related using seemingly unrelated regression techniques. The Dedah et al. approach also adds economic structure by constraining the models to conform to what is referred to as an "almost ideal demand" system to ensure that it better adheres to economic principles.

While the model specifications differed, they provided very similar results regarding the impact of Chesapeake production on Chesapeake price. The price flexibility from the LKM study based on annual data was -0.37. The price flexibility estimate of -076 from the Dedah et al. study was based on quarterly production data. Given that virtually all Chesapeake production occurs in only two quarters, the Dedah et al. price flexibility for Chesapeake Bay when adjusted to an annual flexibility would be -0.38. Both approaches are limited to predicting how the market will respond given that they are premised on current industry structure. The development of a much larger level of regular Chesapeake production concurrent with the large production levels in the Gulf of Mexico and from the West coast will create market conditions outside the levels of either recent or historic observed data.

A second round of peer review comments was still concerned with the underlying validity of the inverse demand model, even if the estimated price flexibility was a good approximation of the "true" value. In response, additional changes were made to the inverse demand specification including adding a real disposable income variable and incorporating imports of fresh or frozen oysters. Because of data availability, the use of import data required changing the dates included in the regression from 1950-2006 to 1975-2006. The advantage of using the longer time period is that it includes some observations at higher levels of production that might be anticipated with a restored resource in Chesapeake Bay. This was the main rationale for using the 1950-2006 data, production in the original analysis. By the 1980's, Chesapeake production was only 37% of the average production of the 1950's, whereas, including some data from the 1970's allows us to include observations where production was still around 65% of the 1950's level. Production from 2000-2006 was only 2% of the 1950's level. The 1975-2006 time period seems like a reasonable compromise to trade-off accounting for structural shifts and including observations near the level at which production projections are going to be made for the analysis. The model used is then:

(1) $P_{ch} = \alpha + \beta_1 X_{ch} + \beta_2 X_{ma} + \beta_3 X_{ne} + \beta_4 X_{sa} + \beta_5 X_g + \beta_6 X_{pa} + \beta_7 TT + \beta_8 INC + \beta_9 VG + \beta_{10} IMP + \varepsilon$

where P_{ch} is the annual real price in Chesapeake Bay, X are per capita annual landings subscripted by the producing region (ma=Mid-Atlantic, other than Chesapeake; ne= New England; sa = South Atlantic; g= Gulf of Mexico), TT is a year time trend variable, INC is real per capita disposable income, VG is zero for the period 1975-1990 and is equal to the per capita Gulf production for 1991-2006, IMP are imports of fresh/frozen or fresh/frozen/salted/brine oyster products, α and β's are parameters to be estimated and ε is the error term. The model was estimated using ordinary least squares.

Results

The revised model has a significantly greater own price flexibility than was original estimated, so these new results require significant updating of the projections in the EIS. The model explanatory power actually increases to an r^2 of 0.89 (n=32) from an r^2 of 0.75 (n=57).

Table 1. Model results from inverse demand for Chesapeake Bay oyster production.

	Coefficients	*Standard Error*	*t Stat*
Intercept	-0.77543	2.24424	-0.34552
X_{ch}	-26.14640	6.50971	-4.01652**
X_{ma}	91.12326	28.38465	3.21030**
X_{ne}	17.98797	13.15814	1.36706
X_{sa}	-24.96263	52.19655	-0.47824
X_g	-7.12168	4.34319	-1.63973
X_{pa}	30.61914	11.96673	2.55869**
INC	0.00042	0.00019	2.27427**
VG	-17.52835	4.66819	-3.75485**
IMP	-31.35519	39.23607	-0.79914
TT	-0.15412	0.08389	-1.83713**

**indicates coefficient is significance at the 95% confidence level

The key variable for the analysis that follows is the own (Chesapeake) bay price coefficient which is significant and of expected sign (negative). Two of the significant parameter estimates, Mid-Atlantic production and Pacific production are unexpectedly positive indicating that increased production from these regions is predicted to increase price in the Chesapeake region. Since Mid-Atlantic production has been historically small compared to other producing regions, even with the high coefficient, this impact on Chesapeake price is small. Given the relatively larger production of Pacific oysters, the positive effect on Chesapeake price is potentially more problematic. From a predictive point of view, since production from other regions is held constant throughout the analysis, this does not pose a problem. However, the unexpected sign may be indicative of more structural complexity in the oyster market that is not being captured in this simple approach. In particular, the assumption of exogenous production from this region which is so heavily dependent on aquaculture as opposed to natural production might explain the results. Coefficient estimates may be biased if this is the case.

The estimated price flexibility under the revised analysis is -0.24, and the 95% confidence range is from -0.10 to -0.41. The demand schedule with 95% confidence limits is presented in Figure 1.

Discussion of Results

Our analysis as modified by the peer review comments as well as the Dedah paper agree that significant increases in Chesapeake oyster production will lead to lower prices in the region. While the data presented here will be used for subsequent analysis, it is important to mention reasons why the actual performance of the Chesapeake market may differ from what is predicted.

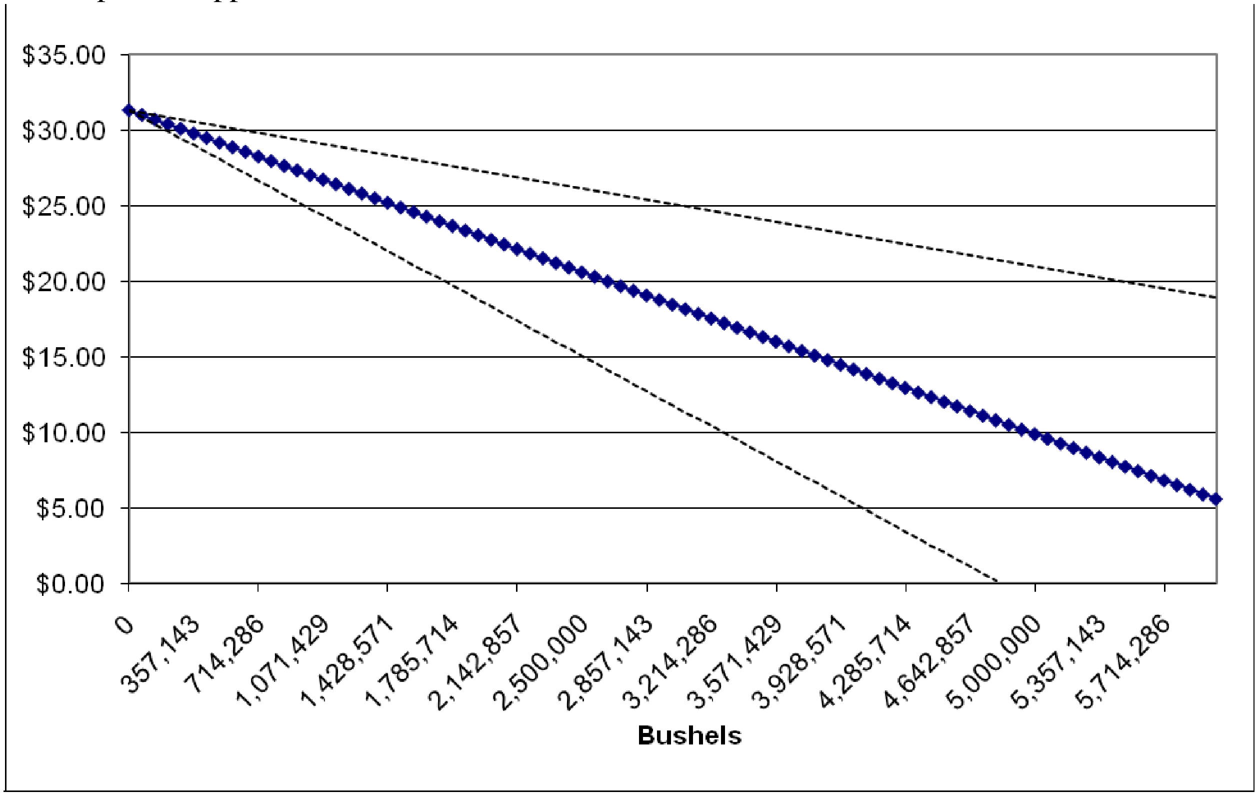
Some reasons why the responsiveness of Chesapeake Bay oyster prices to Chesapeake production will be less than predicted (higher price for a given increase in quantity) include:

- A greater share of future Chesapeake oyster production is sold in the higher valued halfshell market
- Other major producing regions have production declines such as occurred in the Gulf as a result of hurricanes in 2005
- The oyster industry engages in effective marketing and retailing that increases the demand for oysters and expands the market

Some reasons why the responsiveness of Chesapeake Bay oyster prices to Chesapeake production will be greater than predicted (lower price for a given increase in quantity) include:

- Increasing concerns and awareness about food-borne illness
- Market infrastructure, particularly for new or expanded processing capability will be limited by competing nearshore land use.
- Labor limitations will limit expansion of processing sector (e.g., blue crab processor have uncertainties regarding continuing to use H2-B visa laborers to meet localized industry labor shortage)
- Other producing regions also expand oyster production beyond historical levels
- Imports become more of a factor
- Expansion of production of competing seafood products such as mussels and hard clams could lower demand for oysters

Figure 1. Oyster demand showing bushel prices versus Chesapeake bushels harvested. Dashed lines represent upper and lower bounds at 95% confidence limits.



Difference in demand for *C. virginica* and *C. ariakensis*

For evaluating the alternatives in the environmental impact statement, it is important to know if there would be a significant difference in the oyster demand outlined above if it was based on *C. ariakensis* as opposed to *C. virginica*. Previous studies (Grabowski et al., 2003; Bishop and Peterson 2005) have demonstrated that there may be some minor differences in consumer preferences for the two species, but it is not clear how these limited surveys would translate into an expanded oyster market.

From the point of view of production to meet this demand, there is evidence from the Virginia Seafood Council trials that the yield of shucked oysters (i.e., oysters per gallon or pint from a bushel harvested) is significantly greater for *C. ariakensis* compared with a bushel of *C. virginica*. A.J. Erskine (pers. comm.) has found from the Virginia Seafood Council trials that triploid *C. ariakensis* shucks out at about 182 oysters to the gallon compared with 400 *C. virginica*. This higher yield per bushel would result in a steeper demand curve than in figure 1, with higher prices per bushel and the market demand being met with fewer bushels harvested. The Virginia Seafood Council trials also revealed that concerns about shelf life of *C. ariakensis* shellstock due to that oyster gaping as compared to *C. virginica* were a real concern. Another limiting factor in marketing of *C. ariakensis* as a halfshell product is the prevalence of *Polydora* infestation. Given this difference, it would be reasonable to expect that production based on *C. ariakensis* would have a heavier weighting of shucked versus halfshell oysters when compared with production from *C. virginica*.

The higher shucking yield for *C. ariakensis* would make it a higher valued product than *C. virginica* in that market, but its diminished suitability as a halfshell product would work in the opposite direction in regard to the observed average price per month that our model is based on. Adding to the uncertainty, is not knowing how these differences would work themselves out in the marketplace in an industry that is orders of magnitude larger than the one we currently observe. Given these restrictions, we determined that using the simple Chesapeake Bay own price flexibility estimate for both *C. virginica* and *C. ariakensis* price predictions is the most reasonable approach and is how prices are predicted for each of the alternatives analyzed.

2) **Given the projected demand for oysters, what will be the overall level of industry production? How will industry production be divided between different production technologies such as the public fishery, bottom culture, and off-bottom culture?**

A stated goal of the Environmental Impact Statement is a restored oyster population that would be able to support a sustainable harvest of 4.9 million bushels a year. This does not imply that that has to be the actual level of harvest in order to meet the EIS goals, but the population would have to be large enough to support that level. In Figure 2, we plot the 4.9 million bushel a year level of production on the demand schedule. The prediction from the demand model is that at that level of production, prices will fall from current levels to about $10.22[5] per bushel, with the 95% confidence range of $9.75 - $21.14. The minimum observed real price for Chesapeake Bay oysters was $20.07 in 1974. Using that minimum price as an indicator of the minimum feasible market price suggests that there is a small probability (~7%) that the level of production indicated in the EIS goal is feasible. The quantity from the demand schedule corresponding to the minimum

[5] All prices in this document are expressed in 2006 dollars, using the Bureau of Labor Statistics consumer price index.

observed market price is 2.6 million bushels, comparable to average harvests in the 1970's, and the 95% confidence range is 1.7-5.4 million bushels.

As another indicator of likely production quantities from Chesapeake Bay, we also used data from the 2005 industry survey price scenario from LKM. In that study, oyster industry members suggested an equilibrium price of $19.36 per bushel. Using the estimated demand relationships, the industry member price prediction compared to the minimum observed price translates into slightly higher production of 2.8 million bushels with a 95% confidence rang of 1.8-5.8 million bushels. Given the uncertainties, we use 2.6 million bushels as the best estimate of the maximum Chesapeake Bay industry size resulting from an enhanced resource base.

<u>How are the size and number of oyster producing firms determined?</u>

Economic theory suggests that the size (in terms of quantity harvested) of an individual oyster producing firm will be determined by the relationship between production costs and the amount of oysters produced. That relationship will depend on the technology used to produce oysters and will have a point where the average cost per oyster produced is minimized. Each firm will produce at that minimum average cost point. For expository purposes supposes all firms are identical and have a minimum average cost of $20.07 when they produce 2,600 bushels annually. That would lead us to conclude that there would be 1,000 identical oyster firms producing at the minimum cost so that total industry production was 2.6 million bushels. At that point, all firms are producing at minimum cost and the total demand for oysters has been met, leading to market equilibrium.

Just like the market for oyster products, the production of oysters is much more complex than the simple example given above. For one, oyster production, particularly in the public fishery is highly regulated with limits on gear and limits on harvest. These limits often prevent firms from operating at production levels that minimize production costs. We also observe that firms are not identical in the gear that they use or in the skill of the oystermen in employing the gear. Private aquaculture production has an entirely different cost structure compared to the public fishery, and private aquaculture firms are employing a variety of techniques with varying levels of success. Combining the availability of these different oyster production techniques with a lack of systematic cost and returns data collection for each technique, makes it extremely difficult to determine the industry structure that would emerge from a restored oyster population. Below we examine what is known about production costs in order to shed some light on possible industry structure.

3) <u>What might the production costs for intensive private oyster aquaculture be? What would be the difference between *C. virginica* and *C. ariakensis* production?</u>

Lipton (2007) used data from the Virginia Seafood Council trials as the best representation of what production costs for intensive aquaculture would be in Chesapeake Bay. Since that report, two more production years have provided data on C. *ariakensis* performance, and the most recent trials included small scale trials with triploid *C. virginica*. By including all the trial data, we can begin to capture some of the variability and uncertainty of intensive aquaculture production costs and returns in Chesapeake Bay. For example, since the first round of trials, growers have experienced planting mortalities, mortality from predation, freezes and mortality from unknown causes. With limited information on full scale production of intensive oyster aquaculture in Chesapeake Bay, this pilot data remains the best source of information on which to predict production costs.

Some important qualitative information has been gleaned from the Virginia Seafood Council trials. Originally, it was thought that intensive oyster aquaculture would have to be geared towards a higher-priced half shell market because of relatively high operating costs compared with extensive aquaculture and the public fishery. However, the problem with *C. ariakensis* not closing as tightly as *C. virginica* and therefore having a shorter transportation life for the half shell market and the problem of shell scarring related to *Polydora* infestation has limited the suitability of *C. ariakensis* for the halfshell market. As a result, a much larger percentage of *C. ariakensis* was marketed as a shucked product in the most recent trials. Also, small scale trials (10,000 seed) were conducted with triploid *C. virginica*. Although extensive economic data similar to that from the *C. ariakensis* trials is not yet available, preliminary data showed that triploid *C. virginica* had very good survival compared with *C. ariakensis*, but slower growth.

The updated economic analysis of intensive aquaculture of triploid *C. ariakensis* is modified from the Lipton (2007) analysis of aquaculture alternatives. It is based on developing a representative firm based on the three separate Virginia Seafood Council trials. A variety of grow-out technologies and techniques have been employed in the VSC trials. We have not attempted to determine the economic performance of a single technology, but rather, combined these to represent our current state of uncertainty about which technology will emerge as the preferred technique. In all likelihood the industry will be comprised of variations on several technologies depending on the specific environmental conditions in an area and the market the grower is trying to meet. The following assumptions, drawn from the trial data are made about operations of our baseline representative firm:

1) The oyster firm plants 1.3 million oyster seed per year
2) Time from planting to market is 12 months
3) Total spending on durable and non-durables supplies is $63.5 thousand, this is broken into:
    a. Capital costs with a 5 year life = $57.2 thousand
    b. Maintenance and repair costs are 10% of the total supply costs = $6,350
    c. Non-durable supplies are 10% of capital costs = $5,720
4) Seed costs are initially set at $0.01 apiece as indicated in the VSC trials.
5) Average oyster survival to market is 77%, with a standard deviations of 21%
6) The average price of oysters sold is $0.20 with a standard deviation of $0.05
7) Operations require approximately 250 man-hours per month. The peer review was concerned about the low wage rate used ($10/hour). We adjusted the wage rate to range from $10-$15 an hour with a mean of $12.50.
8) Monthly fuel costs are $165 with a $3.55 standard deviation.
9) The cost of capital to initiate the operation is modeled by a ten-year loan of $100,000 at an 8.5% interest rate.
10) As indicated in Lipton (2007), no management costs were included in the initial analysis of the VSC trials. We included a $40,000 per year management charge to the enterprise along with $4,000 in other miscellaneous fees such as accounting, legal, and insurance.

<u>The Baseline Firm (VSC Data)</u>

There is only a 26% probability that the firm described above would be solvent over a ten-year time period. The problem is that paying a management fee of $40,000 in the first year depletes the cash reserves to the point where the firm needs much higher than average oyster survival and sales in the first few years to continue operations into the future. Therefore, we determined that the enterprise would need a $150,000 loan as opposed to the $100,000 used in the previous analysis. Once that adjustment was made, there was a 100% probability of success. This firm, as described above, formed the baseline for further adjustments for the EIS analysis.

Seed and Market Prices

There is no well functioning private market for hatchery produced oyster seed in the Chesapeake region for which to obtain estimates of seed prices. We have been assuming $0.01 per seed. In a December 20, 2007 Oyster Recovery Partnership presentation to the Maryland Oyster Advisory Commission, a seed price of $0.02 apiece was assumed.[6] To reflect this uncertainty in seed prices, we have increased the estimated seed cost to aquaculture enterprises to $0150 average with a standard deviation of $0.05 After this adjustment is made, we start running scenarios by dropping the output price to determine the point where the probability of a firms economic survival starts to drop significantly.

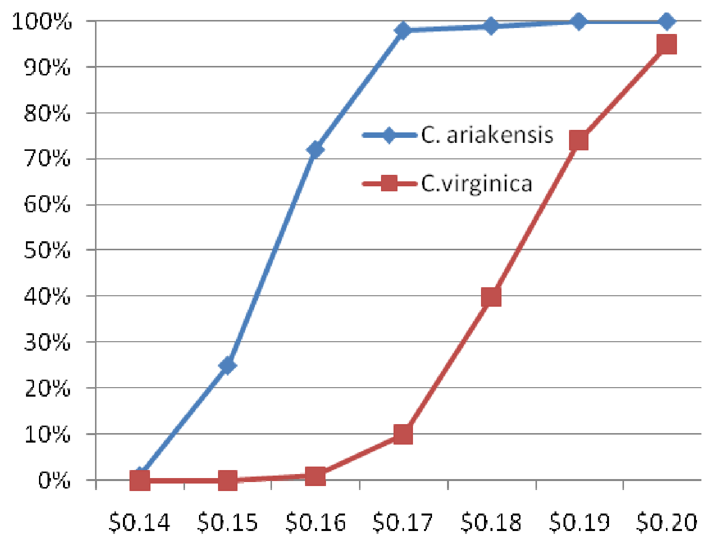
C. ariakensis compared to *C. virginica* intensive culture

With only limited data on triploid *C. virginica* grown in these intensive systems, we kept all cost and operating assumptions the same as for *C. ariakensis* with the exception of time to market. For triploid *C. virginica* we assumed time to market to be 18 months. The additional six months to market had a significant impact on the probability of economic success of the aquaculture enterprise at prices lower than the current $0.20 per oyster (Figure 2).

Based on the limited costs and returns data for triploid oyster production in Chesapeake Bay, it appears that triploid *C. ariakensis* can be a viable economic enterprise at a minimum price of $0.16-$0.17, and triploid *C. virginica* at a price of $0.19-$.20 per oyster. Although these are our best estimates, it should be clear from the analysis that conditions outside the range of assumptions used in the modeling can lead to markedly different results. For example, an actual oyster seed price closer to $0.02 or an average mortality closer to 50% would make either of these enterprises more risky than shown here.

[6] http://www.dnr.state.md.us/fisheries/oysters/mtgs/122007/meeting122007.html

Figure 2. Probability of economic success for intensive oyster aquaculture of *C. ariakensis* and C. *virginica* at different output prices.



4) What are the private industry costs of harvesting natural or publicly-maintained oyster beds?

At the other end of the spectrum from the intensive oyster aquaculture production examined above, is the harvest of wild oysters from naturally-populated oyster bars or from oyster bars that have been enhanced through public restoration and repletion efforts. As long as the abundance was sufficiently dense on the oyster bars, this would clearly be the lowest cost oyster production technology since it only entails the cost of harvesting. Wieland (2006) estimated oyster harvesting costs for different gear types in Chesapeake Bay. Daily operating costs ranged from $176 a day for shaft tongers to $375 a day for dredgers. Obtaining a cost per oyster to compare with other production methods is difficult because it will depend on the density of oysters and any restrictions on harvest. For illustration, Wieland (2006) used the average 2005 and 2006 catch per day by gear type. His cost per bushel estimates ranged from a low of $16.60 for shaft tongers to a high of $29.76 per bushel for dredge boats. The variability in estimating the cost per oyster is even greater because there is no standard estimate of the number of oysters in a bushel. Throughout our analysis, we have been using a figure of 275 oysters per bushel. We have seen other estimates of up to 400 oysters per bushel. One of the things that is not clear in these various estimates is whether they include only market size oysters or all live oysters. Harvest costs per oyster, based on Wieland's (2006) cost estimates and catch per day range from as low as $0.04 per oyster based on 400 oysters per bushel to $0.11 per oyster for a high cost dredge operation at 275 oysters per bushel.

5) What are the costs of extensive aquaculture production of oysters in Chesapeake Bay? How do these costs differ for triploid *C. virginica* versus triploid *C. ariakensis*? How do these costs differ for disease-resistant hatchery seed?

Almost all the recent harvest from Chesapeake Bay is based on some form of extensive aquaculture. In this form of aquculture, suitable bottom is found or made suitable by placing shell or bagless dredging to return shell to the surface. Oyster seed on shell is either obtained from natural seed areas or from hatchery seed that has been set on shell. The seed is placed on the bottom where it remains until reaching market size. Variations on this form of aquaculture are practiced by private growers who lease bottom (mostly Virginia) or by the state (mostly Maryland) in support of a "public" fishery. High mortality, principally due to disease has rendered this from of aquaculture as it has traditionally been practiced not viable. If survival rates were similar to the rates in intensive aquaculture, production costs would likely fall inbetween harvesting from a healthy wild fishery and intensive aquaculture. To get these survival rates up, growers are interested in using disease-resistant hatchery produced oysters and/or faster growing triploid oysters that may reach market size before succumbing to disease mortality (*C. virginica*) or are not as susceptible to disease mortality (*C. ariakensis*).

Production cost data for extensive oyster aquaculture in Chesapeake Bay that would allow for a detailed analysis is very limited. The data provided at the February 2006 Aquaculture Workshop was simply for a cost to obtain wild oyster seed that then experienced a high mortality. We showed that based on typical mortalities in Chesapeake Bay, the cost per bushel harvested was on average, \$82/bushel while the price received was about \$30. While we could calculate what survival would have to be to break even on seed costs (16%), no information was available on additional costs such as labor. Thus, we were not able to run the simulations like the ones based on the extensive data from the Virginia Seafood Council trials.

We do not have to run the aquaculture simulations to know that oysters with greater survival and faster growth will outperform, on an economic basis, higher mortality, slower growing oysters at the same market price. However, without knowing the production cost of this type of operation, it is not possible to determine the level of production, if any, that is feasible.

6) What is the potential role of aquaculture in achieving a restored Chesapeake Bay oyster industry of 2.6 million bushels a year? How will the roles differ for an industry based on *C. virginica* compared with *C. ariakensis*?

The hypothesized restored oyster fishery of 2.6 million bushels is assumed to consist of the same breakdown of product for the shucked and halfshell market as we estimate to historically be the case for Chesapeake Bay. From the industry survey in LKM (2006), it was estimated that 70% of Chesapeake oysters are shucked with the rest going to the halfshell market.[7] The inverse demand model predicts that under the equilibirum oyster market, average oyster prices will decline about 35% from current levels. If current halfshell prices are around \$0.24 each, then current shucked oysters must be priced at about \$0.05 each to equal the weighted average price. A decline in weighted average price of 35%, keeping the same ratio of shucked to halfshell product, would lead to about a \$0.03 a piece price for shucked and a \$0.16 each price for halfshell. Referring to Figure 2, the halfshell price, based on current estimates of production costs, is feasible for *C. ariakensis*, but not for *C.virginica*.

C. virginica production would still be feasible at smaller aggregate production levels. For example, oveall industry production of 1.1 million bushels is predicted to lead to a price decline of about 21%, which would keep halfshell prices near \$0.19 each. At this price level aquaculture firm survival probability is about 75%, but declines precipitously at lower prices. The halfshell market would be 30% of the 1.1 million bushels, or 330,000 bushels. This would support approximately 94

[7] Muth et al. 2000 used a 25% to halfshell estimate for Atlantic, other than New England, oyster production. Their figure was based on discussion with industry experts.

of our representative aquaculture firms producing about 3,500 bushels of *C. virginica* for the halfshell market.

Assuming *C. ariakensis* production being feasible for the “fully restored” 2.6 million bushel oyster market would result in a halfshell market of about 780,000 bushels supplied by about 223 of our representative aquaculture firms. As mentioned previously, the viability of C. ariakensis as a halfshell oyster may be diminished by marketing issues related to shelf life and susceptibility to *Polydora* infestation scarring the shells. Results from the Virginia Seafood Council trials also indicate a large percentage of C. ariakensis being marketed for the shucked market. The one measure of 120% greater shucking yield from triploid *C. ariakensis* compared to *C. virginica* raises the possibility that *C. ariakensis* might be a viable oyster for the shucked market. For example, if shucking yield alone is the determining factor in processor’s willingness-to-pay for shucked oysters then a processor paying $0.05 each for *C. virginica* would also be willing-to-pay $0.11each for *C. ariakensis*. Intensive aquaculture does not appear to be feasible at that low price, but a more extensive and lower cost aquaculture of *C. ariakensis* might be feasible. At a C. virginica price for the shucked market of $0.07 each, the equivalent C. ariakensis price would be over $0.15 each. At this price, intensive aquaculture of C. ariakensis has a 25% probability of economic success according to the Monte Carlo simulations. As was stated in the outset, reported oyster prices are aggregated from a variety of markets, so it is not unreasonable to assume that a portion of the oysters for the shucked market sell for higher prices than represented by the averages, and thus, may allow for feasible aquaculture production for at least a portion of the shucked market.

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D3 ECONOMIC ANALYSIS BACKGROUND SUPPORTING DOCUMENT C/ESTIMATING COSTS OF IMPLEMENTING ALTERNATIVES

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The purpose of this section is to provide more detail than is provided in the main document on the development of cost estimates for implementation of the various alternatives in the EIS. Estimates of unit cost data consisting of cost per acre for habitat restoration and cost per seed were provided by individuals knowledgeable about current costs in each jurisdiction (Maryland, Virginia and the Potomac River). The location and amount of habitat acres restored and the amount of seed planted for each of the ten years are detailed in Section [Insert]. The unit costs were then multiplied by the appropriate acres or seed quantity to determine the in the field implementation costs.

<u>Habitat Restoration Cost</u>

In the Potomac River and Virginia, only shell was considered for habitat restoration. In Maryland there are four alternative materials—shell, slag, stone, and concrete being considered for use for habitat restoration. In Virginia and the Potomac, the cost of shell was estimated at $1.50 per bushel and an application rate of 1,500 bushels per acre was used to calculate the cost per acre restored. For comparison purposes, based on a shell yield of 449.1 cubic yards per acre, shell costs in Virginia and the Potomac were $5.01 per cubic yard.

Habitat restoration costs were higher in Maryland; with shell at $14.33 per cubic yard. Other materials costs are higher than shell, but yield about 1,000 cubic yards per acre. Of the alternate materials, slag provides the second lowest cost of habitat per cubic following by stone and concrete, respectively (Table 1). Maryland habitat restoration costs will depend on site location, material used, and number of cubic yards of material Three scenarios for Maryland costs -- a high, medium and low – were developed based on the combination of materials used for restoration. The low cost scenario refers to when shell and slag are used. Shell and stone materials are used in the medium scenario and shell and concrete are used in the high scenario.

Maryland and Potomac River annual habitat restoration costs do not vary through the ten year time horizon because the same actions are taken in each year (Table 2). Virginia annual habitat restoration costs vary by year related to different restoration activities in each year. The annual habitat restoration costs for Maryland under the proposed action are $2.7million, 3.4 million, and $4.2 million dollars under low, medium, and high scenarios respectively. Potomac River annual habitat restoration costs under the proposed action are $0.4 million dollars. For Virginia, the annual average habitat restoration cost under the proposed action is $6.1 million dollars.

Seeding cost

There is no well documented estimate of the unit cost of seed for Chesapeake Bay restoration. Throughout the analysis we have been using an estimate of $0.01 per seed. We also assume that seed costs are the same for *C. virginica* and *C. ariakensis*.being The number of seed employed per acre in Maryland depends on whether it is being placed on a reserve or sanctuary. Reserves receive 1 million seed per acre while 2 million seed per acre are planted in the Maryland sanctuaries. Potomac River plantings are 1 million seed per acre. Virginia uses a denser planting of 5 million seeds per acres.

With these price assumptions, Maryland average seed costs per year are $13.2million, $2 million, $12.3 million, and $11.2 million under proposed action, alternative 1, alternative 2, and alternative 7 respectively (Table 3). The average seed costs per year for Potomac River are $0.5 million, $0.3 million, $1 million, and $0.3 million under the proposed action, alternative 1, alternative 2, and alternative 7, respectively. Virginia average seed costs per year under proposed action, alternative 1, alternative 2, and alternative 7 are $2.3 million , $0.5 million, $1.8 million, and $1.8 million, respectively.

Monitoring and Management Costs

Maryland DNR obtained estimates of current monitoring and management costs. It is estimated that Maryland spends approximately $722 thousand a year on managing the oyster resource and another $970 on monitoring, while the Potomac River Fisheries Commission spends approximately $50 thousand on management and nothing on monitoring. No estimate was available from Virginia. To estimate Virginia's expenditures we used the ratio of the total monitoring and management costs in Maryland and the Potomac to the total restoration expenditures and applied this to Virginia's restoration expenditures. At a 30% rate of management and monitoring to restoration activities, Virginia is estimated to spend approximately $791 thousand on management and monitoring.

For comparison of alternatives we had to determine how monitoring and management costs would change based on the scale of restoration activities. In discussing the nature of management and monitoring activities we determined that they would not scale up at a constant rate related to the scale of restoration activities, but they would need to increase since, for example, more oyster bars would need to be monitored in an expanded restoration framework. To capture these increases we approximated management and monitoring costs as equal to the current costs plus 10% of the incremental restoration costs compared to Alternative 1 (Table 4).

Overhead

In order to determine appropriate allocation of agency overhead charged to the cost of alternatives we used OMB Circular A-76[1] as guidance. Circular A-76 is used for establishing appropriate charges for federal competition of commercial activities. Under

[1] http://www.dla.mil/j-3/a-76/OMBCircularA-76New.html#1.

Attachment C Section (2).A.10., Standard Cost Factors, a rate of 12% of pay and non-pay costs is required. We applied this overhead rate to the total of habitat restoration, seeding, and monitoring and management costs for each of the alternatives.

Table 1. Cost per cubic yard of alternative habitat restoration materials depending on volume used and area planted.

Shell
$14.33

Slag Zone	Volume Category (Cubic Yards) A (2k - 5k)	B (5k-10k)	C (>10k)
1	$23.76	$23.28	$22.57
2	$24.48	$23.99	$23.26
3	$28.08	$27.52	$26.68
4	$30.96	$30.34	$29.41

Stone Zone	Volume Category (Cubic Yards) A (2k - 5k)	B (5k-10k)	C (>10k)
1	$33.84	$33.16	$32.15
2	$34.56	$33.87	$32.83
3	$38.16	$37.40	$36.25
4	$41.04	$40.22	$38.99

Concrete Zone	Volume Category (Cubic Yards) A (2k - 5k)	B (5k-10k)	C (>10k)
1	$47.52	$46.57	$45.14
2	$48.24	$47.28	$45.83
3	$45.00	$44.10	$42.75
4	$47.50	$46.55	$45.13

Table 2. Habitat restoration cost

Area	Alternative	habitat cost ($)									
		year 1	year 2	year 3	year 4	Year 5	year 6	year 7	year 8	year 9	year 10
MD--low	Proposed action	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546
--med		3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256
--high		4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026
MD--low	1	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546
--med		3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256
--high		4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026
MD--low	2	8,359,584	8,359,584	8,359,584	8,359,584	8,359,584	8,359,584	8,359,584	8,359,584	8,359,584	8,359,584
--med		11,152,014	11,152,014	11,152,014	11,152,014	11,152,014	11,152,014	11,152,014	11,152,014	11,152,014	11,152,014
--high		14,603,094	14,603,094	14,603,094	14,603,094	14,603,094	14,603,094	14,603,094	14,603,094	14,603,094	14,603,094
MD--low	7	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546	2,717,546
--med		3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256	3,436,256
--high		4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026	4,218,026
PRFC	Proposed action	353,958	353,958	353,958	353,958	353,958	353,958	353,958	353,958	353,958	353,958
	1	353,958	353,958	353,958	353,958	353,958	353,958	353,958	353,958	353,958	353,958
	2	247,500	247,500	247,500	247,500	247,500	247,500	247,500	247,500	247,500	247,500
	7	353,958	353,958	353,958	353,958	353,958	353,958	353,958	353,958	353,958	353,958
VA	Proposed action	6,469,068	2,546,118	6,781,259	9,026,834	6,644,953	8,239,309	9,552,494	3,216,064	7,230,207	1,437,328
	1	2,261,700	890,168	2,370,848	3,155,940	2,323,193	2,880,608	3,339,878	1,124,393	2,527,808	502,515
	2	9,014,092	7,336,330	10,485,914	18,340,568	15,004,608	12,684,509	16,900,923	5,767,394	9,858,507	3,358,934
	7	6,469,068	2,546,118	6,781,259	9,026,834	6,644,953	8,239,309	9,552,494	3,216,064	7,230,207	1,437,328

Table 3. Seed cost

Area	Alternative	seed cost ($)									
		year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10
MD	proposed action	2,500,000	4,000,000	7,000,000	9,500,000	12,000,000	17,000,000	20,000,000	20,000,000	20,000,000	20,000,000
	1	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
	2	2,000,000	3,490,000	5,010,000	7,490,000	10,000,000	15,010,000	20,000,000	20,000,000	20,000,000	20,000,000
	7	500,000	2,000,000	5,000,000	7,500,000	10,000,000	15,000,000	18,000,000	18,000,000	18,000,000	18,000,000
PRFC	proposed action	530,000	530,000	530,000	530,000	530,000	530,000	530,000	530,000	530,000	530,000
	1	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000
	2	250,000	450,000	700,000	900,000	1,200,000	1,250,000	1,250,000	1,250,000	1,250,000	1,030,000
	7	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000
VA	proposed action	1,000,000	1,500,000	2,500,000	2,320,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
	1	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000
	2	500,000	1,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
	7	500,000	1,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000

Table 4. Estimated annual monitoring and management costs by alternative ($ million).

Alternative	MD	VA	Potomac
1	$1.70	$0.80	$0.50
2	$3.50	$1.80	$1.40
7	$2.60	$1.30	$0.80

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D4 FINAL REPORT/A BACKGROUND ECONOMIC ANALYSIS FOR THE PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT REGARDING THE RESTORATION OF THE CHESAPEAKE BAY OYSTER FISHERY USING THE NON-NATIVE OYSTER, *CRASSOSTREA ARIAKENSIS*

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FINAL REPORT

A Background Economic Analysis for the Programmatic Environmental Impact Statement Regarding the Restoration of the Chesapeake Bay Oyster Fishery Using the Non-Native Oyster, *Crassostrea ariakensis*

January 2006

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Background

The Chesapeake Bay oyster, *Crassostrea virginica*, is a natural asset. The oyster resource supplies a flow of goods and services that contributes to the overall welfare of individuals and society as a whole[1]. The oyster's most obvious and easily measured value has been as a food resource. Consumer demand for oysters creates an opportunity for producers to earn income and business profits catching and processing oysters to satisfy that demand. Also contributing to the asset value of the oyster resource is its *in situ* value as an important habitat for other Chesapeake Bay species and its role as a filter feeder in the functioning of the Chesapeake Bay ecosystem (Newell 2004). The value of the oyster in this case is indirect; it is derived from the value that comes from the human use of species (both recreational and commercial) that benefit from oyster habitat or the benefits that humans perceive from the filter feeding role of oysters. There may also be a non-use value associated with Chesapeake Bay oysters that derives from individual's valuing the fact that oysters exist in the Bay, irrespective of any direct or indirect use value.

The direct use value and the indirect use value of oysters pose a potential conflict. For oysters to be of value as a food source, they must be removed from the Bay, thus affecting their ability to provide the indirect habitat and filtering services. The standard fisheries bioeconomic problem (Clark 1976) seeks to optimize the gains from removals while accounting for the contribution that harvested oysters would have made to growth and reproduction contributing to future harvests (i.e., the opportunity costs of harvest). Indirect values increase the opportunity costs of harvests, as harvested oysters no longer provide habitat for themselves or other species and they no longer provide filtering

[1] see Henderson and O'Neil (2003) for an overview.

capability. The failure to acknowledge the total opportunity costs of oyster harvest in Chesapeake Bay management strategies contributed to the long term decline of the resource and, consequently, its asset value. In the latter part of the twentieth century, the main value derived from the remaining natural oyster resource was seed production for either a principally private leased bottom fishery in Virginia or a repletion program on public grounds in Maryland. Finally, disease diminished even the value of oyster reproductive capacity since many of the seed oysters were unable to survive to market size.

The goal stated in the programmatic Environmental Impact Statement is to restore the Chesapeake Bay oyster population to a level that will sustain harvests comparable to harvests in the 1920-1970 time period. Historical harvest figures indicate that the annual average harvest (computed on a decadal basis) of Chesapeake Bay oysters from 1920-1969, ranged from 3.6 million bushels to 5.8 million bushels, and averaged 4.9 million bushels. Presumably, this number represents the harvest target range of the proposed objective. Although these harvest figures are mostly from the period prior to both the onset of outbreaks of MSX and then Dermo in Chesapeake Bay, and the period when the Maryland oyster repletion program started to return benefits, there is no evidence to indicate that these harvests were self-sustaining. Nevertheless, we will use this figure of a 4.9 million bushel annual harvest in the following analysis of the commercial industry, recognizing that the population to sustain such a harvest may be greater than the one that existed during the 1920-1969 period.

In order to achieve the stated goal, the EIS proposes eight alternatives, including a no action alternative and a combination of actions alternative. The remaining six proposed actions include:

1. Expansion of the existing native oyster restoration program.
2. A harvest moratorium with compensation for watermen
3. Aquaculture of native oysters
4. Aquaculture of triploid non-native oysters
5. Introduction of an alternative strain of *C. ariakensis* or an alternative non-native species.
6. Introduction of diploid *C. ariakensis* and termination of native oyster restoration programs.

The purpose of the economic analysis that follows is to summarize what is currently known about the economics of oyster restoration in order to inform the development of an economic impact statement. In section I we look at the direct benefits that might accrue from the proposed actions, that is, the benefits related to the oyster fishery. Section II examines what is known about the potential for aquaculture of *C. ariakensis* compared with performance of *C. virginica*. It is based principally on the field trials that were conducted in Virginia water using triploid *C. ariakensis.* Section III summarizes knowledge about other costs and benefits associated with oyster restoration.

I. Direct Benefits – the Oyster Fishery

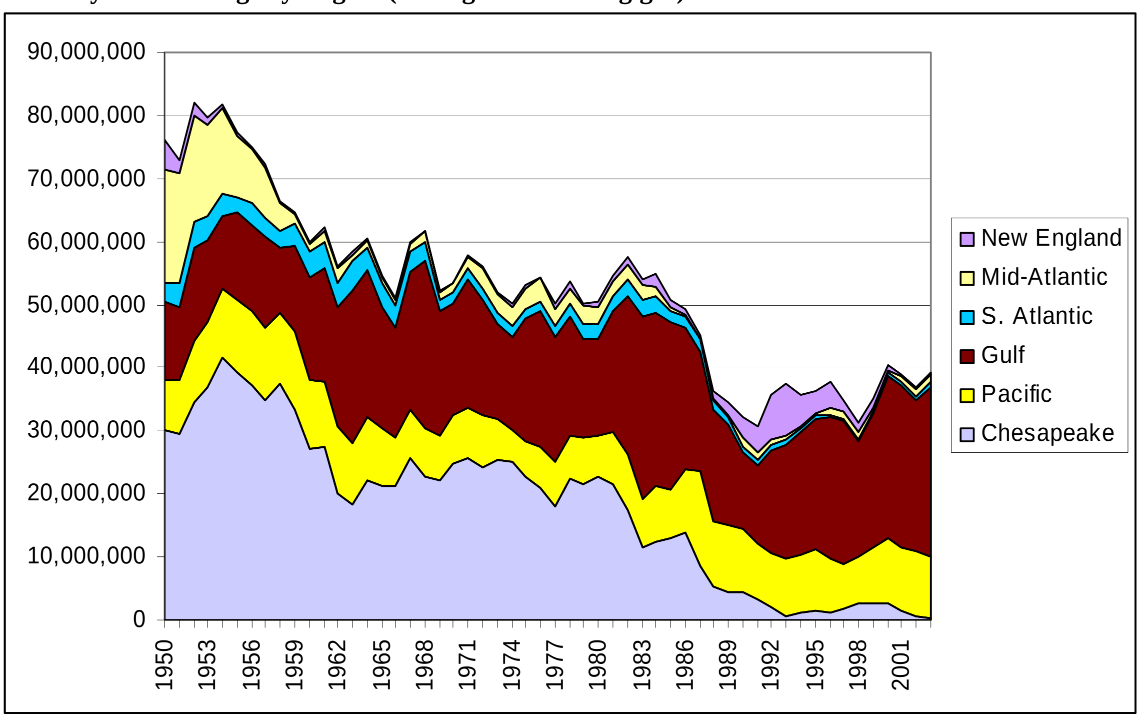
The U.S. Oyster Market

The Committee on Nonnative Oysters in Chesapeake Bay (CNOCB) report for the National Research Council (2004) does an excellent job of reviewing the current and historical role of the Chesapeake Bay oyster fishery in the U.S. oyster market. We briefly review and update the supply and demand situation here, but refer the reader to that source and Lipton and Kirkley (1994) and Muth et al. (2000) for greater detail.

Production

As can be seen in Figure 1, the U.S. supply of oysters (including both *C. virginica* and *C. gigas*) has fallen by about 50% from around 80 million pounds of meats in the early 1950's to less than 40 million pounds in 2003.[2] Figure 2 uses the same landings data to show the production market share (i.e. volume, not value) provided by each region of the country. Small growth in Gulf and Pacific landings with a declining

Figure 1. U.S. Oyster Landings by Region (C. virginica and C. gigas)



overall harvest translates into large increases in market share so that in 2003, these two regions supplied 94% of the market. There is also an interesting period from 1988-1999

[2] A few other oyster species are harvested in the United States, but the level of landings is inconsequential compared to *C. virginica* and *C. gigas*.

where New England production had a significant market share with significant implications for oyster prices discussed below.

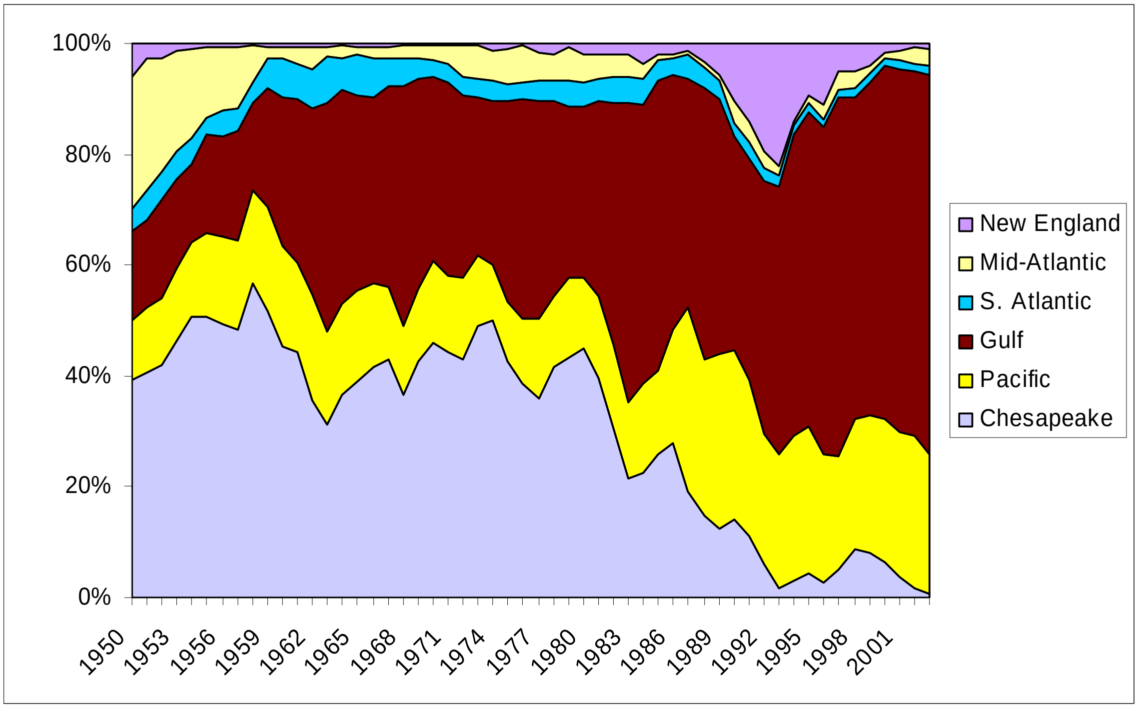


Figure 2. Market share (by volume) of oyster landings by region.

Demand

There are a limited number of studies of oyster demand (see Lin et al. 1991; Berry 1992; Keithly and Diop 2001), and few of recent vintage to provide meaningful information that can be used to predict the consumer response to a revitalized Chesapeake Bay oyster fishery. As can be seen in figure 3, one gets a different picture of price responses in the oyster fishery depending on whether they are looking at nominal or real prices. Nominal prices show a steady increase over the 1950-2003 period. However, when adjusting for inflation, we see a remarkably stable real price of around $3.00 per pound of meats, except for a brief period of unusually high prices from 1987-1992.

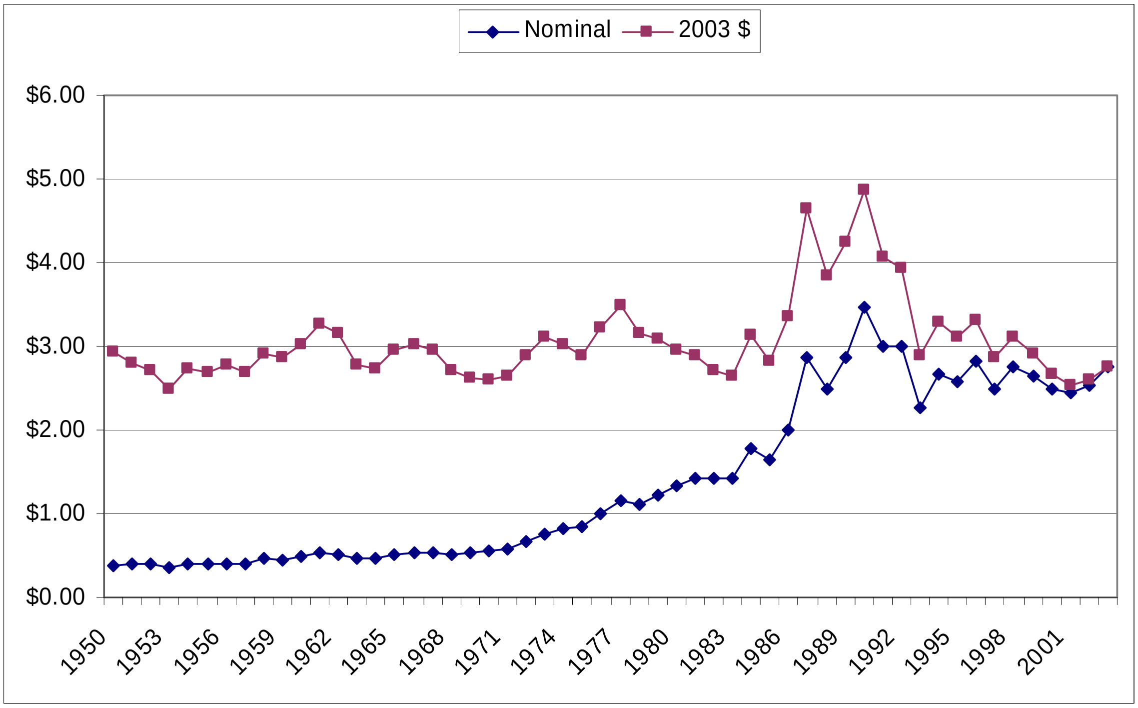


Figure 3. Nominal and current year (2003) U.S. oyster prices.

The increase in aggregate oyster prices from 1987-1992 corresponds with the period of increased production and market share expansion for New England oysters discussed above. New England oysters are mainly targeted for the higher value half shell market. In 1986, New England oyster prices rose 40% over the previous year's level. By 1993, production in New England hit an all time high for the study period of 8.4 million pounds of meats and a 22% share of the market by volume. But by 1993, New England oyster prices had dropped back down to 42% of the 1986 high. As a result, corresponding production fell back down from a peak of over 8 million pounds of meats to less than half a million. As a parallel to ecological sustainability, it appears that these higher oyster prices were not sustainable in the marketplace.

Given the decline in production and the relative unresponsiveness of real price to this decline, there is strong evidence that the demand for oysters in general has declined significantly over the last fifty years. This is somewhat verified by the study presented in Lipton and Kirkley (1994) and detailed in Berry (1992) that compared oyster consumption in three different food consumption surveys in 1977, 1980, and 1987.[3]

A Model of Inverse Demand for Chesapeake Bay Oysters

Any serious attempt to enhance native fish or shellfish populations for commercial purposes should begin with an examination of the market. Boyce et al. (1993) conducted a study involving the intentional enhancement of a fishery resource. In this study the emphasis was on programs designed to enhance the population of native salmon for commercial purposes. Contrary to expectations, it was determined that the enhancement program actually decreased net social benefits and producer welfare because it facilitated the expansion of commercial production at the same time the supply of farm raised salmon increased in the market. This had the effect of substantially reducing welfare, and in particular, ex-vessel prices and producer welfare for Alaskan salmon.

Estimating the inverse demand for oysters (i.e., price as a function of quantity) can help in making projections about future oyster prices under different scenarios by providing price flexibility estimates. The inverse demand relationship can also be used to estimate changes in consumer surplus, an approximation of the welfare measure used in benefit cost analysis. This is a simple approach and it has limitations caused by failure to consider the entire system of demand and supply equations; the system of equations for each of the different types of oysters; a demand specification inconsistent with traditional

[3] These are the USDA National Food Consumption Surveys of 1980-1981 and 1987-1988 and the 1981 NMFS seafood consumption survey.

economic theory; and extremely limited data.[4] The results, therefore, should be viewed more from a qualitative rather than quantitative perspective.

Our inverse demand model is specified as:

$$P_{CB} = \alpha + \delta D + \beta_{CB} H_{CB} + \beta_{MA} H_{MA} + \beta_{NE} H_{NE} + \beta_{SA} H_{SA} + (\beta_{G}+ \beta_{Vv}D_{Vv}) H_{G}+ \beta_{PC} H_{PC}$$

where P is the ex-vessel price and H is reported landings subscripted by the region: CB = Chesapeake, MA = Mid-Atlantic; NE = New England; SA = South Atlantic; G = Gulf of Mexico and PC = Pacific coast. D corresponds to a dummy variable that takes the value 0 for the 1950-1978 period and 1 for the 1979-2003 period. The dummy variable tries to capture a structural shift in demand as suggested by the Berry (1992) study. There is also a binary dummy variable subscripted Vv, corresponding to the 1991-2003 period when California required warnings regarding consumption of Gulf of Mexico oysters because of the risk of the bacterial pathogen *Vibrio vulnificus*. Keithly and Diop (2001) found that the relationship of Gulf of Mexico oyster prices and Chesapeake prices dramatically shifted as a result of this concern. The subscripted α, δ and β correspond to model parameters to be estimated using ordinary least squares regression. The model is estimated for the 1950-2003 landings and value data available from the National Marine Fisheries Service.

Results from the inverse demand model estimation are given in Table 1. The model has strong predictive capability with an R^2 of 0.79. All model parameter estimates are significantly different from zero at the 95% confidence level except for New England landings which is not significant and the *Vibrio vulnificus* dummy variable which is significant at the 90% level. Chesapeake, Gulf and Mid-Atlantic landings negatively effected Chesapeake price, whereas, South Atlantic and West Coast prices had a positive

[4] See the recent work on inverse demand systems for fish by Park et al. (2004).

and significant effect. The dummy variable parameter was negative and significant indicating a downward structural shift in demand when comparing the pre 1979 period to the 1979-2003 period.

Table 1. Results from Chesapeake Bay inverse demand model.

	Coefficients	*Standard Error*	*t Stat*
Intercept	4.109317	0.478911	8.580544**
Chesapeake	-7.2E-08	1.1E-08	-6.57307**
Mid - Atlantic	-5.4E-08	1.53E-08	-3.50706**
New England	1.98E-09	3.65E-08	0.054304
South Atlantic	3.67E-07	6.94E-08	5.290569**
Gulf of Mexico	-5E-08	1.41E-08	-3.53745**
Pacific Coast	1.52E-07	2.77E-08	5.468255**
Dummy	-0.55648	0.167197	-3.3283**
Vibrio vulnificus	-1.5E-08	8.37E-09	-1.76588*

R^2 = 0.79; d.f. = 45; **significant at 95% confidence level; * 90% confidence level

Price flexibility, the inverse of elasticity, provides an estimate of the ratio of the effect of a percentage change in quantity on the percentage change in price. Calculated at the mean of the data used in the estimation, the price flexibility for Chesapeake Bay oyster production is -0.37. Thus, a 1% increase in Chesapeake Bay production will result in a 0.37% reduction in Chesapeake Bay price. But the current situation is no where near the mean of the data so that using this estimate of flexibility would not be reflective of expected changes from current conditions. The mean Chesapeake Bay catch for the 1950-2003 period is around 17 million pounds, whereas the 2003 harvest was only about 237 thousand pounds. Mean Chesapeake Bay price is $3.53 and the 2003 prices was $4.10.

To simulate the effect on Chesapeake Bay price of a large increase in local production from current levels we calculated a predicted price based on the last five years of data (1999-2003) for each of the areas of harvest. The predicted Chesapeake Bay price, using Chesapeake Bay harvests equal to the five year average is $3.87 (in 2003 dollars).

To predict the ex-vessel price for Chesapeake Bay oysters under a restored fishery scenario, we convert the target level of 4.9 million bushels to pounds of meat using an assumption of 7 pounds of meats per bushel. Thus, Chesapeake production would be 34.3 million pounds of meats. Keeping all other area's production constant at the 1999-2003 production level, the predicted Chesapeake Bay price resulting from this increase is $1.51, which translates back to an exvessel price of $10.58 per bushel.

Because cost data is not collected for the oyster fishery, it is difficult to comment on the supply (harvest) response to an increasing stock of oysters in the Chesapeake Bay. However, an exvessel price of $10.58 per bushel in 2003 dollars is significantly below any historical low price for oysters and it is reasonable to assume that oystering at this price would not be profitable. Thus, although the restoration of a population of oysters sufficient to sustain harvests at the 4.9 million bushel level may be technically feasible; it is not economically feasible under projected market conditions and we would not expect a viable fishery at that level. It should be noted that this simple price response model does not capture the full suite of market interactions between regions. A more sophisticated multi-market model would need to be developed to reflect how increased supply from the Chesapeake region will affect prices and thus, production from other regions. Here, we have kept other region production constant. Nevertheless, ultimately the market place and consumer demand will determine the total harvest and price of oysters from Chesapeake Bay. The market will tend toward an equilibrium price and harvest that equates prices across regions, although accounting for quality differences (e.g., perceived safety) and transportation costs.

<u>An Industry-Informed Scenario of a Restored Oyster Fishery</u>

For this section we surveyed the industry to gain insight into industry members' beliefs about the market that will result from a restored oyster fishery in Chesapeake Bay. Surveys were mailed or hand delivered to 16 oyster dealers in Virginia and 12 dealers in Maryland. Responses were received from 10 Virginia oyster dealers and 5 Maryland dealers. The information gained from this survey can be used to understand the beliefs held by key industry leaders regarding the economic consequences of particular actions taken in regard to the oyster fishery:

1) As an informed, but biased, prediction of potential industry status

2) To understand the motivation for the level of industry support for a particular proposed action

3) To compare with the results from the statistical modeling of the oyster market.

The first survey question attempted to determine what oyster dealers felt they would have to pay to oyster growers or watermen for either *C. virginica* or for *C. ariakensis* if Chesapeake Bay production of either oyster was equal to the stated goal (4.9 million bushels). With the limited knowledge they have about the market for *C. ariakensis*, Virginia dealers felt on average that it would sell at a premium relative to *C. virginica*; whereas, Maryland dealers felt that the native oyster would sell at a premium. The Virginia results are skewed by two responses (small sample size due to the small size of the extant industry is a problem for this entire part of the analysis) where the dealers guessed that C. *ariakensis* would have a huge premium over *C. virginica*. There were seven out of ten Virginia dealers who felt that they would pay the same or a lower price for *C. ariakensis* than they would for *C. virginica*, and all the Maryland dealers felt the *C. ariakensis* price would be the same or lower than *C. virginica*.

Responses to the first question also provided an indication of industry beliefs regarding price responsiveness to the increased Chesapeake Bay production at the harvester level. For dealers in both states, they felt that oyster prices to harvesters would decline about 22% from current levels of $24 per bushel to $18.80 a bushel for a restored *C. virginica* fishery. The median response for most likely price for both species was $18.00 a bushel.

As evident from for the earlier analysis of oyster prices, the percentage of product that goes to the halfshell market will have a significant effect on industry revenues. We asked the dealers participating in the survey what they thought was the current size of the halfshell market for oysters harvested from Chesapeake Bay or for shellstock imported into the Bay region for distribution. There was a wide variation by dealer in response to this question, but the median response was that 35% of the current Chesapeake Bay oyster market is for halfshell.

So what does the industry think a restored oyster fishery market would look like in terms of halfshell versus shucked product? The median response was that a *C. virginica* fishery restored to historical harvest levels would consist of a 30% halfshell market. On the other hand, they thought a *C. ariakensis* based fishery, would be about 22% halfshell.

We polled the industry on how their output prices would change as a result of a restored fishery based on either *C. virginica* or *C. ariakensis*. We got responses for prices for shucked and halfshell oysters and whether they were "wild" or "cultured". A summary of the median responses is given in Table 2.

Table 2. Median responses of oyster industry experts for wholesale oyster prices resulting from a restored fishery.

	C. virginica	*C. ariakensis*
Shucked, price per gallon	$38.00	$38.00
Wild, price per hundred	$20.00	$18.00
Cultured, price per hundred	$20.00	$17.50

Industry expectations are that their will be no difference in price between the species for the shucked product, but *C. virginica* will have approximately a $2.00-$2.50 premium per hundred count over the *C. ariakensis* price regardless of whether the product is harvested from the wild or cultured. Compared to recent Fulton Fish Market wholesale prices, the $38.00 price per gallon of shucked oysters represents a 21% decline in price for selects. Halfshell market prices are dependent on where the product is from. No recent prices for Chesapeake halfshell oysters were available, but the $17.50 - $20.00 price range is below the price of $40.00 per hundred count for Connecticut cultured oysters and above the $14.50 price for Gulf of Mexico wild oysters.

We also asked the industry to provide their estimates on how their profitability might vary depending on the species and product form. While not equal to economic rent and the appropriate welfare measure that we seek in a benefit cost analysis of the proposed actions, the responses do provide a relative indicator of the industry's perception of what the potential benefits may be. The results are given in Table 3.

Table 3. Industry expectations of profits based on product form.

	C. virginica	*C. ariakensis*
Shucked (wild), profit per gallon	$6.50	$8.00
Shucked (cultured), profit per gallon	$6.50	$7.00
Halfshell (wild), profit per hundred	$5.00	$5.00
Halfshell (cultured), profit per hundred	$5.00	$5.00

From the above, we can aggregate the data to develop a scenario of what industry experts feel a restored Chesapeake Bay fishery might look like. We are assuming that the industry will reach a state where it is harvesting 4.9 million bushels a year from the Chesapeake Bay. The industry believes that regardless of the species used, this will translate into an ex-vessel value or gross watermen/grower income of $88.2 million. Note that this is 25% lower than one would estimate using 2003 prices, so there is some acknowledgement in the industry responses that an increase in supply of oysters will lead to some decrease in price.

According to the survey participants, the difference between an industry based on *C. virginica* versus *C. ariakensis* starts to manifest itself in the difference regarding halfshell versus shucked product, with 30% and 22% going to the halfshell market for each species, respectively. The implication is that there will be a different value and profit at the wholesale level. To calculate the revenues and expected profits, we assume production of 1 gallon of oysters from a bushel and 225 oysters to a bushel. Thus *C. virignica*, under this scenario yields at the wholesale level $130 million worth of shucked product and $66 million worth of shell oysters for halfshell. The figures are slightly different for C. ariakensis with $145 million for the shucked market and $43 million for the halfshell market. While revenues are slightly higher for *C. virginica*, profits are higher for C. ariakensis with profits of $40 million compared to $37 million.

In summary, given limited direct knowledge regarding C. ariakensis and the large amount of uncertainty in projecting changes due to large scale shifts in the oyster market, industry experts see little difference in an industry based around *C. ariakensis* compared with *C. virginica*. This industry analysis does not address the time frame or the cost necessary to create this new market level. Watermen or grower incomes and processing industry profits reported here are not welfare benefits that can be used in a benefit/cost analysis of the proposed actions.

Combining the Industry Scenario With the Inverse Demand Analysis

The industry scenario above appears reasonable in foreseeing a 22% decline in exvessel oyster prices with a restored oyster fishery, but seems overly optimistic when compared with the inverse demand analysis which predicted a 61% price decline. One possibility is that the industry has realistic expectations about what are sustainable exvessel prices relative to the upstream market they face and their costs of processing and handling oysters.

A reasonable approach would be to take the industry price predictions and then determine what size fishery would result in those prices. To do this we simply used our inverse demand estimating equation and solved for Chesapeake Bay landing as a function of predicted price and the harvest in all other regions at the average for the 1999-2003 period. Thus, the $18.80 price per bushel for either species would translate into an exvessel price of $2.69 per pound of meats.[5] Solving for the quantity that results in this price, yields an estimate of Chesapeake Bay landings of about 18 million pounds of meats or 2.57 million bushels. At this level, Chesapeake Bay watermen and producers gross income would be $48.4 million, significantly less than the industry prediction of $88.2 million, but significantly more than the 2003 income of under $1 million. Table 4

[5] This is one area where there may be a significant difference in impacts between the two species if *C. ariakensis* has a higher meat yield per bushel than *C. virginica*. See the discussion on Virginia field trials for more on this topic.

summarizes the scenario, carrying forward the analysis to the next market level, based on the industry scenario of wholesale prices.

Table 4. A scenario for a sustainable oyster industry in Chesapeake Bay.

Species	Harvest (million bushels)	Value ($ million)	Shucked Value ($ million)	Halfshell Value ($ million)
C. virginica	2.57	$48.4	$68.2	$34.6
C. ariakensis	2.57	$48.4	$76.1	$22.6

Welfare Implications of the Commercial Fishery

The exvessel and wholesale values of the oyster fishery calculated above are gross revenues and should not be interpreted as indicators of the net benefits from a restored oyster fishery in Chesapeake Bay. The appropriate welfare measure attempts to determine income or revenues net of all opportunity costs. For example, watermen income increases by $48.4 million, but oyster harvesting is not a costless activity, so costs such as fuel, gear and labor must be considered. Lack of cost data makes it difficult to calculate these expenses. Even with cost data an issue arises related to the opportunity cost of watermen’s labor. Labor costs must consider the opportunity cost of labor, that is, what the watermen could have earned if they had not spent that time fishing. It is conceivable that some watermen have greater earning potential when they are not on the water, but forgo higher income because they prefer working the water to other forms of employment (Anderson 1980). An additional concern is the effect of the common pool nature of much of the fishery (i.e., for the part of the fishery that does not rely on leased bottom). In this case, the classic fishery problem resulting from attenuation of property rights may lead to economic overfishing even when regulations prevent biological overfishing. Economic overfishing is the dissipation of net economic benefits (resource rents) that the fishery would otherwise produce (Gordon 1954). The result is that the $48.4 million income to watermen is an estimate of the upper bound of net benefits that must be adjusted downward to account for fishing costs and the opportunity cost of watermen labor.

The economic benefits to other market levels such as the wholesalers must be adjusted in a similar manner. The estimates of $102.8 million worth of wholesale product for *C. virginica* or $98.7 million for *C. ariakensis* are not welfare measures. First of all, these numbers double count the exvessel value, that is, the price of a wholesale oyster includes the price paid to the watermen for the oyster plus the expense of adding value by processing, packaging and transporting the product, plus the profit to the processor. Only that increase in profit to the processor is a potential welfare gain from restoration of the oyster resource, and even of that, only the profit that they earn from oysters over and above they might earn from investing in processing some other product would count. For example, if the processors earn greater profits because they no longer have to transport oysters from other regions, it would be that increased profit that would be the measure of the welfare gain, not the total value of their processing output. Even then, over time, market factors might shift to eliminate these benefits and the welfare gains to Chesapeake Bay processors might lead to welfare losses to Gulf of Mexico or other processors from outside the region.

Oyster consumers will unambiguously benefit from a restored Chesapeake Bay oyster fishery. They will have available to them, a greater quantity of oysters at a lower price. We can approximate this consumer surplus benefit from our estimated inverse demand if we assume that this demand curve represents a general equilibrium result so that all the markets adjust to the increase in the availability of Chesapeake Bay oysters. Under that scenario, because exvessel demand is ultimately derived from consumer demand we can measure the consumer surplus with the single market demand curve (see Just et al. 2004). Using this approach, we find the gain in consumer surplus from an increase in Chesapeake Bay harvest of 2.57 million bushels of oysters is $11.6 million, annually.

Table 5. A summary of welfare gains (in million, 2003 dollars) from an increase in Chesapeake Bay oyster harvest to 2.57 million bushels per year.

	Gross value	Net Benefit	Comments
Harvesters/producers	$48.4	?	Depends on fishing costs and earning power of watermen in alternative employment.
Processors/Packers	$98.7-$102.8	?	Depends on costs of oysters, costs of creating value-added and profits relative to alternative investments.
Consumers	?	$11.6	Depends on assumptions regarding nature of inverse demand curve used to estimate.

Additional Issues

In addition to all the caveats mentioned above, there are a number of other issues that need to be considered related to the benefits of a restored commercial oyster fishery in Chesapeake Bay. For example, the above analysis does not reveal a large distinction in benefits between a fishery based on *C. virginica* versus a *C. ariakensis* fishery. The only major distinction taken into account above is due to a slight difference in industry beliefs about the size of the halfshell market for each species. If there is a major difference in demand for the two products, particularly if there are true taste and quality differences, this could have an impact on the results. Other factors that might impact results include differentials in the costs of harvesting and product yields.

Another important factor to considering when weighing the potential benefits of a restored fishery is the time frame over which the benefits might accrue. It will take several years to restore oyster resources in Chesapeake Bay to a level that would support the level of fishery we anticipate. Since much of the expense of the proposed alternatives will occur early in the process, this timing will have an impact on calculation of benefits. Lipton et al. (1992) discuss the role of the timing of benefits and costs related to the potential introduction of *C. gigas* into Chesapeake Bay. Since the data suggests that there might not be a significant difference in commercial fishery benefits, once the industry has been fully restored, regardless of the alternative chosen, the greatest difference among alternatives in this regard may be the timing of restoration. Thus, every thing else being equal, from the viewpoint of the commercial fishing industry and oyster consumers, the alternative that restores oysters the fastest will have the highest net benefits. As will be discussed later, not everything else is equal, particularly in relation to risks associated with the introduction of a non-native oyster.

II. Virginia Seafood Council Triploid Ariakensis Trials

Background

As part of it on-going competitive process the Virginia Fishery Resource Grant Program (VFRGP) funded a two-year project to provide overall project management for the Virginia Seafood Council's non-native oyster pilot grow-out study. The funding provided for a professional science manager to assist the VSC in conducting the research and providing liaison between industry and the various entities interested in the research implementation. The position was funded for the two year grow-out experiment and information developed as part of this demonstration project is summarized herein.

The cooperative Virginia Seafood Council (VSC) Virginia Institute of Marine Science (VIMS) industry-based field trial was designed to address two main objectives. The first was to determine if growing triploid *C. ariakensis* in Virginia's Chesapeake Bay and the seaside of the Eastern Shore was economically feasible for both large and small companies. The second was to produce some initial market assessment of triploid *C. ariakensis***.**

In order to determine economic feasibility each participant agreed to track their input costs including fuel, labor, supplies, etc. This information is meaningful when related to income generated from oysters sold into both half-shell and shucking markets. Another objective of this project involved the evaluation of differing grow-out methods. Several types of gear were used, which enabled some general comparison among grow-out methods and growth of *C. ariakensis* in various environments.

Methodologies Employed

Grow-out methods used in the VSC field trials included: traditional "Taylor Floats," off-bottom cages, long-line systems (bags on bottom), re-bar racks, land-based crab shedding tanks, and an experimental raft system. Some of these grow-out systems were part of separate VFRGP project grants, but were also components of the VSC field trials. For example, "Shores and Ruark Seafood" (Urbanna, VA) grew the triploid *C. ariakensis* in an experimental long-line system that was approved for development by a VFRGP grant. In addition, "Shore Seafood" (Saxis, VA) employed an experimental raft system during the fall and winter to grow-out triploid *C. ariakensis* that was also part of a separate VFRGP grant.[6]

Generally the methods included:

- *Off-bottom cages* – ADPI/OBC bags constructed of rigid polyethylene with varying mesh and bag sizes were the primary method of containment. The mesh size used depends on the size of the oyster to be contained. The bags are then secured inside a 4' x 4' cage, with feet, constructed of metal with a total height of not more than 12" off the bottom. The cages can also be anchored using hooks made of iron reinforcing bar.

- *Bags on rack* – Racks consist of $^{3}/_{8}$" to $^{1}/_{2}$" reinforcing bar welded to produce vertical sides of approximately 18" and a length of 10' to 20'. These racks were driven into the bottom in rows, end to end, with working aisles of approximately 3' to 4' between rows. The racks have an off bottom height of not more than 12". ADPI/OBC bags were strapped side by side onto the rack using wire ties, nylon self-locking cables, or rubber bungee cords.

- *Long-lined bags on bottom* – ADPI/OBC bags were secured together by a long line and anchored to the bottom. The number of bags per line varied according to site. Hard bottom sites were typically chosen to ensure that bags did not become silted over.

[6]The use of this system had to be temporarily discontinued for summer 2004 due to the close proximity of units (stacks of tray inserts in the raft) and the possibility of reproduction imposed by the conditions set forth in the VSC's Army Corps of Engineers permit extension document. A complete description of the VSC FRGP project sites and methods may be found at <http://www.vims.edu/vsc/sites.html>

- *Floats* – "Taylor Floats" typically were used, consisting of a 4 inch PVC rectangular ring with a 1 inch coated hard wire basket secured using several tie wraps. Oysters contained within ADPI/OBC bags are then placed inside the floats.

- *Crab shedding tanks* – An existing land-based flow through system was used to further nursery seed from the deployment size of 20mm up to approximately 40mm.The rectangular wooden tanks, which typically house soft crabs before they molt, are approximately 36 inch x 60 inch x 12 inch with a central drain that was screened to prevent escapement. Oysters contained within ADPI/OBC bags were placed inside the tank.

A significant aspect of this project involved diverse marketing strategies employed by each grower. For example, some of the larger shucking facilities processed oysters on site and sold oysters via their established retail and food service customers. Alternatively, smaller aquaculture farms sold primarily "shell stock" oysters to retail, restaurant and food service institutions, and/or directly to the consuming public. A few aquaculture farms also sold shell stock oysters to larger shucking facilities to determine meat yields.

In conjunction with the VSC industry field trial, VIMS implemented a companion study entitled "Biosecurity and Comparative Field Trials of Triploid *C. ariakensis* with *virginica*" which enabled scientists, industry members, and state and federal agencies to collect and have access to related biological and ecological data.[7] (Hudson) The

[7] The VIMS biosecurity project is updated at http://www.vims.edu/vsc/

biological (growth and mortality) data are summarized here in conjunction with the economic information gathered from the growers.

As a result of damage sustained during Hurricane Isabel in September 2003, two participants were unable to participate in the VSC project. Therefore, only eight field sites housed oysters. Nine growers participated, however, as two growers occupied one field site and shared the 100,000 oysters.

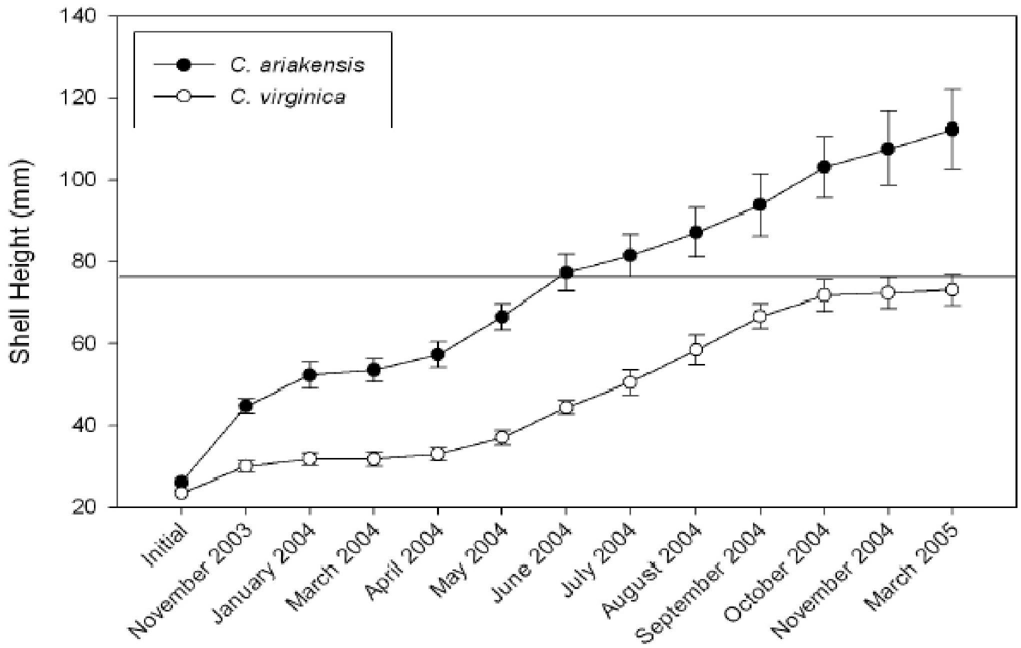
Results

C. ariakensis deployed at all sites during October, 2003 grew very well and generally obtained market size by the spring of 2004. Despite cooler water temperatures and potentially lower food availability, *C. ariakensis* grew quickly once acclimated to site specific environmental conditions. Triploid *C. virignica*, deployed concurrently, did not immediately grow like *C. ariakensis*. In fact, *C. virginica* generally grew very little from deployment until mid-spring 2004. On average across all sites *C.* ariakensis grew 38% faster (range 15%-65%) than *C. viriginica*. and suffered significantly less mortality (7% relative to 20% respectively)[8].

Some *C. ariakensis* were lost due to winter icing at the Saxis, Burgess, Kinsale, Urbanna, Yorktown (Crewe) and Chincoteague sites. Although *C. virginica* experienced little winter icing mortality, growers reported that *C. ariakensis* appeared to be more sensitive to severe cold temperatures if exposed.

[8] The mortality comparison is derived from the VIMS biosecurity project. C.ariakensis mortality within the commercial trials was reported to be 10%, there was no comparison with C.virginica as part of the VSC trial.

Figure 4. Comparison of average shell height growth for all VSC site for C. ariakensis and C. virginica. Error bars represent one standard error. (Hudson)



Within 7 months of field planting (Spring 2004) *C. ariakensis* were beginning to reach market size (76 mm.). Growers at higher and moderate salinity sites were marketing hundreds to thousands of *C. ariakensis* primarily for the half-shall market. *C. virginica* was growing but not nearly at the rate of *C. ariakensis* , nor were the *C. virginica* of marketable size. As depicted above, on average, C. ariakensis reached. market size within 9 months of deployment. In contrast, on average the *C.virginica* still had not reached market size after 18 months of deployment.

Given the delay in deployment and general disruption from Hurricane Isabel, a new federal permit extension was issued by USACOE on July 1st, 2004 which included nine additional grow-out conditions. This is noteworthy for this presentation as one condition required the growers to prematurely harvest oysters and/or further reduce the density of oysters per unit (i.e. cage, bag, or float). It is believed that this measure directly impacted the results of the industry trials. This requirement imposed inefficiencies in terms of the grow-out economics as well as resulting product marketability. The new permit condition required the growers to purchase more gear while expending more labor in culturing the *C. ariakensis*. Additionally the condition put the growers in a position where they had to harvest smaller ("standard") oysters and disadvantageously sell the "culls" on the market at a time of the season when oyster product demand is comparatively low.[9] In summary, these additional constraints increased variable costs while also reducing per unit value.

Grow-out Costs

As depicted in Table 1, costs of production varied significantly from site to site . Some growers, (Sopko-Hudgins, Ruark-Urbana, and Crewe-Yorktown) used existing materials and supplies and primarily older cages to contain oysters. Other growers (Mason-Chincoteague, Bevans-Kinsale, and Leggett-Yorktown) chose to purchase new coated wire cages, which totalled from $1,000 to $4,000 in initial investment costs. In general, minimal initial investments were made in labor, fuel, and other miscellaneous aquaculture costs. Per-unit labor appears to be consistent with typical aquaculture techniques, although as noted above, increased biosecurity and required harvest and splitting of oysters as part of permit extension conditions increased these per-unit labor costs.

When using an imputed labor cost of $10.00/ hour the average wage bill for all trials was $4,095, or 37% of the variable costs of grow-out. The average annual cost of supplies was $5,740, or 52% of grow-out expenses. These supply costs vary

[9] The greatest demand for oysters occurs traditionally around Thanksgiving, Christmas and Lent.

considerably both in amount and type between the different grow-out methods outlined above. The treatment of most of these inputs as annual expenses (including such things as wire, cages, floats, bags, cables, etc.) likely understates the annual grow-out profit estimated here, as much of these materials may be re-used for more than one grow-out cycle. The decision to expense these costs here was made because of the variability of such costs and the fact that typically such materials may be expensed under Internal Revenue Service guidelines. Assigning a standard useful life to fabricated gear such as floats, cages, etc. would be arbitrary given their custom made nature. With the exception of the oyster culture raft (Saxis), which is depreciated over an estimated useful life of 7 years, other gear and equipment are expensed.

Table 6. Virginia Seafood Council Oyster Grow-out Average Cost and Returns 2003-2005	
Cost Category	Average (Range)
Labor Cost	$4,095 ($2,580-$5,280)
Supplies	$5,740 ($700-$10,484)
Fuel	$223 ($50-360)
Seed	$879 ($773-1,000)
Electricity	$12.50 (0- $100)
Total Cost	$10,951 ($4,499-$16,035)
Oysters Sold	87,985 (77,320-99,998)
Total[10] Revenue	$20,999 ($18,557-$23,000)
Balance	$10,049 ($2,801-$17,677)

Grow-out Returns

Within 8 months of deployment, initial market information was gathered. From December 2003 through June 2004, growers reported approximately 204,940 triploid *C. ariakensis* had been sold to both the half-shell and shucked markets. Also, from July through August 2004 another 78,950 *C. ariakensis* were marketed in both sectors. Product was distributed to both novice and experienced oyster consumers, and large and small half-shell and shucked markets.

Overall, at the completion of the trials in March 2005 growers had marketed 703,878 *C. ariakensis* oysters reportedly worth $167,998.10. Oysters were sold both as shucked product and half-shell. The overall average sales price was $.24/oyster. The gross revenues reflected here include the shucked sales. When adjusting for the cost (value added) of the shucking operation the average revenue from oysters going into

[10] Oysters were sold both as shucked product and half shell. The gross revenues reflected here include the shucked sales. Overall average sales price was $.24/oyster. When adjusting for the cost (value added) of the shucking operation the average revenue from oysters going into shucking should be reduced by $.03-$.04 per oyster to an estimated $.20-$.21/ per oyster based upon the average price estimated by industry of $42-$44 per gallon.

shucking should be reduced by $.03-$.04 per oyster yielding an estimated $.20-$.21 per oyster.

Table 7. Combined Virginia Seafood Council Oyster Grow-Out Cost and Returns 2003-2005									
	Kinsale	Burgess	Urbanna	Hudgins	Yorktown (Crewe)	Yorktown (Leggett)	Saxis	Accomack	Chincoteague
Labor Hours	516	528	344	258	149	223	445	483	330
Labor Cost	$5,160.00	$5,280.00	$3,440.00	$2,580.00	$1,490.00	$2,230.00	$4,450.00	$4,830.00	$3,300.00
Supplies	$5,553.00	$9,441.00	$9,516.00	$700.00	$202.00	$4,783.00	$10,484.00[11]	$2,342.00	$2,904.00
Fuel	$200.00	$275.00	$360.00	$295.00	$150.00	$175.00	$90.00	$190.00	$50.00
Seed[12]	$885.20	$939.00	$773.20	$924.00	$404.90	$499.98	$775.00	$837.58	$999.98
Electricity	$0.00	$100.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Cost	$11,798.20	$16,035.00	$14,089.20	$4,499.00	$2,246.90	$7,687.98	$15,799.00	$8,199.58	$7,253.98
Oysters Sold	88,520.00	93,900.00	\77,320.00	92,400.00	40,490.00	49,998.00	77,500.00	83,752.00	99,998.00
Total [13] Revenue	$21,244.80	$22,536.00	$18,556.80	$22,176.00	$10,122.50	$12,499.50	$18,600.00	$19,262.96	$22,999.54
Balance	$9,446.60	$6,501.00	$4,467.60	$17,677.00	$7,875.60	$4,811.52	$2,801.00	$11,063.44	$15,745.56

[11] The raft culture system capital cost ($6,500) is amortized (5%) over a 7 year expected useful life rather than expensed as other grower supplies.

[12] Each grower (8) paid $1000 for the triploid technology and nothing for the actual seedFor the sake of budgeting $0.01 per oyster is a reasonable proxy. Personal Communication, S.K. Allan, ABC. April 20, 2005.

[13] Oysters were sold both as shucked product and ½ shell. The gross revenues reflected here include the shucked sales. Overall average sales price was $.24/oyster. When adjusting for the cost (value added) of the shucking operation the average revenue from oysters going into shucking should be reduced by $.03-$.04 per oyster an estimated $.20-$.21/ each based upon the average price estimated by industry of $42-$44 per gallon.

Discussion

This pilot project has demonstrated that culturing triploid *C. ariakensis* is feasible in Virginia waters even under relatively rigid grow-out protocols. Initial investments ranged from a few hundred to a few thousand dollars depending on the purchase of new or used grow-out systems. One challenge for industry arises due to the fact that *C. ariakensis* have proven to grow quite fast, relative to the native oyster. This creates a situation where the *C. ariakensis* need to be tended on a more frequent basis than the native oyster. Otherwise, crowding and smothering may occur which ultimately leads to mortality.[14] Using existing aquaculture techniques, it appears as a result of this project, that a relatively small investment of $1,500 to $10,000 when combined with skilled shellfish culture management can realistically grow-out 100,000 triploid *C. ariakensis* with gross returns ranging from $18,600 to $23,000.[15]

Based upon these pilot demonstration projects, it is evident that a profit can be made with triploid *C. ariakensis* aquaculture. Even though initial investments in more elaborate systems can be high, such capital costs would be amortized over a period of time and the grow-out returns realized for several year classes of oysters. Further the relatively short period from field planting to market grow-out provides enhanced cash flow. This suggests that *C.ariakensis* is an attractive oyster for such small scale culture relative to other oyster varieties. Accelerated growth is additionally attractive to growers who, faced with decades of increasing oyster mortality due to diseases, value the reduced risk associated with a shorter grow-out period. Indeed, a positive grow-out cash flow in

[14] Given the rapid growth industry is considering relatively low stocking rates per bad to accommodate more rapid growth. This is expected to reduce labor costs and further minimize bio-security questions.

[15] The average price received for all sales of “half shell” C. ariakensis was $.215 each. The average price for shucked C. arikensis was $42-44 per gallon.

one to two years of operation is unprecedented in Virginia's molluscan shellfish aquaculture industry.

Preliminarily market returns indicate that this oyster is an exceptional shucking product. Growers were encouraged with meat yields as high as 11-14 pints/bushel compared to an expected range of 7-8 pints/ bushel for C. *virginica*. Furthermore industry's initial response to shucking *C. ariakensis* was positive. Operators of shucking houses grade oysters according to the number of pints that can be produced from a bushel of culled oysters. The relative quality of oysters is primarily determined by this yield. The table below summarizes shucking yield relative to industry evaluation of shucking quality.

Table 8. Oyster Yield Per Bushel and Industry Grade

4 Pints	Poor
5 Pints	Below Average
6 Pints	Average
7 Pints	Good
8 pints	Very Good
9-10 Pints	Exceptional

These results confirm that *C. ariakensis* presents the potential for an exceptionally profitable shucked product. Processors find it advantageous to buy oysters which yield the most meats per bushel reducing the volume of shell stock to be handled. This is reflected in the fact that, traditionally, processors pay premium prices for higher grade (yield) oysters. Additionally, shucking houses processing *C. ariakensis* reported that the oyster is easily opened and shuckers could readily remove the meat product from the shell stock.

In contrast, the *C. ariakensis* half shell product was reportedly not as well accepted, relative to *C. virginica*, as the shucking product. A relatively short shelf life seems predominant regardless of salinity. Oysters that were kept dry and in ambient air temperatures often lasted only one to two days. Oysters kept in cool storage (~ 45-50^{o} F) survived for up to 3-5 days, although those oysters kept in cold storage (32^{o}F) were subject to a slightly earlier mortality. Growers observed during in this initial trial that grow-out method may have an effect on shelf life. For example, oysters that have remained inter-tidally since deployment, even through the cold winter months, may have had a longer shelf life.

As reported, several grow-out methods were employed during the VSC demonstration project. Interesting differences and experiences were observed. For example, long-line bags on bottom (Urbana) seem to expedite the growth of *C. ariakensis*. This may be due in part to the native habitat of *C. ariakensis,* which can be muddy bottom. In addition, crab-shedding tanks, which are bio-secure, appear to be an effective intermediate step in culturing *C. ariakensis* (Burgess). Prior to field deployment, tanks can be used to increase shell height, possibly avoiding predation from crabs and/or skates. Industry members learned that oysters should be removed from tanks prior to freezing conditions; otherwise, mortality may become a problem. Floats encourage oysters to grow very quickly as they take advantage of surface phytoplankton blooms. Oysters in floats are also protected during freezing temperatures, as the basket of the float sits a foot or more below the water's surface. (VSC)

Discussion of Near-term Impacts

There are estimated to be approximately one to two dozen commercial oyster farms in Virginia, with annual production capability at around 250,000 oysters per farm.[16] Most animals are sold to local niche markets, including restaurants, grocery stores, and farmers markets, in addition to some online sales. While all growers are interested in increasing production, small- scale producer markets may not support significant increase. However, smaller scale aquaculture farms producing 300-900 bushels/year are considered realistic scenarios and a profitable scale of operation based upon current culture techniques. It appears that the culture of *C. ariakensis* represents a potential for expansion of this current capability as demonstrated in the VSC field trials.

The potential for large-scale oyster planting, such as traditionally practiced in Virginia, appears to be promising with the allowance of extensive culture of *C. ariakensis*. The current interest in remote setting and continued culture of triploid animals suggests a real development opportunity may be furthered with the use of non-native oysters. It is believed that current hatchery potential for triploid oysters is fixed; however, continued success in triploid grow-out would foster additional industry investment in existing commercial hatcheries. To summarize, based upon these initial grow-out trials, both on bottom culture of shucking products and expansion of aquacultured half-shell production may be economically feasible.

To put this investigation into the current economic context of Virginia's oyster industry, it is important to compare the VSC limited pilot trials (which produced gross

[16] Currently Virginia does not specifically license or permit shellfish aquaculture operations, therefore an exact accounting of the firms involved in shellfish aquaculture is not available. The estimates here are based upon informal market assessments conducted as part of the Virginia Fishery Resource Grants Program.

grower revenues of $168,000) with the entire traditional oyster fishery in Virginia. That industry reportedly harvested 23,804 lbs. of oyster meats valued at $100,972 during 2004.

Clearly, the prospect for significant enhancement of the oyster producing sector has been demonstrated with these trial introductions. The sales of the *C. ariakensis* contributed a total economic impact of $310,000 to the Commonwealth. When the production details of C. ariakensis are combined with the existing aquaculture capacity represented by small, yet knowledgeable, growers, the potential for immediate expansion seems clear. With implementation of *C. ariakensis* grow-out by the 24 small-scale oyster aqua-culturists in Virginia, a first year harvest of approximately 4 million oysters could be easily expected. The "farm gate" value based upon recent prices would approximate $1.0 million the first year, with a total economic impact to the state of Virginia of $1.84 million.

Detailed Production and Grow-out Results by Site

As with *C. Virginica*, *C. ariakensis* growth varies considerably from one region to another (and even from one part to another on the same ground) and from year to year on the same grounds.

Table 9. High Salinity VSC Sites Grow-Out Variable Cost and Returns 2003-2005

Costs and Returns	Accomack	Chincoteague	Average
Labor Hours	483	330	406.50
Labor Cost	$4,830.00	$3,300.00	$4,065.00
Supplies	$2,342.00	$2,904.00	$2,623.00
Fuel	$190.00	$50.00	$120.00
Seed	$837.52	$999.98	$918.75
Electricity	$0.00	$0.00	0
Total Cost	$8,199.52	$7,253.98	$7,726.75
Oysters Sold	83,752	99,998	91,875
Total Revenue	$19,262.96	$22,999.54	$21,131.25
Balance	$11,063.44	$15,745.56	$13,404.50

Figure 5. Comparison of growth by VSC site for C. ariakensis and C. virginica at individual sites within the high salinity regime. Values represent shell height growth averaged at individual site. Error bars represent one standard error. (Hudson)

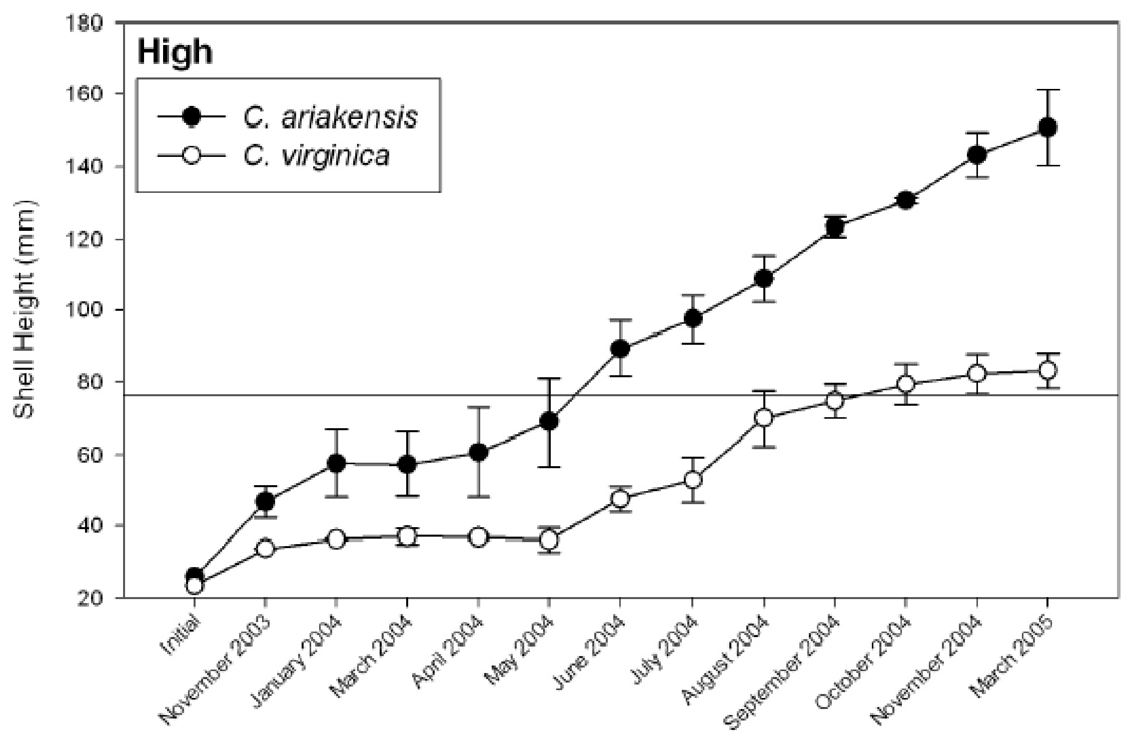


Table 10. Medium Salinity VSC Sites Grow-out Variable Cost and Returns, 2003-2005

Costs and Returns	Hudgins	Saxis	Yorktown Combined
Labor Hours	258	445	372
Labor Cost	$2,580.00	$4,450.00	$3,720.00
Supplies	$700.00	$10,484.00	$4,985.00
fuel	$295.00	$90.00	$325.00
seed	$924.00	$775.00	$904.88
electricity	$0.00	$0.00	$0.00
Total Cost	$4,499.00	$15,799.00	$9,934.88
Oysters Sold	92,400	77,500	90,488
Total Revenue	$22,176.00	$18,600.00	$22,622.00
Balance	$17,677.00	$2,801.00	$12,687.12

Figure 6. Comparison of growth for C. ariakensis and C. virginica in a medium salinity regime. Values represent shell height growth averaged over all sites with similar salinities. Error bars represent one standard error. (Hudson)

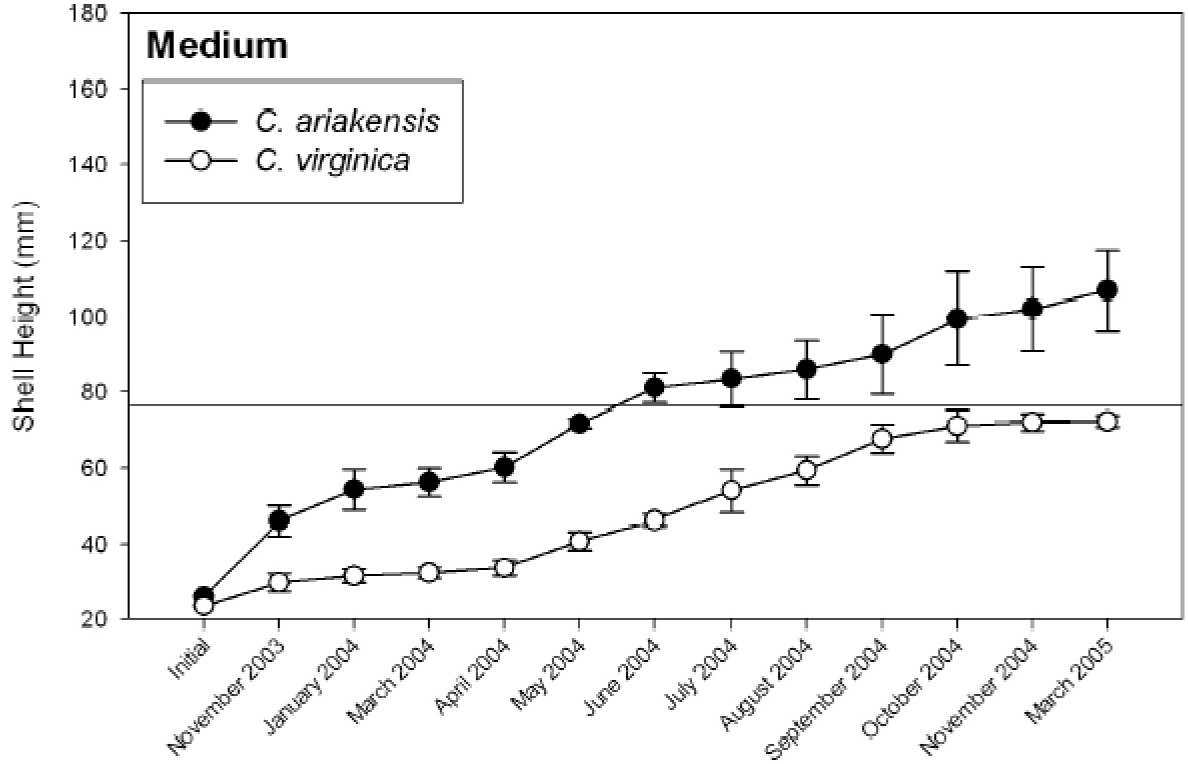
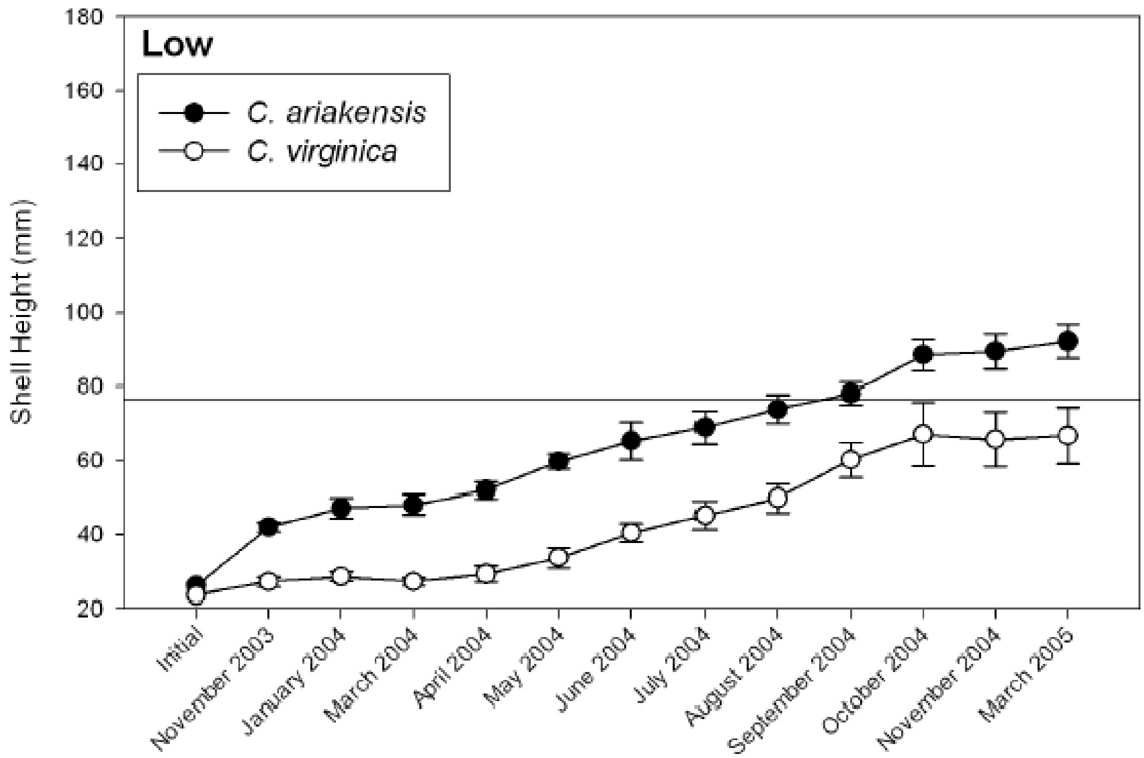


Table 11. Low Salinity VSC Sites Grow-out Variable Cost and Returns, 2003-2005

Costs and Returns	Kinsale	Burgess	Urbana	Average
Labor Hours	516	528	344	463
Labor Cost	$5,160.00	$5,280.00	$3,440.00	$4,626.67
Supplies	$5,553.00	$9,441.00	$9,516.00	$8,170.00
Fuel	$200.00	$275.00	$360.00	$278.33
Seed	$885.20	$939.00	$773.20	$865.80
Electricity	$0.00	$100.00	$0.00	$33.33
Total Cost	$11,798.20	$16,035.00	$14,089.20	$13,974.13
Oysters Sold	88,520.	93,90	77,32	865

	00	0.00	0.00	80.00
Total Revenue	$21,244 .80	$22,5 36.00	$18,5 56.80	$20 ,779.20
Balance	$9,446. 60	$6,50 1.00	$4,46 7.60	$6, 805.07

Figure 7. Comparison of overall growth for C. ariakensis and C. virginica within a low salinity regime. Values represent shell height growth averaged over all sites with similar salinities. Error bars represent one standard error. (Hudson)



Overview of Comparative Growth and Mortality

Growth data show *C. ariakensis* outperforming *C. virginica* without exception at every site (every salinity regime). Disease sampling from all sites has indicated light infections for both species, a situation that might be peculiar to the time period of the project. However, it is also possible that triploidy, *per se*, may decrease the incidence of disease.[17] Except for a couple of incidents of icing that killed both species, mortality has

[17] Personal Communication. Stan Allen

been relatively low, somewhat higher in *C. virginica* than *C. ariakensis*. These results are also contrary to those of Grabowski et al. (2004) who reported relatively higher mortalities across sites, and higher mortality in *C. ariakensis* than *C. virginica* at high salinity.

It is likely that high salinity and most medium salinity sites can realize nearly 100% harvest within a year. Not known is whether the same can be realized at lower salinity sites, since growth is somewhat slower there. In addition to the clear advantage of improved cash flow and return on investment, a major advantage of a one-year crop rotation would be accommodation of the concerns for biosecurity in non-native *C. ariakensis* aquaculture.

The table below summarizes the disposition of oysters from the 9 individual grow-out investigations (8 sites) in terms of oysters sold and mortality per trial. Overall deployment of 790,054 *C. ariakensis* oysters was reported, with 703,878 oysters ultimately marketed and a final mortality rate of 10.3 % (81,796)[18].

[18] This compares with 7% mortality associated with the VIMS biological studies attendant to this grow-out project.

III. Indirect Use and Non-Use Benefits

It is likely that a large share of potential benefits from the proposed alternatives will be in the form of non-market, indirect use generated benefits. In this case, oysters are not valued directly, but instead for their contribution to the production of some other Chesapeake Bay good or service (Hicks et al. 2004), and there are no markets to acquire these goods and services.

Non-market goods are not traded and have no corresponding market price. Such goods include environmental and ecological resources, outdoor recreation, and numerous other amenities. As already suggested, nonmarket goods may have both direct and indirect use values. If an increased abundance of oysters improves water quality in some areas, housing prices for waterfront homes in those areas might have higher values[19]. There are five possible types of indirect use values (Kahn 1998): (1) existence, (2) bequest, (3) altruistic, (4) option, and (5) the value of ecological services.

All of these types of indirect use values, and particularly the value of ecological services, are likely to be important to the economic valuation of the proposed alternatives. Existence value is simply the welfare an individual receives from knowing a resource or state of the environment exists, even though that individual may never have any intention of using the resource. Bequest value is the economic value or benefit an individual receives by knowing that the resource will be available for use in the future for society to experience. Option value is the welfare an individual receives by maintaining or preserving the option to use the resource in the future. Altruistic value is similar to the "feel-good" value; that is, an individual values the opportunity for other people to enjoy

[19] see Leggett and Bockstael (2000) for a study demonstrating the impact of water quality, measured as fecal coliform, count on housing values in Anne Arundel County, Maryland.

the resource. Ecological values are those indirect use values generated from a state of the environment or resource (e.g., oysters filter algae, which in turn, improves water quality and may help maintain biodiversity).

A recent report prepared for the Chesapeake Bay Foundation by Hicks et al. (2004), examines the potential benefits of native oyster reef restoration Hicks et al. determined that just recreational anglers would realize benefits of approximately $640 thousand per year for restoring 1,890 acres at 73 reef sites in the Bay. The total cost of the restoration of the 1,890 acres was determined to equal $27.0 million. When calculating the net present value of the 30 year stream of benefits, assuming a discount rate of 3.0 %, it was determined that just the recreational benefits would equal approximately 50 % of the cost of the restoration.[20] However, since recreational fishing is just one class of benefits derived from oyster reef restoration, it is necessary to look at other large categories of benefits as well.

In the same study by Hicks et al., it was shown that there were other sources of indirect benefits.[21] Using a mail survey of residents of New Jersey, Delaware, Maryland, Virginia, and North Carolina, Hicks et al. determined that the potential economic value or non-use benefits of a ten year oyster reef project, consisting of 10,000 acres of oyster sanctuary and 1,000 acres of artificial reef, to be at least $115 million. These indirect uses include enhanced water quality; possible increased populations of other species of fish; improved fish habitat; and improved recreational boating and water-based activities.

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[20]Because of changes in individual preferences over time and inflation, it is necessary to convert future dollar values to present dollar values. This is done by dividing the annual value of $640.0 thousand by a factor of $(1.0 + 0.03)^t$, t = 0,…,29, and indicates time. Note that any value raised to the power of zero equals one. The value 0.03 is the social time rate of preference for society. The cumulative value of $640.0 thousand over the 30 year horizon equals $12.9 million.

[21] Because the services provided by oyster reefs cannot be purchased or sold in a market, it is necessary to examine the potential non-market value using a hypothetical market (Hicks et al. 2004).

Unfortunately, the study by Hicks et al. (2004) focused solely on restoring native oyster reefs, and not actually on options for increasing the population of oysters in the Bay via enhancing the abundance of non-native (*Crassostrea ariakensis*) oysters. Given that respondents likely equated oyster reef restoration with enhanced abundance of native oysters, the results presented in Hicks et al. likely can be interpreted as being indicative of the value society places on improved resource levels of, at least, the native oyster. It remains uncertain as to how society might value differently the introduction of the non-native oyster. Society may view the introduction of the non-native as being too risky, and thus, they may be only concerned about the potential social costs of introducing *C. ariakensis*. Alternatively, society may have a clear preference only for restoring the native oyster, *C. virginica*.

There have been numerous studies on the introduction of non-native, exotic, or invasive species. In most cases, however, the introduction was accidental, and did not involve the introduction of oysters of any species. For example, a good case in point is the accidental introduction of zebra mussels and the Veined rapa whelk. Zebra mussels have been determined to negatively affect power plants and compete with indigenous populations for food. The potential harm caused by the Veined rapa whelk is still under investigation, but it is known that it preys on other mollusks in the Bay (e.g., oysters, clams, and mussels). In a 1993 report by the Office of Technology Assessment (OTA), it was reported that the monetary costs associated with biological invasions in the United States, alone, was between $4.7 and $6.5 billion annual. Most recent research has revised these estimates upward to $100.0 billion (Pimentel et al. 2000). Settle and Shogren

(2002), in an examination of the introduction of Lake trout to Yellowstone Lake, found that it would cost approximately $33.8 million to eliminate the non-native Lake trout.

Numerous studies have been conducted on determining the non-market value of the ecological services of various resources. For example, a study by Lynne et al. (1974) determined that the economic value of protecting marshes equaled $0.30, which equals approximately $0.94 in 2004 values, per acre relative to enhancing the population of blue crabs.[22] Much of the interest about introducing *C. ariakensis* is related to the perception of enhanced water quality and improved ecological services likely to result from an enhanced population of oysters in the Chesapeake Bay. In a 2004 study by Lipton, it was demonstrated that the economic value of improved water quality, just to Maryland boat owners, was approximately $7.3 million per year or $243 million in present value terms using a 3% discount rate. No attempt was made to estimate the economic value to Virginia boat owners or of the ecological services of improved water quality.

Unfortunately, there have been no economic studies linking ecological services and introduction of the non-native *C. ariakensis*. Significant contributions of social welfare or net benefits to society, however, are likely to be derived from the potential contributions to the production of other Chesapeake Bay goods and services (e.g., enhanced populations of blue crab and striped bass because of improved water quality and habitat). In many instances in which data are limited, limited estimates of benefits to society are possible using the methods of benefit transfer and meta-analysis (Songhen 2001). Both of these approaches, however, require estimates of the economic value from

[22]Hicks et al. (2004) provide numerous references on more recent studies; also, see the journal Ecological Economics, which contains numerous economic valuations of the ecological services of natural resources. For a comprehensive discussion on approaches for valuing ecological services, see Randall and Gollamudi (2001), "Dealing with the Analytical Challenges of Valuation: Aquatic Nuisance Species Control."

either the introduction of *C. ariakensis* elsewhere or the introduction of other, but similar (e.g., the introduction of *C. gigas* in the Pacific Northwest during the early 1900s), non-native species either in the same area or elsewhere. Unfortunately, there does not appear to have been any studies on the economic value of introducing similar non-native species in the United States, particularly in the Chesapeake Bay region.

Potential ecological benefits would be expected to mostly derive from enhanced water quality, which would be expected with higher resource levels of oysters. Improved water quality would be expected, in return, to improve resource levels of all the Bay's finfish and shellfish resources, along with improvements to submerged aquatic vegetation and essential fish habitat. All water-based recreational users (e.g., boaters and swimmers) would also be expected to realize increased benefits because of improved water quality. Waterfront property owners would also be expected to realize higher benefits because of improved water quality.

Cerco and Noel (2005), using existing Chesapeake Bay models have made some preliminary estimates of water quality improvements associated with and increase in oyster populations. Specifically, they have estimated how an increase in the population of oysters to the target level would reduce chlorophyll concentrations, decrease light attenuation, increase SAV biomass, and increase average summer dissolved oxygen compared to baseline 1994 levels. The economic study most directly tied to this estimate is the recreational striped bass fishing study by Lipton and Hicks (1999). The estimated that an increase in bottom dissolved oxygen in Chesapeake Bay so that levels of monitoring stations never fell below 5 mg/l (a much more optimistic scenario than the Cerco and Noel calculations) would result in annual net benefits to recreational fishermen of only $254,000 in 2005 dollars. These values are low because the striped bass population, at least in terms of numbers, is relatively healthy. According to Lipton and Hicks, a decline in water quality from the baseline 1994 levels would result in a significant decline in striped bass catch rate with losses estimated to range from $6.5-$9.5 million per year.

Costs and Risks

The potential benefits of oyster restoration discussed above are the opportunity costs of the no action alternative. At the other extreme of economic value are the potential costs of introducing *C.* a*riakensis*. These potential costs include the cost of research; the cost of the actual introduction; the potential costs associated with the potential introduction of new diseases; the costs of resource management; the potential costs associated with the loss of the indigenous oyster, which is not known; and the potential failure of the introduction. It remains unknown how larger population levels of *C. ariakensis* will affect reproduction, recruitment, the weight and growth, and mortality of other finfish and shellfish in the Bay and associated tributaries.

Risk and uncertainty about the benefits of the alternatives are likely to be quite high as well. For example, market demand for oysters has been declining over years, and thus, will there be a sufficient market to handle increased supply? The analysis above relied on an assumption of stable demand. Despite the apparent large degrees of risk and uncertainty relative to the introduction of *C. ariakensis*, it is possible, when appropriate information is available, to provide an assessment of the economic value or net benefits of introducing *C. ariakensis* to the Chesapeake Bay.[23]

[23] Russell (2001) provides a comprehensive review of methods and procedures, which can be used to assess the economic benefits in the presence of risk and uncertainty.

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APPENDIX 1

INDUSTRY OYSTER SURVEY

Dear Chesapeake Oyster Dealer,

An environmental impact statement is in the process of being prepared for a proposal to establish an oyster population that reaches a level of abundance in Chesapeake Bay that would support sustainable harvests comparable to harvest levels during the period 1920–1970. A variety of alternatives are being explored to achieve that goal including the introduction of a non-native oyster Crassostrea ariakensis, expansion of native oyster restoration and repletion programs and various combinations of alternatives.

As an industry leader we are interested in your expert opinion on important characteristics of the oyster market that will accompany a return to sustainable harvests of 4.9 million bushels a year from the Chesapeake Bay. Please use your industry knowledge to fill in all the responses to the current survey. There are no right answers; it is your expert judgment that counts. Once we collect completed surveys from all the major oyster dealers in the Chesapeake region, we will provide you with a summary of the survey results (i.e., industry average responses to all the questions).

1. According to preliminary Maryland DNR figures, in the most recent oyster season (2003-2004), the average bushel price to watermen for oysters was approximately $24. If Chesapeake Bay landings are 4.9 million bushels per year, what is your best estimate regarding

	for virginica	for ariakensis
a. The lowest price per bushel	$______	$______
b. The highest price per bushel	$______	$______
c. The most likely price per bushel	$______	$______

2. To the best of your knowledge, what range in percentage of the recent Chesapeake Bay harvest and shellstock brought into the region is destined for the halfshell market:

a. Lowest percentage halfshell	______%
b. Highest percentage halfshell	______%
c. Most likely percentage halfshell	______%

3. What is your best estimate as to what percentage of a restored oyster fishery of 4.9 million bushels a year from the Chesapeake Bay will be sold for the halfshell market?

	for virginica	for ariakensis
a. Lowest percentage halfshell	______%	______%
b. Highest percentage halfshell	______%	______%
c. Most likely percentage halfshell	______%	______%

4. Looking at Fulton market data for 2003, the average annual price for select shucked oysters were approximately $48 per gallon. What price per gallon for select oysters would you expect if the Chesapeake Bay oyster fishery were restored to 2-3 million bushels a year?

	for virginica	for ariakensis
a. The lowest price per gallon	$______	$______
b. The highest price per gallon	$______	$______
c. The most likely price per gallon	$______	$______

5. Looking at Fulton market data for 2003, average annual shell oyster prices ranged from approximately $14.50 per 100 count box for Gulf of Mexico wild oysters and $40 per 100 count for cultivated Connecticut oysters. What price per 100 count would you expect if the Chesapeake Bay oyster fishery were restored to 2-3 million bushels a year?

	for virginica	for ariakensis
a. The lowest price per 100 count **WILD**	$______	$______
b. The highest price per 100 count **WILD**	$______	$______

		for virginica	for ariakensis
c.	The most likely price per 100 count **WILD**	$______	$______
d.	The lowest price per 100 count **CULTURED**	$______	$______
e.	The highest price per 100 count **CULTURED**	$______	$______
f.	The most likely price per 100 count **CULTURED**	$______	$______

6. Given the expected cost of shellstock, processing and handling costs, and wholesale prices for a restored Chesapeake Bay fishery, what is your best estimate of profit margins for the following products

		for virginica	for ariakensis	
a.	The lowest profit per gallon	$______	$______	**WILD**
b.	The highest profit per gallon	$______	$______	**WILD**
c.	The most likely profit per gallon	$______	$______	**WILD**
d.	The lowest profit per gallon **CULTURED**	$______	$______	
e.	The highest profit per gallon **CULTURED**	$______	$______	
f.	The most likely profit per gallon **CULTURED**	$______	$______	
g.	The lowest profit per 100 count	$______	$______	**WILD**
h.	The highest profit per 100 count	$______	$______	**WILD**
i.	The most likely profit per 100 count	$______	$______	**WILD**
j.	The lowest profit per 100 count **CULTURED**	$______	$______	
k.	The highest profit per 100 count **CULTURED**	$______	$______	
l.	The most likely profit per 100 count **CULTURED**	$______	$______	

7. With a restored oyster fishery in the Chesapeake Bay, how many full-time equivalent (FTE) jobs, other than watermen, will be necessary to support the processing, wholesaling and distribution of oysters
   a. The fewest number of FTE jobs _______FTE's
   b. The highest number of FTE jobs _______FTE's
   c. The most likely number of FTE jobs _______FTE's

8. Have you currently had any business-related experience with *Crassostrea ariakensis*?
   ____YES ______NO

9. Are there other issues related to the economics of a restored oyster industry in Chesapeake Bay that you think it would be important for us to know about?

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Thank You