10-2008

Economic Implications of Alternative Management Strategies for Virginia Oysters and Clams

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Recommended Citation

Bosch, D., Kuminoff, N. V., Harris, A., Pope, J. C., Stephenson, K., & Mason, P. (2008) Economic Implications of Alternative Management Strategies for Virginia Oysters and Clams. Virginia Institute of Marine Science, College of William and Mary. https://doi.org/10.21220/V5415V

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October, 2008

Virginia Coastal Zone
MANAGEMENT PROGRAM

This project was funded by the Virginia Coastal Zone Management Program at the Department of Environmental Quality through Grant #NA07NOS4190178 (Task#92.02) of the Department of Commerce, National Oceanic and Atmospheric Administration, under the Coastal Zone Management Act of 1972, as amended.

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0. EXECUTIVE SUMMARY

The Virginia shellfish industry has historically been an important element of the state's economy. After long-term downward trends in the harvest of wild stocks, clam and oyster production from shellfish aquaculture has been growing. This report provides an analysis of the possible ways to support and enhance this expansion through a variety of shellfish policy options. Three general classes of policy alternatives were considered: 1) state policy to increase private grounds available for shellfish production, 2) state research and development programs, and 3) various financial incentives to increase production.

In general, the availability of suitable lease ground is not a large barrier for expansion to oyster aquaculture. Thus, reforms to the state's current leasing policy are unlikely to stimulate significant new production. Existing clam producers, however, identified ground availability as one of the most significant barriers to increasing production. Unlike existing larger producers, smaller clam growers were more likely to see ground availability as a barrier, providing supporting evidence that clam production would expand if more grounds were made available. In general a slight majority of active shellfish producers surveyed supported opening some of the current (unproductive) Baylor grounds to leased shellfish production.

Shellfish aquaculture producers in general identified seed availability and poor water quality as major challenges to the industry. Both oyster and clam producers indicated that state policies to facilitate seed production and improve water quality would do the most to assist their operations. Some conflicts between shellfish growers and surrounding landowners have been widely publicized in the local media, but such conflicts do not appear to be a systematic or widespread obstacle for the industry. Less than 10 percent of oyster growers identified conflicts with surrounding property owners as the most important barrier limiting expansion of their operations. Clam growers expressed even less concern with land owner conflicts.

State sponsored shellfish research has the potential to significantly benefit the oyster industry. Over half of all oyster growers indicated that development of triploid oysters and field trials verifying and testing new genetic strands of oysters would be the most useful lines of research. A firm level simulation analysis of oyster aquaculture operations provides additional support for these conclusions. Simulation results suggest that even small increases in oyster growth rates or reductions in oyster mortality can produce relatively large increases in rates of return on investment.

Financial (price) incentives can be provided or facilitated by the state in a number of ways including direct and indirect subsidy programs, state supported efforts to enhance market margins (value-added through branding or ecolabeling), or payments for the water quality services provided by oysters. Each activity can potentially increase the effective price growers receive for their product. Based on survey results and economic modeling analysis, if these types of programs could provide relatively small increases in oyster prices then production could increase substantially. For instance a 5 cent increase in price (per oyster) may increase production between 50 and 60 percent. Clam producers may face a more significant offsetting price effect (downward pressure on clam prices) if production were to increase substantially.

1. INTRODUCTION

Report Rationale and Objectives

Oyster and clam harvests have historically provided important economic benefits to the state of Virginia. As wild harvests have declined, oyster and clam aquaculture have expanded. Aquaculture of oysters and clams can provide environmental benefits for Virginia's coastal waters including the Chesapeake Bay as well as a source of revenue for growers, processors, wholesalers, and retailers. Virginia faces policy decisions on how best to assist the oyster and clam aquaculture industry and has requested information and analysis on the costs and benefits of shellfish management alternatives. The objective of this report is to evaluate the economic implications of potential management strategies to expand or enhance clam and oyster production in Virginia. The report provides an overview of the industry and lists and analyzes several policy alternatives. The report concludes with an economic assessment of each specific alternative for oyster and clam aquaculture management.

2. SHELLFISH INDUSTRY IN VIRGINIA AND MANAGEMENT ALTERNATIVES

2.1. History and Market Outlook for Virginia's Oyster and Clam Industries

Virginia's coastal waters are home to an array of marine species, including oysters and clams. Over the past 100 years, commercial landings of both oysters and clams have declined substantially due to a combination of disease, harvest pressure on wild stocks, and diminished water quality. This section provides some historical background on oyster and clam production in Virginia and describes the current market conditions in each industry.

2.1.1. Oysters

Over the past century, landings for the Chesapeake Bay native oyster (*Crassostrea virginica*) declined by 99%. In 1880 nearly 117 million pounds were harvested from the Bay, and people felt that oysters were an inexhaustible resource (Alford 1973). By the early 1900s annual harvests had dropped to 20 million pounds, and in recent years harvests have been as low as a few hundred thousand pounds. While overharvesting probably played a role in this decline, parasites like Dermo (*Perkinsus marinus*) and MSX (*Haplosporidium nelsoni)* a spore-forming protozoan that infects all ages of susceptible oysters (VIMS 2005a; 2005b; cited in Miller 2008) are widely credited as the main factors explaining why populations have dropped over the past 50 years and have not rebounded (Alfred 1973). Oyster predators such as cow nose rays have further stymied recent restoration efforts.

Small oyster harvests pose a concern for commercial growers, watermen, and people who care about water quality in Virginia's coastal waters. Oysters are not only a source of income for watermen. Historically, the oyster fishery provided an economic base for many local Bay area communities. Oysters also provide a number of ecological services. For example, it is widely recognized that the filtering capacity of *C. virginica* provides a number of water quality services (Dame 1996; Cerco and Noel 2005; Newell 2004; Newell et al. 2005). Through the filtering of phytoplankton (and seston in general), water clarity can be improved. In addition, the nitrogen and phosphorus embodied in the filtered material can be removed from ambient waters through biomass sequestration (N and P contained in oyster shell and meat) as well as through chemical transformation of oyster feces and pseudofeces (nitrification/denitrification of oyster biodeposits) (Newell 2004; Newell et al. 2005). These processes in turn may aid the growth of submerged aquatic vegetation (SAV) and increase habitat for other marine species. The filtration service provided by oysters provides an additional economic motive for state and federal policymakers to increase commercial oyster production.

Virginia's Oyster Industry: A Historical Perspective

According to data from the National Marine Fisheries Service (NMFS), the U.S. supply of oysters has fallen by more than 50% since 1950.[1] Data on commercial landings in table 2.1.1 reveal that most of this loss has come from declining harvests in the Chesapeake Bay and the Mid-Atlantic region. In particular, the Chesapeake Bay has gone from being the largest oyster-growing region in the nation between 1950 and 1980, to the smallest in recent years. Today, most of the oysters grown in the U.S. come from the Gulf of Mexico and the Pacific coast. In 2006, these two regions accounted for 94% of national production. Figure 2.1.1 provides a map of the major shellfish production regions in the United States.[2]

[1] The NMFS data only accounts for wild harvests and does not record farm-raised oysters

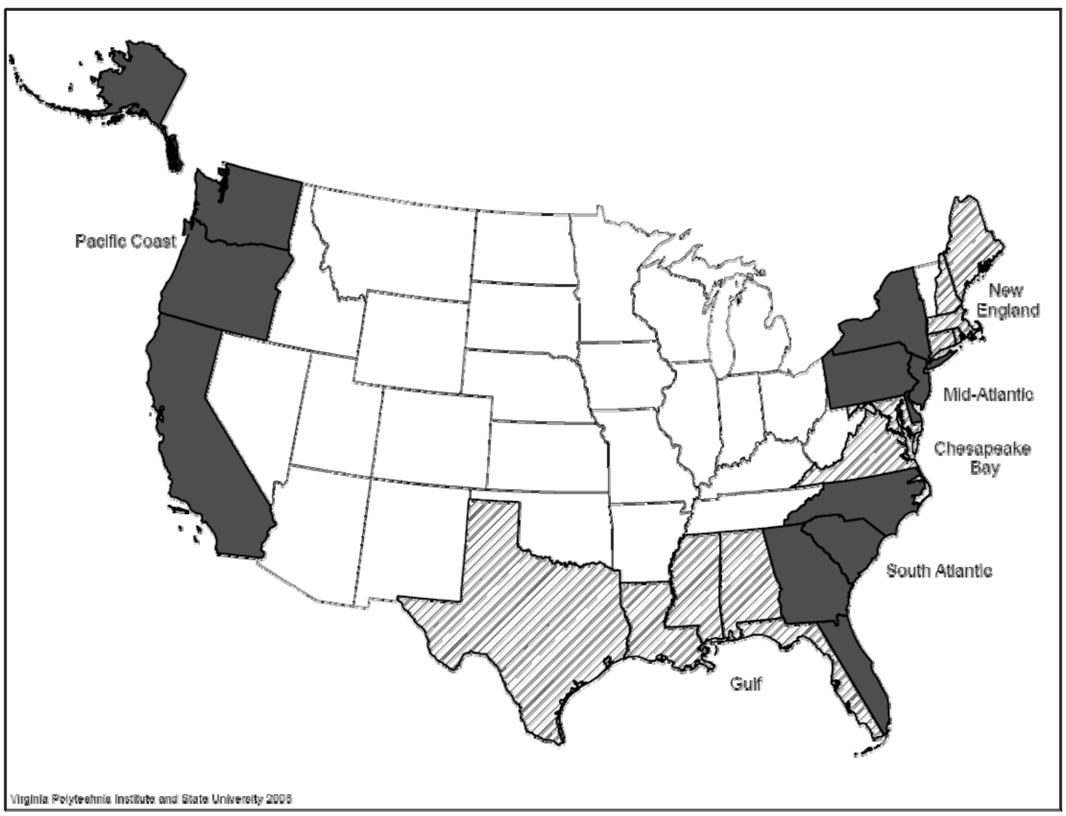
[2] Over this time period production methods have changed dramatically as well. Historically growers would transplant wild harvest seed on privately leased ground and simply wait for the oysters to mature 2-3 years later (Murray and Oesterling 2007). With the onset of disease, intensive aquaculture practices such as cages or off bottom floats are used as a grow-out system to harvest oysters. The percentage of oysters harvested in an aquaculture facility rather than in the wild has increased dramatically as of late.

Table 2.1.1: U.S. Oyster Landings, by Region(million pounds)

Year	Chesapeake	Mid-Atlantic	South Atlantic	Gulf	Pacific	New England	Total
1950	30.0	18.2	3.0	12.3	8.1	4.7	76.3
1960	27.1	1.2	4.2	16.1	11.0	0.5	60.0
1970	24.7	1.4	1.6	17.7	7.9	0.2	53.5
1980	22.8	2.5	2.3	15.5	6.4	1.0	50.4
1990	4.5	1.3	0.8	12.3	9.8	3.3	32.1
2000	2.5	0.4	0.5	25.8	10.5	0.7	40.4
2006	0.3	0.7	0.8	19.7	12.5	0.4	34.4

Quantities refer to total pounds of *C. virginica* and *C. gigas* as reported by the National Marine Fisheries Service.

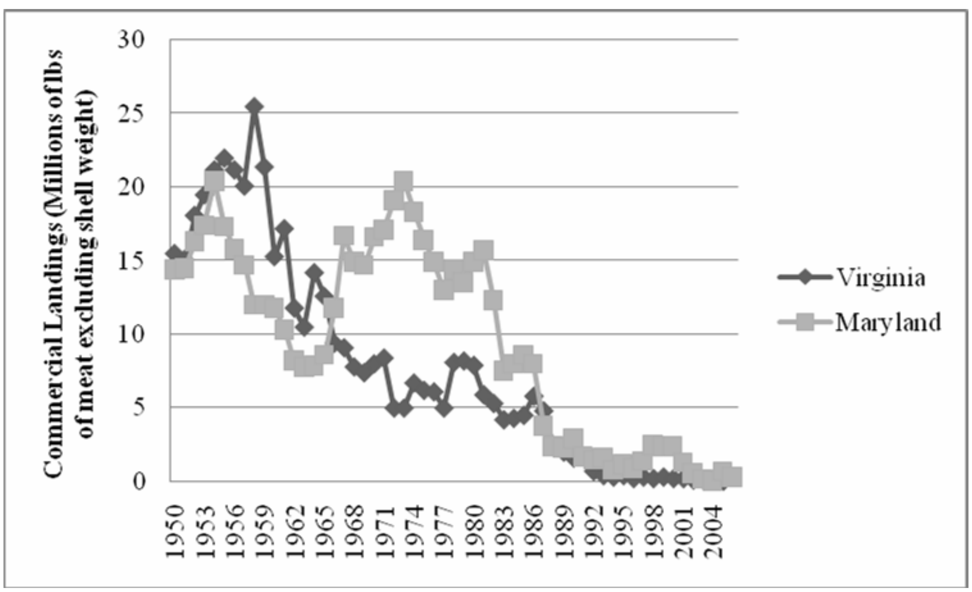
Figure 2.1.1: Major Shellfish Producing Regions in the United States



Source: Shellfish producing regions are delineated by the NMFS http://www.nmfs.noaa.gov/

The Chesapeake Bay can be divided into Maryland waters and Virginia waters. Historically, oysters were harvested either off of private oyster grounds or public oyster grounds. Virginia has historically produced a much greater share of oysters on private ground than Maryland (Santopietro 1986). Growers would transplant wild harvest seed on privately leased ground and harvest mature oysters 2-3 years later (Murray and Oesterling 2007). Called "shell-on-bottom" this technique required growers to occasionally deposit shell on private lease grounds for the seed to attach and grow.   The NFMS data typically reflect only oyster harvest on these public and private grounds. As will be discussed below, current production techniques are shifting to off bottom oyster aquaculture (which is not well reflected in the NFMS data). Figure 2.1.2 illustrates the decline in conventional oyster production across the two states.

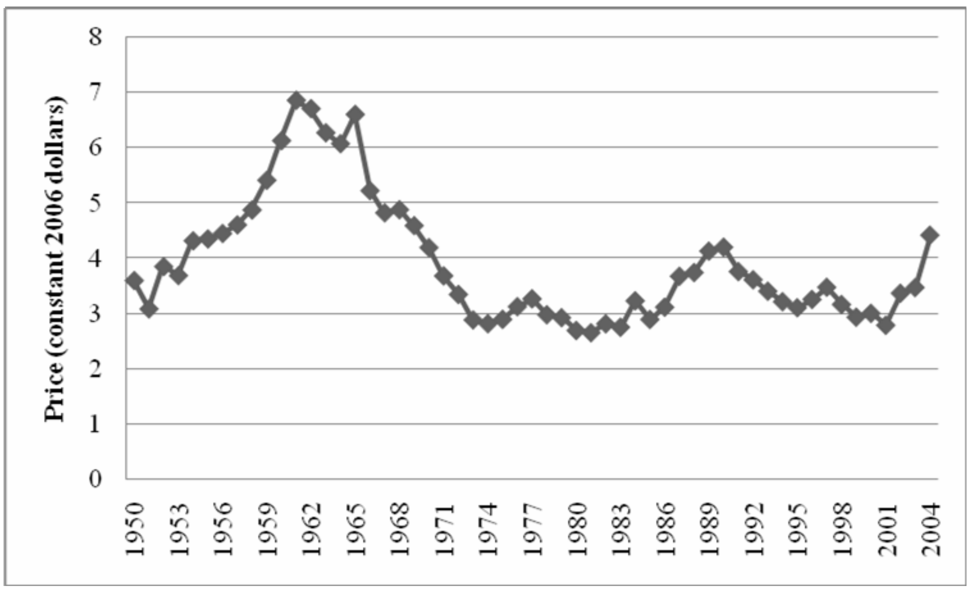
Figure 2.1.2: Oyster Landings in Maryland and Virginia, 1950-2005



Source: National Marine Fisheries Service, Annual Landings Data. The NMFS data only accounts for wild harvests and does not record farm-raised oysters.

As the supply of oysters has declined over the past 50 years, so has the demand. This has been partly due to increasing concern over the potential negative health effects of consuming raw seafood (Kallen 2001). Industry experts also believe that as supplies have dwindled, consumers have "lost their taste" for oysters (Kallen 2001). Nevertheless, data from NMFS suggest that the real price of oysters has remained relatively stable. Figure 2.1.3 displays the trend in the real ex-vessel price of Virginia oysters since 1950.[3] Following a steep decline during the 1960s, the price has consistently ranged between $2.50 and $4.50 per pound.

Figure 2.1.3: Real Price per Pound of Virginia Oysters



Source: National Marine Fisheries Service, Annual Landings Data

[3] Ex-vessel price is the price received by fisherman for their catch. This is also described as "dockside" price (Thunberg, 2008).

Virginia's Oyster Industry: Recent Trends and Market Outlook

In recent years, growers have begun to move away from the traditional shell-on-bottom approach in favor of more intensive off-bottom aquaculture techniques which involve confining oysters in submersible cages, floats and racks. Collectively referred to as off-bottom aquaculture, such techniques can significantly increase the growth rates and decrease the length of time to harvest over traditional on-bottom production. It takes approximately 18 months for the average oyster seed to grow to harvest size in aquaculture conditions.[4] The accelerated growth rates reduce disease mortality by reducing the time oysters are exposed to MSX and Dermo (high disease intensity occurs typically during the warm weather months). Off-bottom aquaculture can also reduce mortality rates by protecting the juvenile oysters from predation. Of course, cages, floats, and racks also require a larger initial investment. For example, a medium sized grower would require an initial investment of $100,000 to purchase 500 cages (Miller, 2008).[5] Because off-bottom production is relatively expensive, it is used primarily by growers who are able to collect a premium for their product by selling fresh oysters directly to seafood restaurants and raw bars, or to shellfish wholesalers.

While Virginia's oyster production is still a small fraction of historical production, it is experiencing significant growth. Table 2.1.2 provides a snapshot of the industry from 2004 to 2007. The number of oysters planted increased fourfold between 2005 and 2007. Given the 18-month growing cycle, we would expect most of the increase in production to occur between 2008

[4] The time to maturity varies with growing technique and can take anywhere from 12 to 24 months.
[5] This figure underestimates the additional cost of an off-bottom operation to the extent that off-bottom production requires a larger investment in seed and post-harvest treatment. According to Miller (2008), a grower with 500 cages would have the following expenses: permitting costs ($1,500), seed costs ($11,000), nursery costs ($8,000), the cost of developing a grow-out system ($8,000), and post harvest treatment costs ($2,000).

and 2009. The data are drawn from an annual survey conducted by VIMS which, according to their estimates, captures 95% of the state's commercial production.[6]

The industry is also highly concentrated. Some 95% of the state's commercial production comes from less than 20 growers (Murray and Oesterling 2007). The industry is also vertically integrated, with almost all the seed produced in Virginia planted by the hatchery owners themselves or sold to other Virginia oyster growers (Murray and Oesterling 2007).

Table 2.1.2: Virginia's Aquaculture Oyster Industry, 2004-2007

	2004	2005	2006	2007
Area leased (acres)	265	282	*DNA*	*DNA*
Oysters planted (million)	8.1	6.2	16.9	24.8
Oyster seed sold (million)	17.6	20.4	26.2	41.2
Market oysters sold (million)	0.85	2.80	3.15	6.59
Share of production sold out-of-state	68%	63%	*DNA*	*DNA*
Farm gate price per oyster (weighted avg.)	$0.30	$0.30	$0.30	$0.30
Value of Production (Million)	0.26	0.84	0.95	1.98

Source: Murray and Oesterling (2008). *DNA* means Data Not Available.

Once harvested, oysters are sold into two separate markets: the fresh market for half-shell oysters and the processing market for shucked oysters. The half-shell market is the primary destination for Virginia aquaculture oysters. This is because growers receive up to 50 cents per half-shell oyster (average around 30 cents) compared to less than 20 cents for oysters sold in the shucked market (Murray and Oesterling 2007). Oyster aquaculture techniques are well suited for growing an attractive product necessary for the half-shell market and higher prices are necessary to offset the higher production costs associated with aquaculture production. In 2004 and 2005 more than 60% of the oysters grown in Virginia were shipped out-of-state (table 2.1.2). For half-shell oysters, the Washington-Baltimore area is the primary out-of-state destination. In general,

[6] The VIMS survey excludes oysters harvested on public grounds.

oysters grown in the Northeast and mid-Atlantic (which includes Virginia) are perceived as being a higher quality product than oysters grown in the Gulf. This allows Virginia growers to collect a higher price. Due to inconsistent supply, however, wholesalers in the Washington-Baltimore area often import oysters from the Gulf, and even the Pacific coast (Kallen et al., 2001).

2.1.2. Clams

The hard clam (*Mercenaria mercenaria*) is a bivalve mollusk that lives in Virginia's saline coastal waters.[7] Virginia's clam industry, which is concentrated on the Eastern shore of the Bay, leads the nation in the culture of hard clams with an estimated production value of $30 million in 2008. Despite the diminished rates of wild harvests from public resources, clam aquaculture is adding significant value to Virginia's seafood marketplace (Murray and Oesterling 2008). Clam aquaculture production became established in the 1980s, experienced significant growth in the 1990s and continues to grow with more than 200 million clams sold in 2007 (Virginia Farm Bureau 2008).

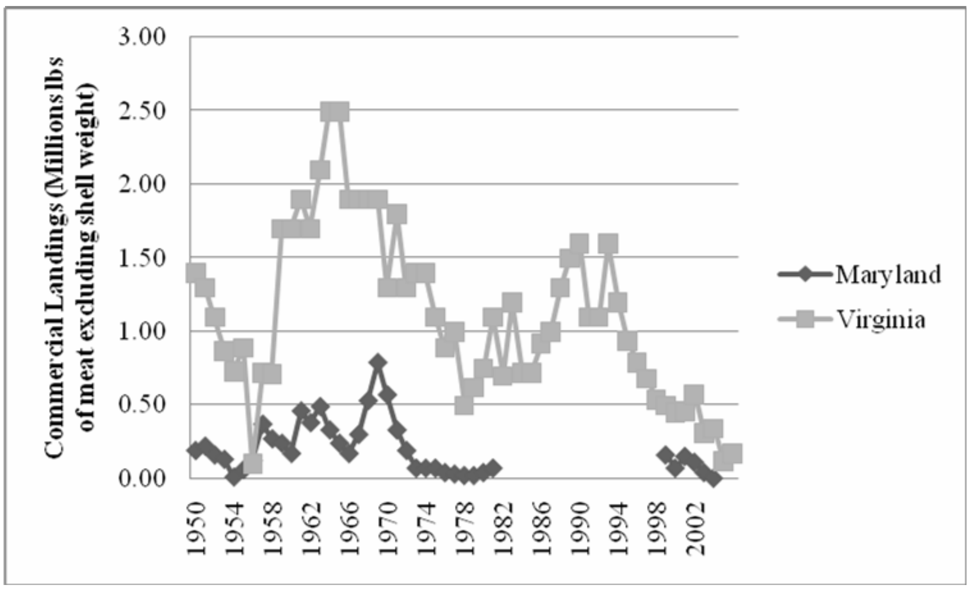
Virginia's Clam Industry: A Historical Perspective

Hard clams have a variable growth rate. Some can require up to 24 months to reach market size, while others can reach maturity in as little as 12 months (FAO Fisheries and Aquaculture). This range reflects variation in salinity across different areas of Virginia's coastal waters, other dimensions of water quality, and variation in the clam size at harvest. As with oysters, the harvest of clams in the Bay from primarily wild stocks has declined since the 1950s (see Figure

[7] This species got its Latin name from the Algonquin Native Americans who used the shells as money (Brierley, 2007).

2.1.4).[8] The traditional approach to harvesting wild clams from public waters, however, has largely been replaced by more intensive growing operations. In recent years, advances in hatchery techniques have created the potential to produce a virtually unlimited supply of seed from selected parent stock. This has allowed growers to increase the scale of their operations.[9] Growers have also learned that spreading gravel, shell or other materials over the sand or muddy bottom before planting seed can provide added protection from predators such as blue crabs and cow nose rays (Murray 2004).

Figure 2.1.4: Annual Clam Landings in Maryland and Virginia, 1950-2006



Source: National Marine Fisheries Service, Annual Landings Data. The NMFS data only accounts for wild harvests and does not record aquaculture-raised clams.

Virginia's Clam Industry: Recent Trends and Market Outlook

[8] Maryland primarily uses hydraulic dredges to haul in wild stock that are severely depleted in the Bay.
[9] In commercial operations, clams are allowed to grow for 10 to 24 months before being harvested with patent tongs or a special type of rake in shallow waters.

Hard clams are the second most valuable crop on Virginia's Eastern Shore, behind nursery and greenhouse products (Murray 2004). The industry is dominated by six Eastern Shore firms who, together, account for 75% of annual state production (Murray 2004). In contrast, the Western Shore has struggled to produce clams due to inconsistent salinity levels.

Table 2.1.3 provides a short synopsis of Virginia's clam industry between 2004 and 2006. The figures in the table come from the annual VIMS survey, which is estimated to capture 95% of the state's annual production of market size clams. While prices remained steady over the three-year period, the number of clams planted nearly tripled from 187 million in 2004 to 512 million in 2006. Sales of clam seed have also increased. Hatcheries reported 87 million seed clams sold in 2006, a 30% increase over the previous year. Current seed sales are a good indicator of clam sales in the near future and growers predicted increasing their seed plantings by 5-10% during 2007.

Table 2.1.3: Virginia Aquaculture Clam Industry, 2004-2006

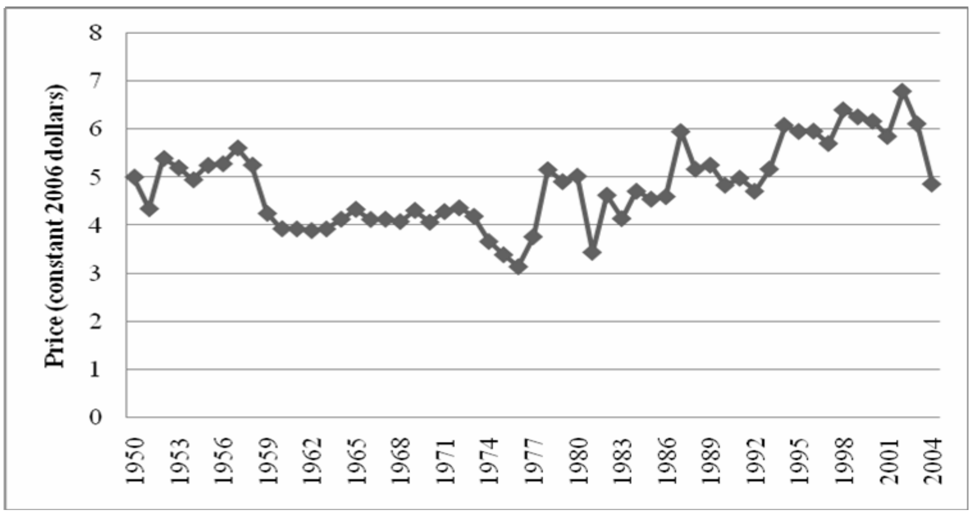
	2004	2005	2006
Acres Leased	6,509	6,569	*DNA*
Clam Planted (Million)	187.2	397.1	512.3
Clam Seed Sold (Million)	*DNA*	67	87
Market Clams Sold (Millions of clams)	150	193.6	194.4
% of Seed Planted in VA	*DNA*	95%	95%
Farm Gate Price per Clam (weighted avg.)	$0.15	$0.15	$0.14

Source: Murray and Oesterling (2008)

Hard clams are marketed whole. Approximately 70% are sold for raw or steamed consumption and the rest are shucked and processed in products such as clam chowder (Whetstone et. al. 2005). The average price per clam has been relatively steady in recent years at around $0.15 per clam. As shown in figure 2.1.5, the average price per pound of Virginia clams has also remained steady around five dollars per pound.[10] Most of these clams (90%) are sold out-of-state (mostly domestic consumption). Virginia growers have the advantage of easy access to both the Washington D.C. and Baltimore markets.

In 2006, Virginia growers produced a total of 194.4 million "market" clams (Murray and Oesterling 2007). This makes Virginia one of the two largest clam producing states in the U.S., along with Florida (Murray 2004).[11] The difference in operation size between the clam and oyster industries is apparent when looking at the gross receipts which for oysters are about $2 million and for clams nearly $30 million (Murray and Oesterling 2007).

Figure 2.1.5: Price per Pound of Virginia Clams



Source: National Marine Fisheries Service, Annual Landings Data

[10] See the NMFS website at http://www.st.nmfs.noaa.gov/st1/commercial/landings/annual_landings.html
[11] Clams from the Eastern shore are not considered Mid-Atlantic and are part of the Chesapeake Bay harvest statistics.

2.1.3. Fisheries Management in Virginia's Coastal Waters

The Commonwealth of Virginia manages Virginia's coastal waters partly as leased grounds and partly as public grounds. Since the end of the colonial period, the naturally productive beds of Virginia's coastal waters have been designated as public grounds (Alford 1973). In 1892, Lieutenant Baylor of the U.S. Navy conducted a survey to assess Virginia's natural oyster bottoms. This survey marked out the naturally productive oyster rocks where there was a presence of live oysters or oyster shell (Thunberg and Shabman 1988). The Baylor Survey identified 250,000 acres of "Baylor grounds" which were subsequently set aside as a public fishery for watermen who use hand tongs (Santopietro et al. 1999).[12] The Commonwealth has continually maintained this area as state managed public grounds since its creation in 1892. Figure 2.1.6 shows the location of the Baylor grounds. They represent a significant portion of the total area available for oyster aquaculture. Also shown in the figure are the private commercial and private noncommercial oyster grounds currently in use.

[12] Article XI of the Constitution of Virginia states: "*The natural oyster beds, rocks and shoals in the waters of this State shall not be leased, rented or sold, but shall be held in trust for the benefit of the people of this State.*." as a part of the passage which designates the Baylor grounds as public Thunberg, L. S. a. E. (1988). "An Evaluation of Alternative Strategies for Virginia Oyster Grounds Management: Economic Considerations in Policy Design." Virginia Agricultural Experiment Station **VSG-88-03**: 105.

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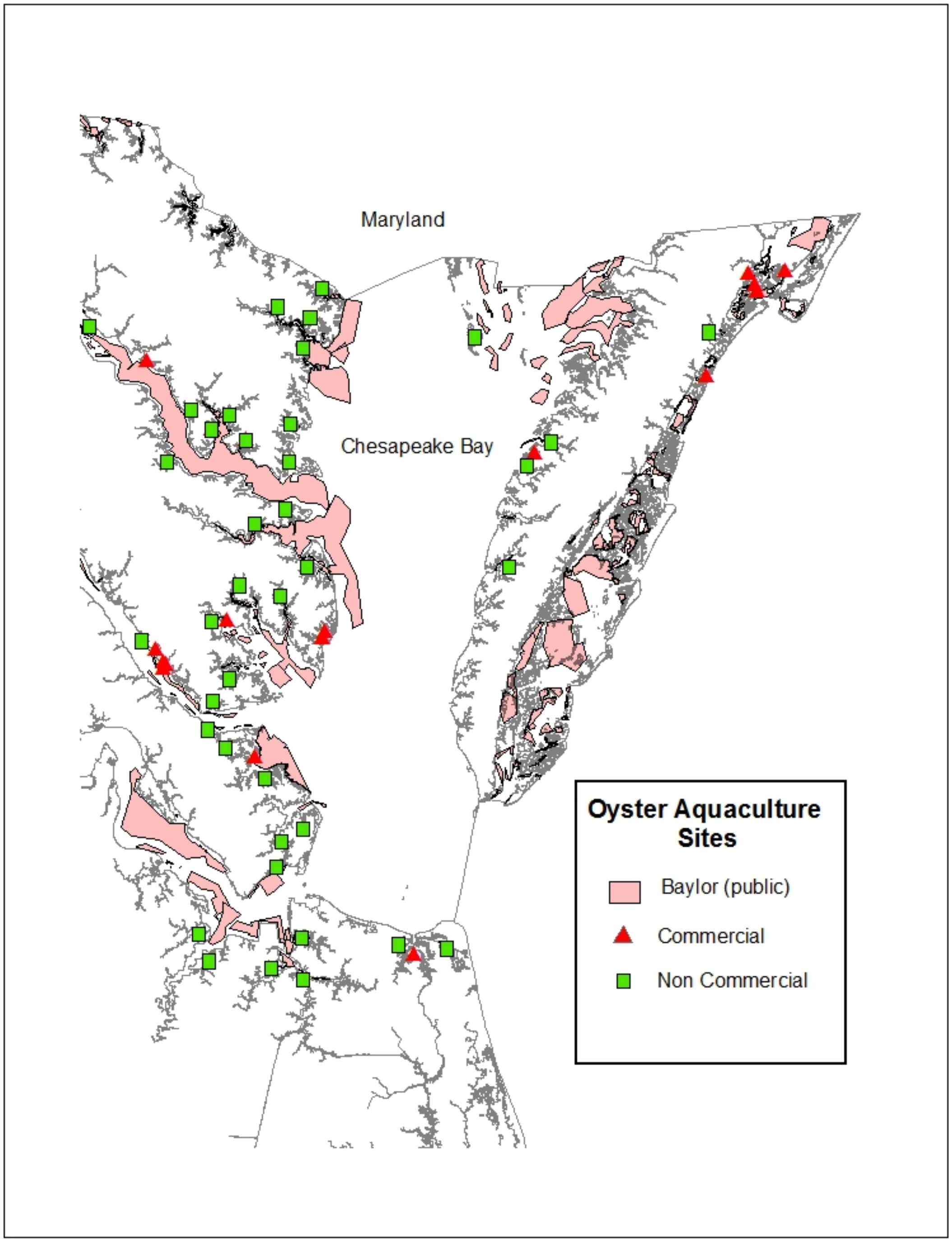
Figure 2.1.6 Oyster Aquaculture in Virginia's Coastal Waters



Source: Virginia Marine Resource Commission[13]

[13] In order to make the map easier to read we often used a single square or a single triangle to represent multiple sites which were clustered together. Oyster commercial and noncommercial are designated by the type of aquaculture permit that was purchased from VMRC in 2002. http://www.dcr.virginia.gov/natural-_heritage/vmrc.htm

Coastal water bottoms in Virginia not designated as part of the Baylor grounds can be leased by private interests. Virginia currently leases over 100,000 acres of coastal waters to commercial interests at a cost of $1.50 per acre per year (Mason 2008). The leasing system is authorized by Virginia Code and is set up for leased areas "to be occupied for the purpose of planting or propagating oysters" (Chapter 6 28.2-603). This language is generally viewed as a "use it or lose it" clause in the sense that leases are granted on the condition of use in shellfish production.

To ensure that commercial oyster growers are not excluded from potentially productive grounds, the Commonwealth has recently established two new policies. The first is the *Oyster Lease Use Plan* (2006) which requires lease holders to answer a questionnaire describing their intended use of the leased area. The questionnaire, administered by VMRC, begins by explicitly stating that leases cannot be purchased for the sole purpose of preventing others from using that water for commercial oyster operations. The second new policy intends to track how leases are being used by requiring growers to report their production on privately leased grounds (Mason 2008). In order to keep their aquaculture licenses, growers will have to report their production to the Virginia Marine Resources Commission on a monthly basis. Neither policy contains an enforcement mechanism against waterfront property owners who hold leases because of the NIMBY (not in my backyard) attitude towards working waterfronts.

Opposition to expanding oyster and clam aquaculture has occurred in both Virginia and Maryland. Waterfront landowners in Maryland have opposed the idea of new clam operations for fear they would obstruct their views of the shoreline (Kobell 2008; Soper 2008). In Virginia, leases have been put on hold due to applicants not citing specific use plans in their applications. The confusion over regulation requirements has fostered a growing controversy between watermen and waterfront property owners who believe the regulations for oyster and clam farming will interfere with the aesthetics of the Bay (Soper 2008). This has caused debates between leaseholders who are complying with VMRCs "use it or lose it" regulations and those who obtain leases to prevent further expansion of the industry.

Another important dimension of Bay management is the complex web of federal, state, and local environmental regulations designed to maintain water quality. While we do not attempt to provide a comprehensive review of environmental policy, one recent regulation is noteworthy because it relates to the policy options we will be considering. In November of 2007, the State Water Control Board (DEQ) proposed regulatory action titled "Water Quality Standards: Policy for the Protection of Water Quality in Virginia's Shellfish Growing waters"; sometimes referred to as "Aquaculture Enhancement Zones." The goal of the enhancement zones is to provide additional protection of the waters that are currently used or could be used for shellfish aquaculture. Specifically, the regulation aims to protect shellfish growing waters from the development pressures facing the Eastern Shore by providing alternative analysis of wastewater treatment for proposed point source discharges to shellfish aquaculture "enhancement zones" (O'Herron et al 2007).[14] The regulation requires additional analysis of waste treatment alternatives, but does not require any more stringent standards than proposed in existing regulations. The enhancement zone provisions could be used to determine whether new point source discharges will be permitted and to justify amendments to current water quality standards (Daub 2007).

[14] According to the Department of Environmental Quality this action mainly affects 9 VAC 25-260 which deals with the narrative and numerical water quality criteria to protect designated uses and is part of the Water Quality Standards found under the Federal Clean Water Act.

2.2. Overview of Policy Options Considered in this Report

This report evaluates a variety of public shellfish management options for Virginia's coastal waters. In broad terms, these include: (1) proposals to redefine or clarify the current leasing system, (2) proposals to invest state funds in research and development for oyster and clam production, and (3) proposals to create direct economic incentives to boost commercial production. This section provides a brief overview of the alternatives considered.

Before proceeding, it is important to point out that this report does not evaluate specific policy options actively being considered by the Virginia General Assembly. Rather, this report considers more general policy changes. We have developed them based on our conversations with policymakers at the Department of Environmental Quality, discussions with industry experts at the Virginia Institute of Marine Science and the Virginia Marine Resources Commission, and feedback from commercial clam and oyster growers.

2.2.1. Redefinition and/or Clarification of Leasing Rights

We consider four proposals for changing the current system of ground leasing and production: reforming the leasing system for the grounds of the Bay, resurveying the Baylor grounds, establishing a set of shellfish enterprise zones, and creating an aquaculture "bill-of-rights".

Option #1: Resurveying Baylor Grounds

The purpose of resurveying the Baylor grounds would be to open up more unproductive public grounds to private leases, thus expanding potential shellfish production sites. A resurvey of Baylor would identify which grounds are no longer productive and would then open up some of these "unproductive" grounds for private leasing. It seems plausible that commercial growers may be able to utilize some areas which are currently unproductive through the use of intensive shellfish aquaculture cultivation techniques.

The geography of Virginia's coastal waters changes through time due to changing tides, changes in surrounding landscape, and hurricanes (Thunberg and Shabman 1988). According to the Maryland Department of Natural Resources over the last one hundred years the sea level in the Chesapeake Bay has risen by approximately one foot. As a result, grounds that were productive during the Baylor survey may be unproductive today. Furthermore, with new GIS technology, it would be possible to provide a more precise mapping of the bottoms than was conducted during the original survey. Researchers at the Virginia Institute of Marine Science are currently working on a GIS project to identify areas within Baylor that would best support aquaculture based on both environmental and physical conditions (VIMS, 2008). The results of their research could serve as a starting point for a new survey.

Option #2: Amendments to the Leasing System

The purpose of reforming the leasing system would be to make changes to the existing leasing program to make more effective use of subaqueous grounds for aquaculture. Currently there are approximately 90,000 acres of subaqueous grounds that are held in private lease (Mason 2008). Leases are issued and managed by the Virginia Marine Resource Commission (VMRC). The fees as of 2006, associated with obtaining a lease for oyster culture are shown in Table 2.2.1 (Mason 2008).

Table 2.2.1: Fee for Oyster Ground Leases (2006)

Application Fee (NONREFUNDABLE)	$25.00
Advertising Cost In the Newspaper Billed to Applicant Directly	cost varies
Surveying: VMRC Survey for Lease Assignment	$510.00
Additional Plat Charge (if needed)	$75.00
Recording Fee for Each Assignment & Plat	$12.00
Assignment Fee for Each Assignment & Plat	$1.50
Rental Amount (Per Acre/Per Yr) (No Annual Charge for Riparian Leases)	$1.50

Note that after some "upfront" costs, once a lease is assigned, the actual rental amount per acre per year is $1.50. The original intention of leased grounds was to "be occupied for the purpose of planting or propagating oysters." according to the "Code of Virginia related to Oyster Planting Ground": §28.2-600 ET. SEQ, Chapter 6. However, many leases are no longer actively being used (Mason 2008).

There are two primary ways in which the current leasing system could be altered to increase utilization of subaqueous bottoms for aquaculture. First, the "use it, or lose it" nature of the original law could be more strictly enforced. This would mean that those lease-holders who no longer actively perform aquaculture on their leases would need to start an aquaculture operation or rent the lease to shellfish producers. A challenge with this approach is defining what constitutes an adequate level of use. The second alternative would be to adjust the rental price mechanism of the leases so that lease rents reflect the value of the grounds for oyster aquaculture. This adjustment may help leased grounds get into the hands of the individuals who value those grounds the most.

Option #3: Establishing Shellfish Enterprise Zones

The individuals who are collectively leasing 90,000 acres of coastal water bottoms face some uncertainty about water quality at their lease site, regulatory pressure, and conflicts with local homeowners. Currently, in Virginia, there is no policy mechanism to address the challenges of land use conflicts. The purpose of establishing "shellfish enterprise zones" would be to eliminate, or manage for, one or more of the impediments to shellfish aquaculture. This would include comprehensive changes in regulatory costs, regulatory time, use conflicts and water quality threats. An enterprise zone is intended to recognize the issues like odor and noise pollution associated with a working waterfront.

Experience with enterprise zones in Maryland can provide some idea of what an enterprise zone in Virginia might look like. Maryland is currently investigating the possibility of developing a series of enterprise zones motivated by the desire to protect against theft, speed up the permitting process, and provide economic incentives for growers. The zones have been proposed for five locations in the Chesapeake Bay, ranging in size from fifty acres to entire river systems (Maryland Oyster Advisory Commisson 2008). While it is too early to say whether the zones will actually be established, we can summarize the main features of the zones that have been discussed to date.

The initial proposal for enterprise zones in Maryland would allow a shellfish grower to have access to the zones if they demonstrate that they are satisfying a set of best management practices (BMPs) defined by the state. Broadly defined, the BMPs involve minimizing pollution and environmental disruption. They outline a set of specific procedures for improving production and preserving the environment which includes minimizing use conflicts, clearly marking corner boundaries, and avoiding sensitive marine habitats. In theory, the state

Department of Agriculture would be responsible for enforcement and would have the authority to conduct annual inspections for compliance. Virginia is exploring the potential benefits of aquaculture BMPs. VIMS has undertaken an effort to develop a BMP handbook and Environmental Code for the Virginia shellfish industry.

Based on these examples, we would envision Virginia's aquaculture enterprise zones providing economic incentives for growers, quieting user conflicts by establishment of aquaculture as a "preferred use" and creating more stringent water quality regulations on urban developers. At the same time, growers may have to demonstrate they are satisfying a set of best management practices.

Option #4: An Aquaculture "Bill-of-Rights" Disclosure Statement

The purpose of developing a "right-to-fish" law or an aquaculture "bill of rights" would be to protect shellfish growers from nuisance lawsuits and conflicts with their urban neighbors. Precedent for a "right-to-fish" law comes from the Right-to-Farm Acts which have been developed by individual states and counties across the nation, including Virginia. In general, these acts aim to reduce nuisance lawsuits that arise when neighbors move into an area where farming takes place and are disgruntled by the inconvenient smells and noises associated with normal farming activities. For example, real estate agents in some areas are required to have potential homebuyers sign disclosure statements which state that they are aware their home is located in an agricultural community where noise, dust, and odors from normal farming operations are part of everyday life. Taking this precaution offers the potential to reassure farmers who are considering investing in improving and expanding their operations that they will not be subjected to nuisance lawsuits. Several states have enacted right-to-fish laws based on similar principles.

Recently, Maryland passed a right-to-fish law for four of its Eastern Shore counties. Dorchester County introduced Bill Number 2005-10 labeled "Dorchester County Seafood Industry Right to Work" and enacted it into legislation on July 1, 2005. The stated purpose of the bill is to protect the rights of those who harvest seafood commercially and provide them protection against nuisance lawsuits along with authorizing the County Council to protect the commercial seafood industry in Dorchester County (2005). In 2007 both Queen Anne's County and Somerset County simultaneously enacted the "Authorization to Harvest Seafood and Engage in the Seafood Industry" Act.[15] This Act explicitly authorizes people to buy, sell, harvest, and operate seafood businesses in conformance with county and State requirements (O'Malley 2007). Calvert County recently enacted a similar Act which takes effect on October 1, 2008. While the wording of these acts is rather vague, the general idea is that they provide a legal basis for shellfish growers to deflect complaints about noise or visual disamenities associated with their normal growing operations.

2.2.2. Research and Development

As discussed earlier, the disease parasites Dermo (*Perkinsus marinus*) and MSX (*Haplosporidium nelsoni)* (VIMS 2005a; 2005b) are major reasons for decline of oyster harvests in Chesapeake Bay. In response, growers have shifted production to lower salinity grounds where the disease is not active (Ewart and Ford 1993; Allen and Frank-Lawale 2008; Luckenbach, Francis Xavier, and Taylor 1999). However, oysters grow slower in lower salinity

[15] The essential element of this Act is to adopt an ordinance, resolution, or regulation or take other action to authorize a person to engage in certain activities related to the seafood industry.

grounds, which lengthens grow out times and exposure to predation and disease. Oyster profits and economic potential are also restrained by the high cost of seed (Bosch and Shabman, 1990; 1989), which lowers growers' profit margins and increases their risk exposure.

Given the importance of disease and seed costs, we envision research and development strategies focusing on two areas: 1) development of disease resistance and/or increasing oyster growth rates; and 2) improvements in seed production, which lower the cost of seed to oyster growers. We do not evaluate potential returns to subsidizing bottom development for planting loose oyster seed (shell-on-bottom). That option has been evaluated by Santopietro (2008) who finds that shell on bottom (public grounds) does not produce a positive economic return.

2.2.3. Financial incentives to stimulate commercial production

Several types of financial incentives could be used to encourage new investments in shellfish aquaculture. Financial incentives could come in the form of either a reduction in taxes/fees or the creation of a subsidy related to shellfish production. Tax reductions or subsidies to encourage production can be direct or indirect. An indirect subsidy is a financial payment on the use of an input that contributes to production. For example, an indirect subsidy for oyster production could be a tax credit or an accelerated depreciation schedule for a capital investment (e.g. oyster cages). Similarly, reduction on lease rates or permitting fees would be an indirect subsidy. In contrast, a direct subsidy would provide a financial incentive based on the number of shellfish produced. A direct subsidy might include a direct financial payment or a tax credit on every oyster produced by a shellfish aquaculturalist.

Financial incentives may also be generated by adding value to the existing product. Value added might come from a new branding or market strategy. State efforts could perhaps help some producers differentiate their product to create a price premium through certification programs. For instance, Virginia already offers a general branding opportunity through the "Virginia's Finest" label. The state could also assist in the development of a state certified "ecolabeling" system. Such a system could certify that shellfish grown under certain verified conditions support restoration efforts in Virginia's coastal waters including the Chesapeake Bay.[16] For example, the Monterey Bay Aquarium's *seafoodwatch* program gives aquaculture oysters their highest possible rating for sustainability. However, the Chesapeake fishery does not currently market its oysters under an ecolabel. In previous survey research, Wessells et al. (1999), Jaffry et al. (2001), and Johnston et al. (2006) have found that consumers indicate a willingness to pay higher prices for seafood products with the MSC ecolabel.

Finally, financial incentives may also be generated by creating new markets for shellfish related products or services. While shellfish producers only receive revenue from the sale of oyster or clam meat, shellfish producers, particularly oyster producers, also provide water quality services. These services might include water clarity and nutrient assimilation services (see discussion above in Section 2.1.1). If the quantity of water quality services from shellfish could be quantified and a payment system created to pay for those services, shellfish producers could receive financial compensation for the water quality benefits provided to the state of Virginia.

Payments for water quality services from shellfish aquaculture production could come from a variety of sources. The state of Virginia currently devotes considerable public funding to partially compensate private entities for undertaking activities to reduce nutrient loads in the Bay. To date these activities have been focused exclusively on paying for actions or technologies that reduce nutrient loading at the source (point and nonpoint). Virginia could

[16] For example, the Virginia signed the Chesapeake 2000 agreement. As part of that agreement, the state agreed to undertake efforts to restore native oysters. A "Bay Friendly" ecolabeling program, for example, could certify oysters that have been produced by aquaculture and thus not harvested from public grounds.

expand their nutrient removal investments to remove nutrients directly from the water (nutrient assimilation) using shellfish aquaculture. In this case, the state could pay aquaculturalists directly for the pounds of nitrogen and phosphorus removed by their production facilities.

Financial compensation could also come from private entities that face binding regulatory requirements to control nutrients but have the option to meet these regulatory requirements offsite from the permitted activity. These programs are often referred to as nutrient offset trading. Under certain conditions, the Virginia nutrient trading program allows regulated NPDES point source discharges to purchase nonpoint source reductions in the event of an annual exceedence of their annual nutrient load limit. One trading option allows the regulated point source to pay the state $11 per pound of nitrogen and $5 per pound of phosphorus to secure these reductions (9 VAC 25-829-10 et seq.). Nutrient trading programs could be modified to allow such offsite nutrient reductions to be purchased from oyster aquaculturalists. Finally, financial payments for water quality services could come from voluntary market incentives. For example, several new initiatives have recently been launched (e.g. Nutrient Neutral Fund) where people make voluntary payments into a fund that would then be used to secure nutrient reductions for the Bay.

This analysis will explore how shellfish production might respond to various price increases. The way these price incentives are achieved (subsidy, valued added marketing, or water quality service payments) is not initially identified. The economic response model investigates how production might change if a policy could produce a given price response. Next, one specific application, financial payments for water quality services, will be investigated in more detail. This report estimates the total amount of nitrogen and phosphorus removed per year per 1,000,000 aquacultured oysters. If the state or private entities would be willing to pay for these reductions at rates comparable to those being paid to point and nonpoint sources, then the potential revenue to shellfish producers from the sale of water quality services could be estimated. A firm level financial simulation model is used to estimate the impact of such compensation on the internal rate of return to typical oyster aquaculture operations (Miller 2008).

3. ANALYSIS OF POLICY ALTERNATIVES

3.1. Results from Grower Survey

In March of 2008, the Virginia Tech research team collaborated with Mike Oesterling, Don Webster and Tom Murray to survey oyster and clam growers in Virginia. Using a mailing list provided by the Virginia Marine Resources Council, mail surveys were sent to 150 shellfish growers. To date, 65 responses have been received —a 43% response rate representing 95% of estimated total production in Virginia. In broad terms, the survey asked growers to: (i) describe the size of their operations, (ii) speculate on how they would change the size of their operations in response to price changes, (iii) comment on the main factors that prevent them from expanding their operations, and (iv) provide feedback on some of the policy options described above.. An example of the original survey and cover letter is provided in Appendix 1.

This section provides a statistical summary of how growers responded to each question on the survey. For each question below, descriptive statistics of the responses are summarized for the top ranked answer, mean or average ranking, and production weighted response. In the summary tables "*Top Score*" measures the share of growers who identified that option as the most important or highest ranking. For example, 15% of the growers who answered identified low price as the biggest barrier to expanding oyster production (see Table 3.1.1). The "*Mean*" is the average of the ranks given by producers to each answer. For oyster price as a barrier to expanding production, the mean response was 3.43 (with 1 being assigned to the most important barrier to increasing production) (see Table 3.1.1). Finally "*Production %* is the number of growers who listed this option as the most important weighted by their share of total state production. For example, in Table 3.1.1, 4% of growers chose "availability of ground" as the most important constraint to expanding their oyster operations. These growers represent 10% of total oyster production (based on their answers to question 15). Not all growers responded with a top choice to each question, or even answered the question; therefore not all questions represent a 100% response rate. For example, the growers who responded to the question about barriers to oyster production (Table 3.1.1) accounted for 82% of total production.

The interpretation of the survey results will be discussed in the policy evaluation section.

Barriers to Expanding Oyster Production

Table 3.1.1: What factors constrain your ability to expand your current oyster production (1 for most important, 2 for second most important, etc)

	Active Oyster Growers			All Respondents	
	Top Score (%)	Mean	Production (%)	Top Score (%)	Mean
A. Availability/cost of seed	50	2.10	53	43	2.21
B. Availability of grounds	4	4.00	10	9	3.72
C. Lack of Market/low price	19	3.43	3	15	3.5
D. Problem with predators (rays, crabs etc)	4	3.60	3	4	3.36
E. Problems with disease (MSX, Dermo)	12	2.95	13	17	2.63
F. Permitting issues/land use conflict	12	3.26	1	11	3.19
	Total		82		

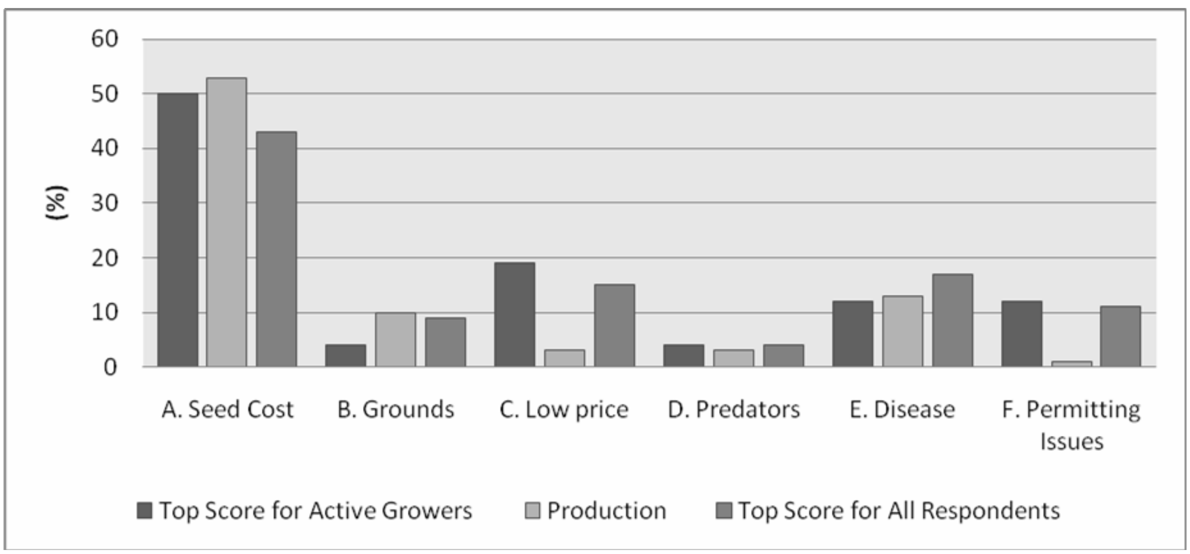


Table 3.1.2: What factors determine whether you would lease a new site (1 for most important, 2 for second most important, etc.)

	Active Oyster Growers			All Respondents	
	Top Score (%)	Mean	Production (%)	Top Score (%)	Mean
A. Convenient location (near my existing aquaculture operation or access or boat ramp)	9	2.90	4	16	2.8
B. Possible conflicts with waterfront property owners, recreational users, etc.	13	3.27	4	10	3.52
C. Potential disease and/or predator pressure on the site	6	3.65	5	6	3.59
D. Water quality (pollution from sedimentation, pesticides, etc.)	34	2.12	48	37	1.97
E. Physical characteristics (salinity, bottom condition, flushing rate, etc.)	38	1.81	29	31	1.95
	Total		90		

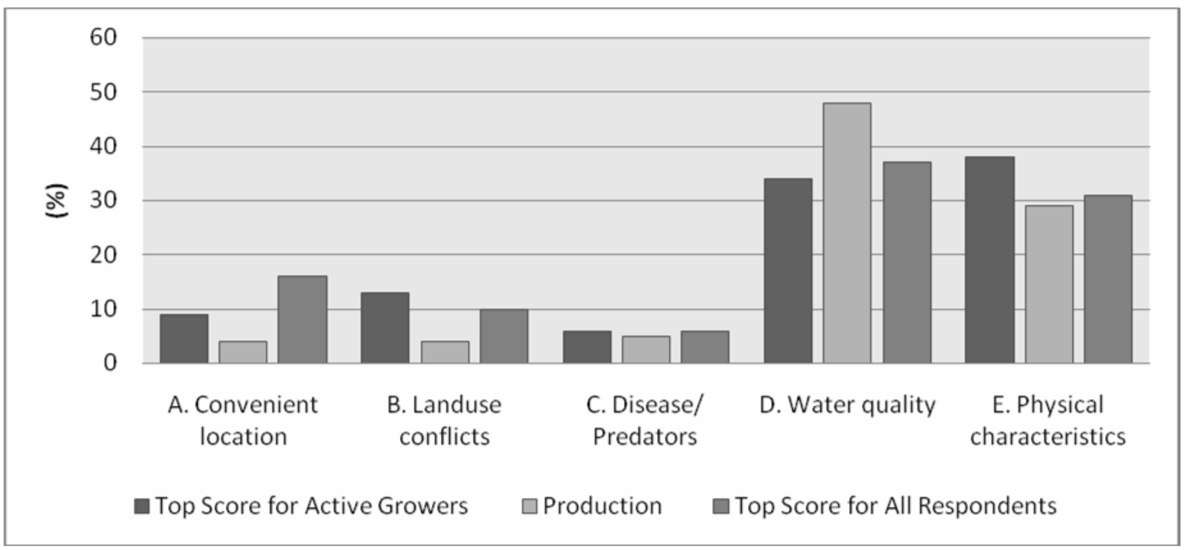


Table 3.1.3: What factors limit your ability to expand in the half shell market (1 for most important, 2 for second most important, etc.)

	Active Oyster Growers			All Respondents	
	Top Score (%)	Mean	Production (%)	Top Score (%)	Mean
A. Can't produce more product on a consistent basis	42	1.89	15	37	1.86
B. Lack of time to expand market contacts	25	2.33	5	18	2.48
C. Lack of market potential for expansion	8	2.89	13	11	2.92
D. Not profitable to expand	8	3.47	0	13	3.28
E. Lack of capital	17	3.26	19	21	3
	Total		52		

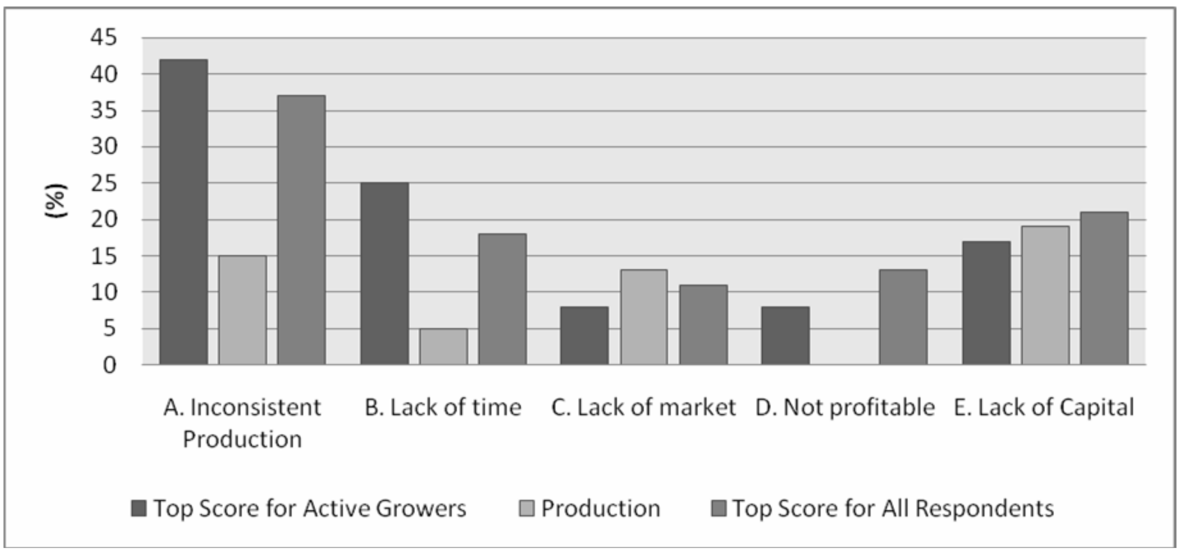


Table 3.1.4: How much of a contract price increase would it take for you to double your current output if you could sell your oysters for a fixed price in the half shell market?

	Active Oyster Growers		All Respondents
	Top Score (%)	Production (%)	Top Score (%)
A. $0.01 (in addition to current price or contracted price)	0	0	0
B. $0.03	0	0	0
C. $0.05	17	29	15
D. $0.10	24	47	26
E. $0.15	14	2	13
F. $0.20	14	1	13
G. I wouldn't increase my output due to other constraints	17	17	23
H. Other (please specify)	14	5	10
	Total	100	

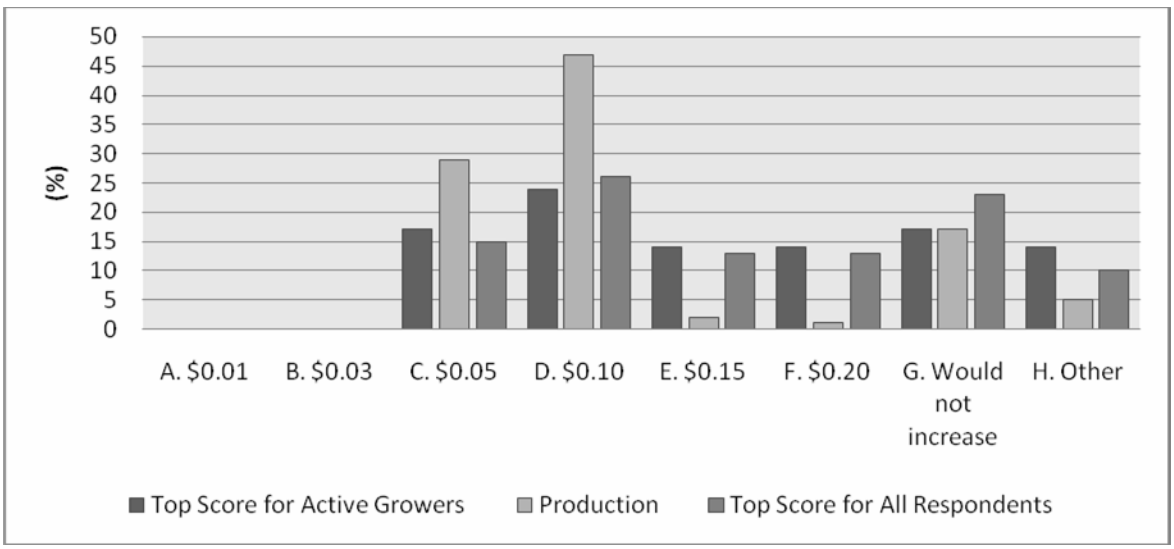


Table 3.1.5: If Virginia producers were to double their 2007 predicted output of 6.5 million oysters to 13 million, what would happen to the price you receive per oyster?

	Active Oyster Growers		All Respondents
	Top Score (%)	Production (%)	Top Score (%)
A. No change in price	67	41	65
B. $0.01 drop in price	0	0	0
C. $0.03 drop in price	4	3	3
D. $0.05 drop in price	4	30	12
E. $0.10 drop in price	8	1	9
F. $0.15 drop in price	4	2	3
G. $0.20 drop in price	13	1	9
	Total	77	

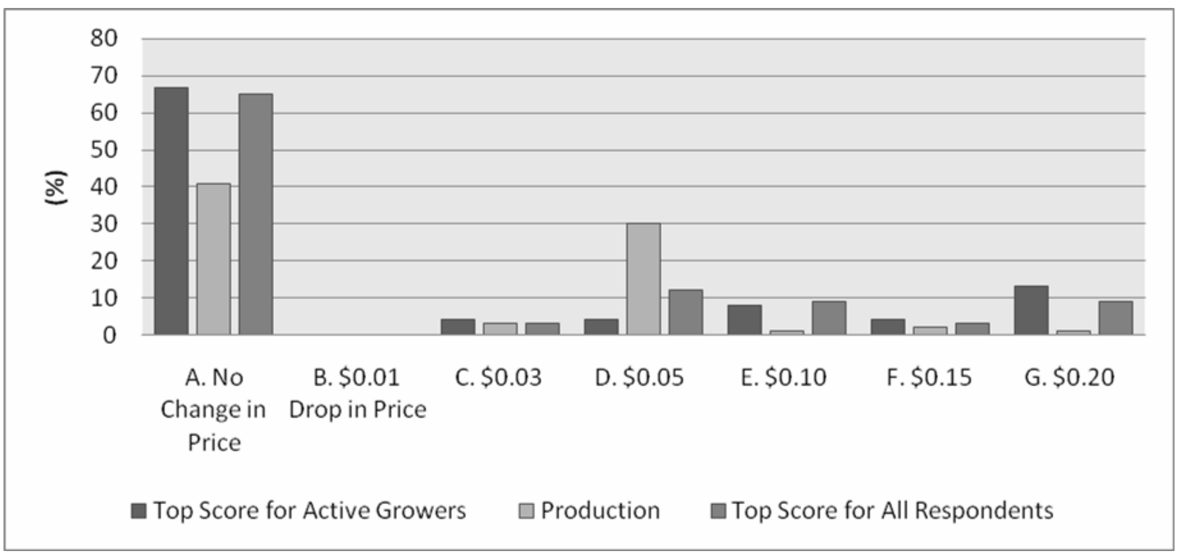


Table 3.1.6: If you do not grow clams now, what increase above current prices would it take for you to start growing them?

	Active Oyster Growers		All Respondents
	Top Score (%)	Production (%)	Top Score (%)
A. $0.01 (increase above current prices)	0	0	0
B. $0.03	5	12	6
C. $0.05	9	1	8
D. $0.10	9	2	6
E. $0.15	5	2	6
F. $0.20	5	0	6
G. I wouldn't grow clams commercially due to other constraints	27	24	22
H. I am already growing clams commercially	36	9	39
I. Other (please specify)	5	30	8
	Total	80	

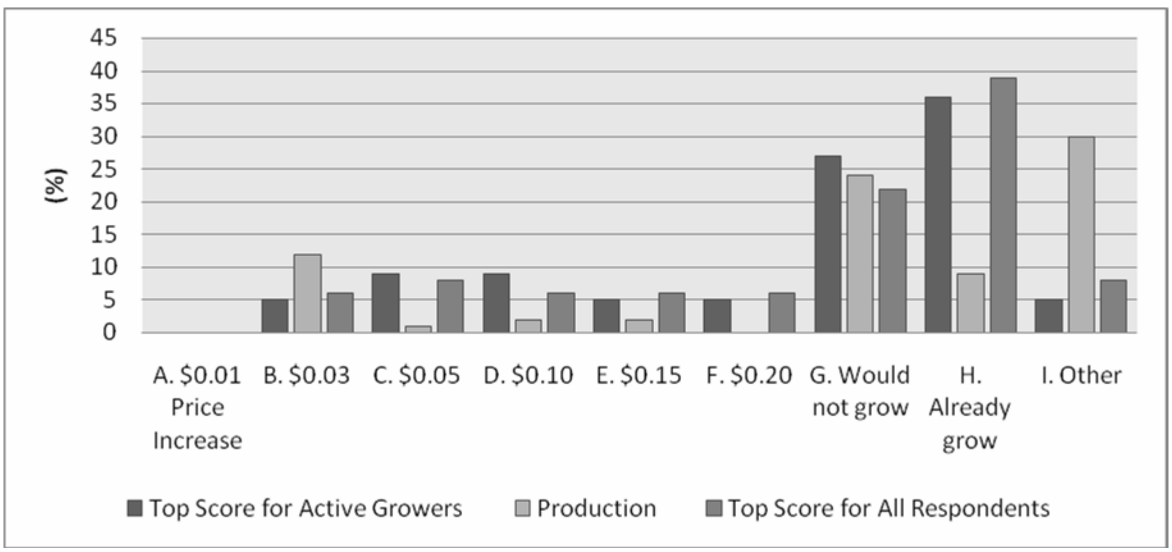


Table 3.1.7: What assistance can state agencies and NOAA (a federal agency) provide (1 for best assistance, 2 for second best assistance, etc.)

	Active Oyster Growers			All Respondents	
	Top Score (%)	Mean	Production (%)	Top Score (%)	Mean
A. Assist with marketing and the development of value added products	16	3.48	5	10	3.56
B. Assist in minimizing conflicts with surrounding landowners and recreational users	9	3.55	5	12	3.21
C. Fund research and demonstration projects targeting defined industry problems	9	3.77	5	8	3.97
D. Enforce 'proof of use' requirements to ensure that leased grounds are being used for oyster production	6	4.57	2	8	4.61
E. Assist with seed production by aiding the development of hatcheries	38	2.61	64	37	2.56
F. Support educational programs for technical training and extension programs	0	4.60	0	0	4.75
G. Protect and enhance water quality	22	2.79	9	24	2.61
	Total		90		

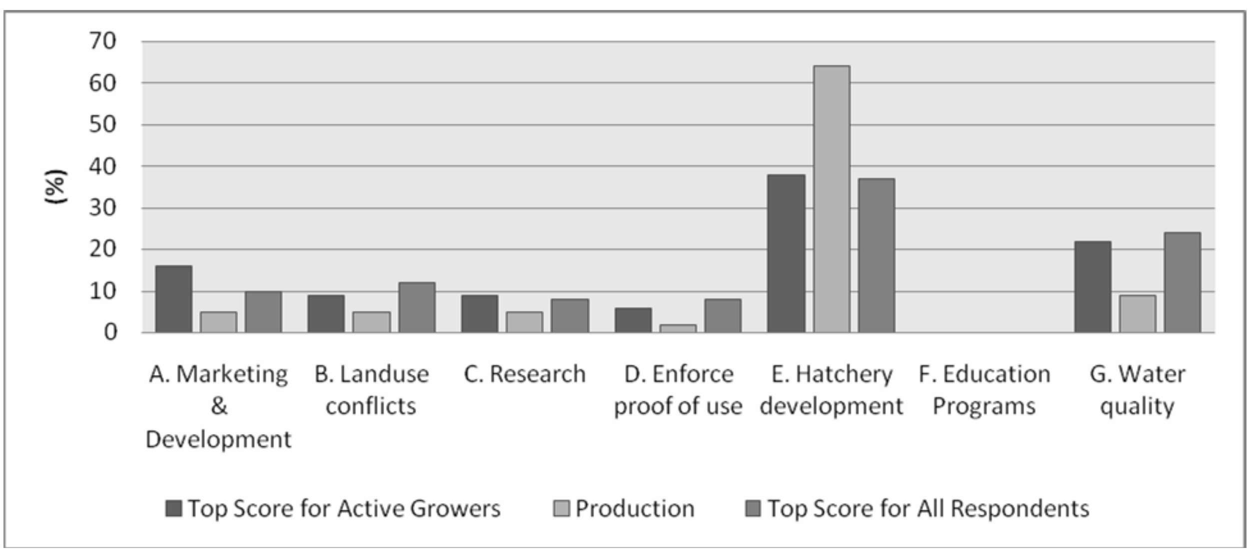


Table 3.1.8: How could state agencies and NOAA develop or support seed/eyed larvae production

	Active Oyster Growers			All Respondents	
	Top Score (%)	Mean	Production (%)	Top Score (%)	Mean
A. Assist with training programs for hatchery managers and technicians	13	3.24	16	15	3.03
B. Provide support for long-term breeding and genetic research	19	2.73	6	22	2.57
C. Develop technology for solving hatchery problems	16	2.87	9	13	2.93
D. Support research for new production methods	10	3.38	2	4	3.33
E. Help provide greater access to triploid seed	32	2.20	22	37	2.06
F. Other (please specify)	10*	2.00	33	9	1.83
	Total		88		

* These respondents either had suggestions to improve current programs or did not want state agency help

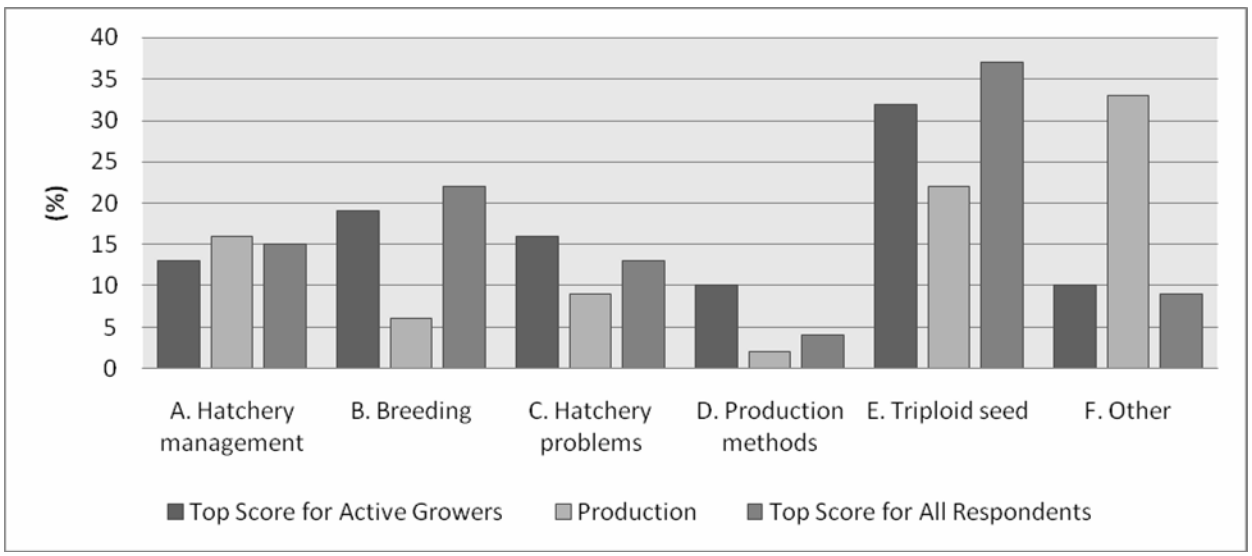


Table 3.1.9: How could state agencies and NOAA provide support for research and demonstration projects (1 for best assistance, 2 for second best, etc.)

	Active Oyster Growers			All Respondents	
	Top Score (%)	Mean	Production (%)	Top Score (%)	Mean
A. Expand and enhance remote setting systems	21	3.09	15	26	2.7
B. Develop more efficient nursery systems	18	2.95	17	17	2.75
C. Develop methods for large-volume material handling	18	2.65	10	17	2.81
D. Support yield verification (field trials for genetic lines)	32	2.57	42	21	2.96
E. Develop new production methods and equipment	7	2.65	4	10	2.57
F. Other (please specify)	4	4.00	3	10	2.5
	Total		91		

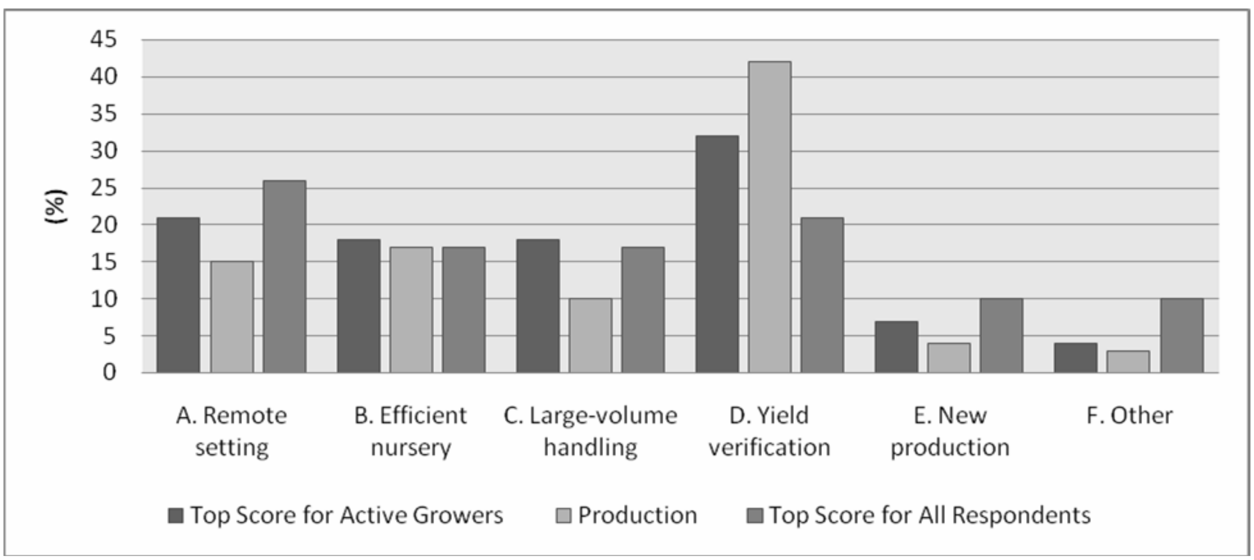


Table 3.1.10: How could state agencies and NOAA provide support in educational programs (1 by best assistance, 2 by second best, etc.)

	Active Oyster Growers			All Respondents	
	Top Score (%)	Mean	Production (%)	Top Score (%)	Mean
A. 4-H and Youth programs (including high school clubs, FFA, and others)	8	3.05	1	7	3.17
B. Vocational-technical school programs	16	2.30	11	17	2.25
C. Community college programs	16	2.45	1	15	2.33
D. Extension programs	56	1.40	72	59	1.45
E. Other (please specify)	4	3.67	3	2	3.67
	Total		87		

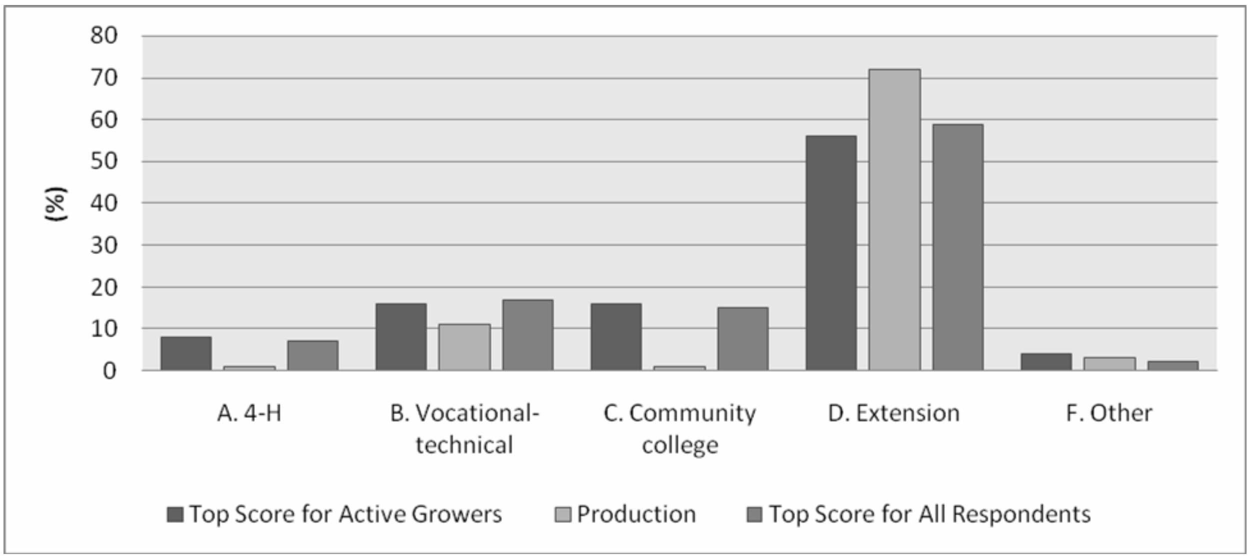


Table 3.1.11: What could state agencies do to improve the current leasing system (1 for best assistance, 2 for second best, etc.)

	Active Oyster Growers			All Respondents	
	Top Score (%)	Mean	Production (%)	Top Score (%)	Mean
A. Enforce "proof of use" requirements on leased bottoms	30	2.21	17	32	2.1
B. Increase the lease price	9	3.93	2	8	3.6
C. Lower the lease price	0	3.64	0	3	3.62
D. Reduce the time and hassle of changing or acquiring leases	22	2.25	3	19	2.29
E. Open up the Baylor grounds for private leases	22	2.36	12	24	2.41
F. Other (please specify)	17*	1.00	40	14	1
	Total		75		

* These respondents were opposed to the state changing the current leasing system

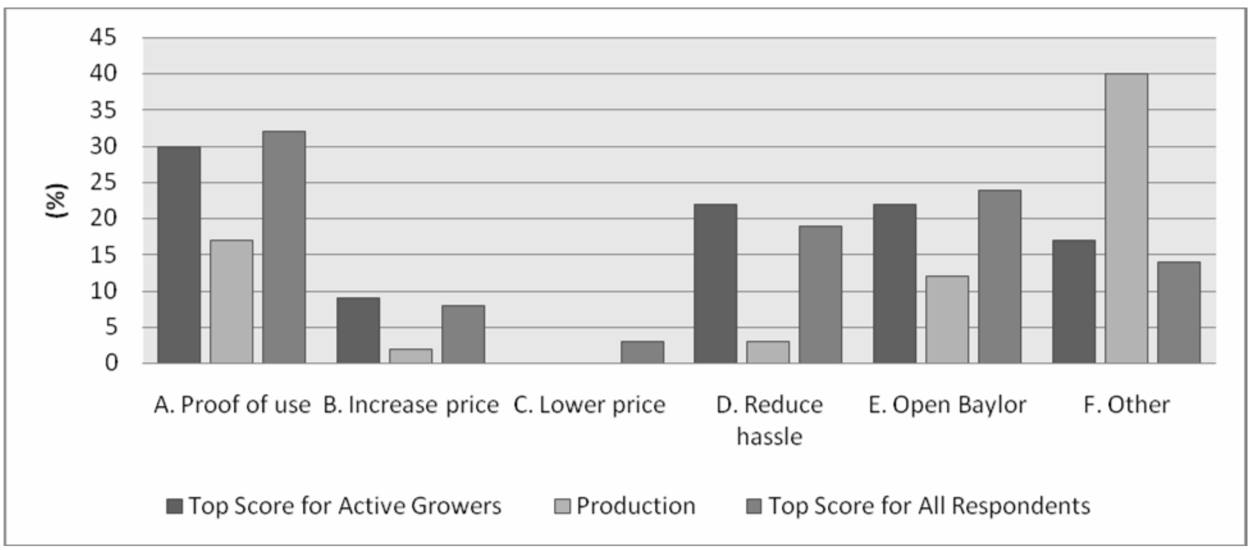


Table 3.1.12: If some Baylor grounds were open for private use, would you lease them?

	Active Oyster Growers		All Respondents
	Top Score (%)	Production (%)	Top Score (%)
A. Yes	41	42	42
B. No	33	39	33
C. Don't Know	26	8	24
	Total	90	

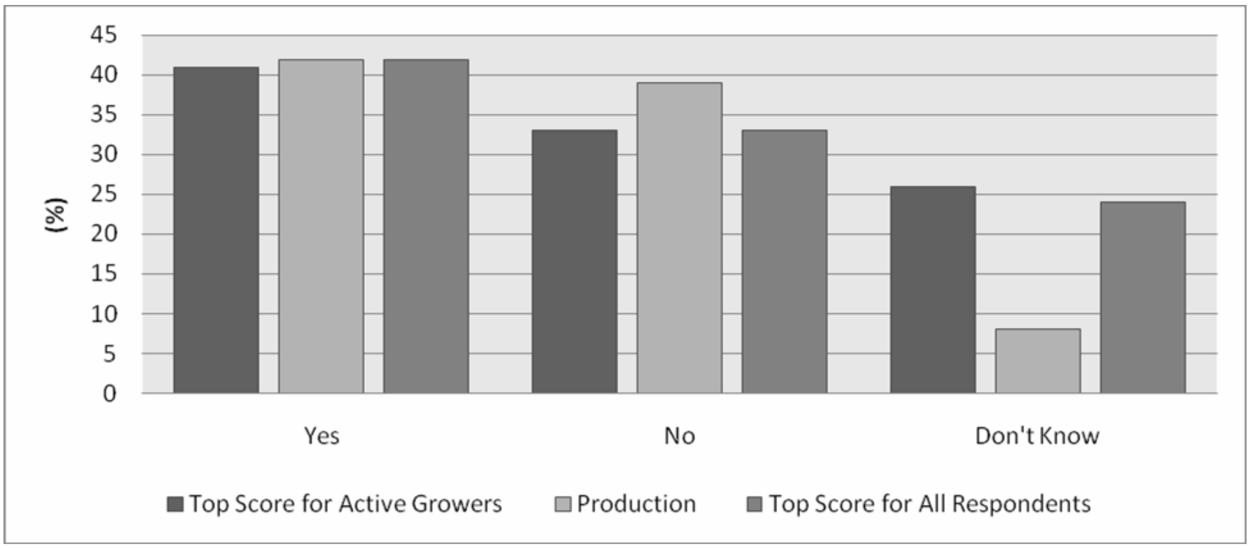
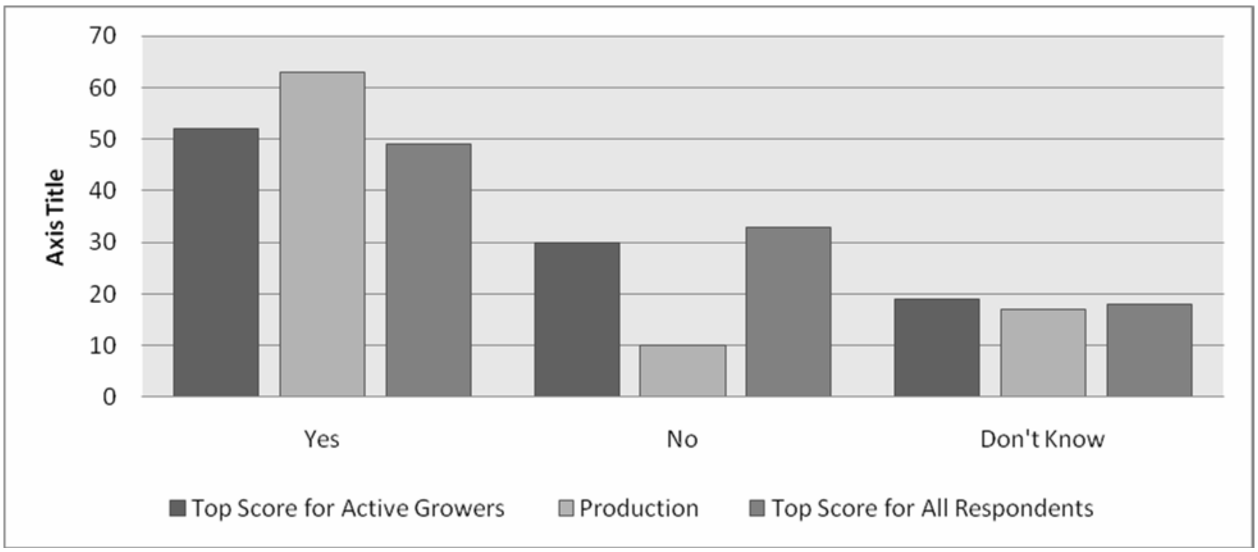


Table 3.1.13: Would you support opening some Baylor grounds for private shellfish aquaculture?

	Active Oyster Growers		All Respondents
	Top Score (%)	Production (%)	Top Score (%)
A. Yes	52	63	49
B. No	30	10	33
C. Don't Know	19	17	18
	Total	90	



Current Commercial Oyster Production

Table 3.1.15: Indicate your oyster production and average market price for 2007 and 2008

2007		**2008 (Estimate)**	
Average price per market oyster	total # market (non-seed) sold	Average price per market oyster	total # market (non-seed) sold
.28	7,071,800	.283	16,230,000

What percent of your total oyster production was grown in containers last year?__82_%

What percentage of your production is typically sold on the half shell market?___91__%

Barriers to Expanding Clam Production

Table 3.1.18: What factors constrain your ability to expand your current clam operations (1 for most important, 2 for second most important, etc.)

	Active Clam Growers			All Respondents	
	Top Score (%)	Mean	Production (%)	Top Score (%)	Mean
A. Availability / cost of seed	21	2.44	5	22	2.37
B. Availability of grounds	25	2.31	37	22	2.4
C. Lack of market	21	2.60	16	22	2.68
D. Problems with predators (rays, crabs, etc.)	14	2.76	3	14	2.6
E. Problems with disease	0	5.42	0	0	5.36
F. Permitting issues / land use conflicts	7	3.69	3	6	3.93
G. Poor or uncertain water quality	11	4.93	27	14	4.61
	Total		90		

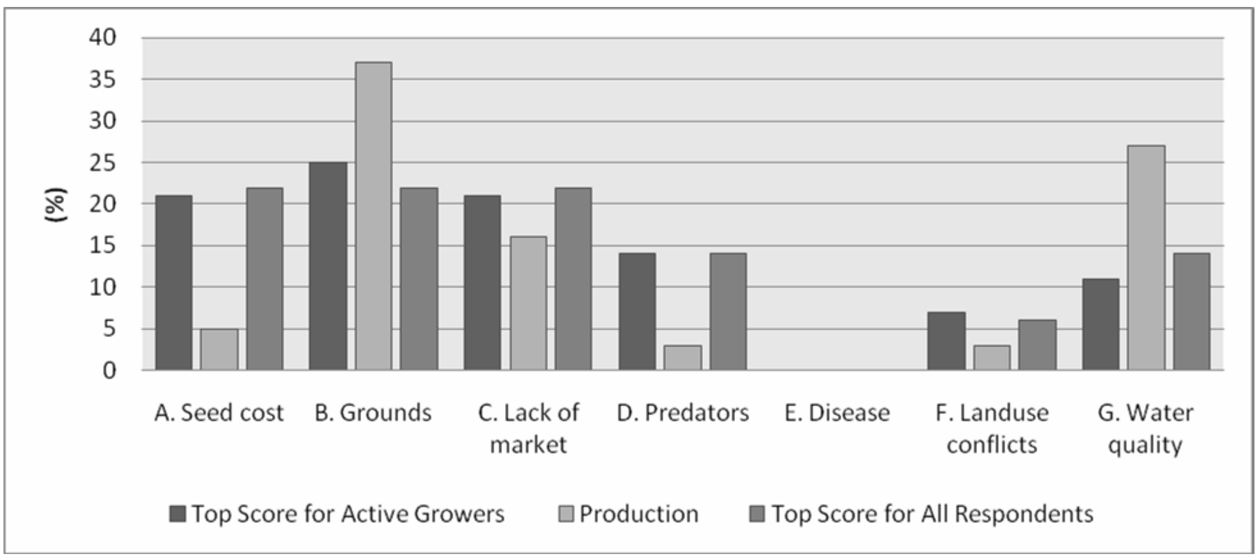


Table 3.1.19: What factors are most important in determining whether you would expand clam production on a new site (1 for most important, 2 for second most important, etc.)

	Active Clam Growers			All Respondents	
	Top Score (%)	Mean	Production (%)	Top Score (%)	Mean
A. Convenient location (near my existing aquaculture operation or access or boat ramp)	22	2.48	14	25	2.34
B. Possible conflicts with waterfront property owners, recreational users, etc.	4	3.74	0	3	3.63
C. Potential disease and/or predator pressure on the site	7	3.47	6	6	3.55
D. Water quality (pollution from sedimentation, pesticides, etc.)	11	2.80	35	17	2.6
E. Physical characteristics (salinity, bottom condition, flush rate, etc.)	56	1.55	44	50	1.62
Total			100		

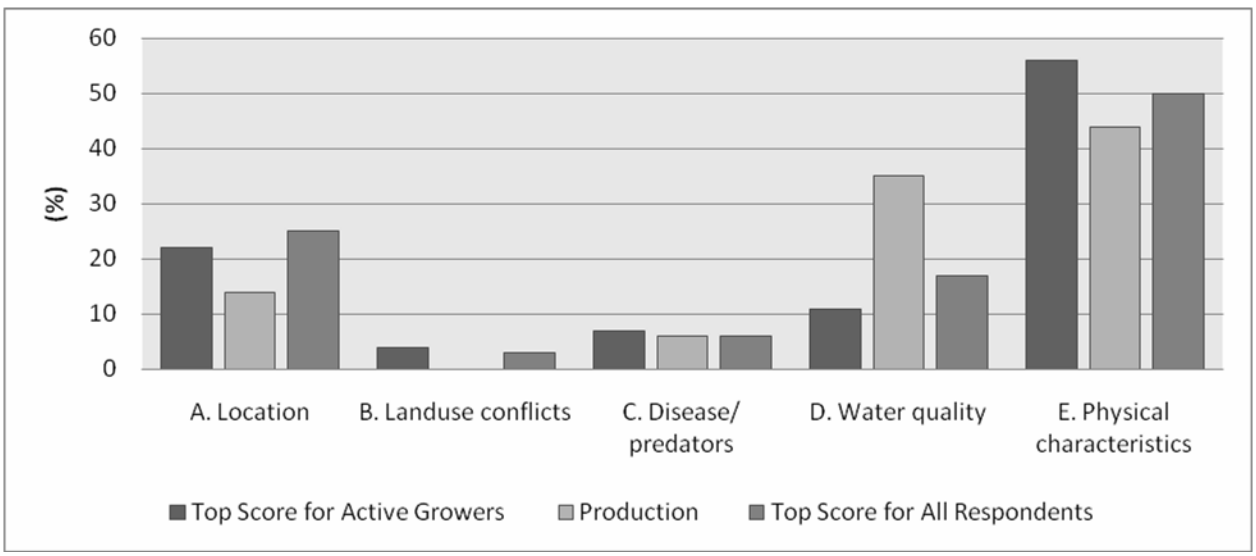


Table 3.1.20: Do you think changes to the current leasing system are needed?

	Active Clam Growers		All Respondents
	Top Score (%)	Production (%)	Top Score (%)
A. Yes	40	15	34
B. No	60	85	63
C. Don't Know	0	0	3
Total		100	

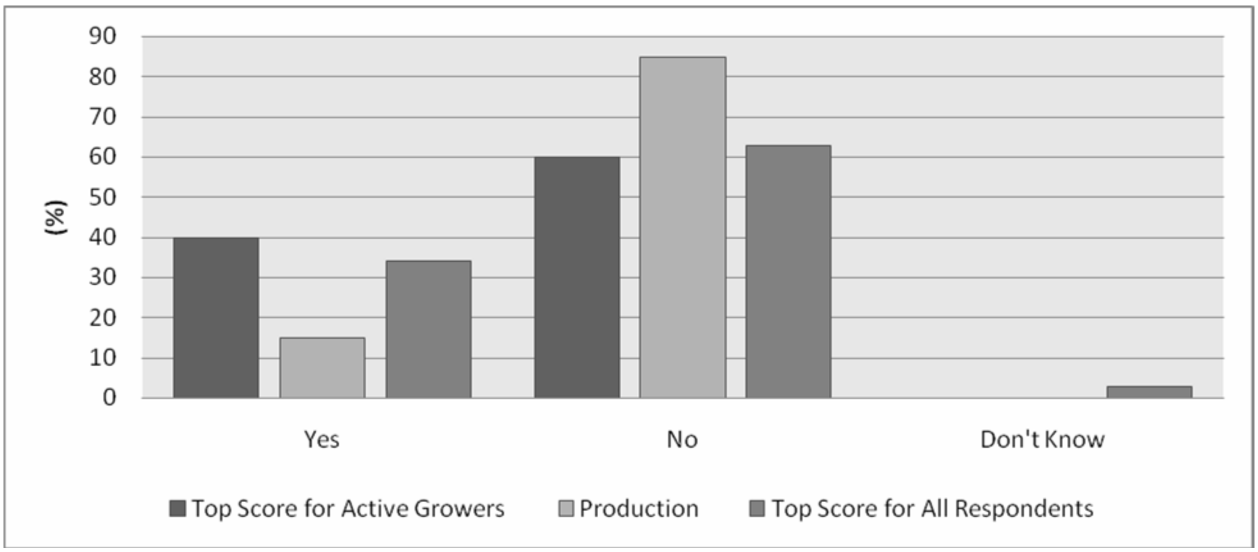


Table 3.1.21: How could state agencies improve the current leasing system (1 for most important, 2 for next most important, etc.)

	Active Clam Growers			All Respondents	
	Top Score (%)	Mean	Production (%)	Top Score (%)	Mean
A. Enforce "proof of use" requirements on leased bottoms	54	1.42	15	63	1.32
B. Increase the lease price	13	2.92	35	10	3.07
C. Lower the lease price	0	4.18	0	0	4.07
D. Reduce the time and hassle of changing or acquiring leases	8	2.18	3	7	2.29
E. Open up the Baylor grounds for private leases	21	2.5	27	17	2.75
F. Other (please specify)	4	4.4	13	3	4
	Total		92		

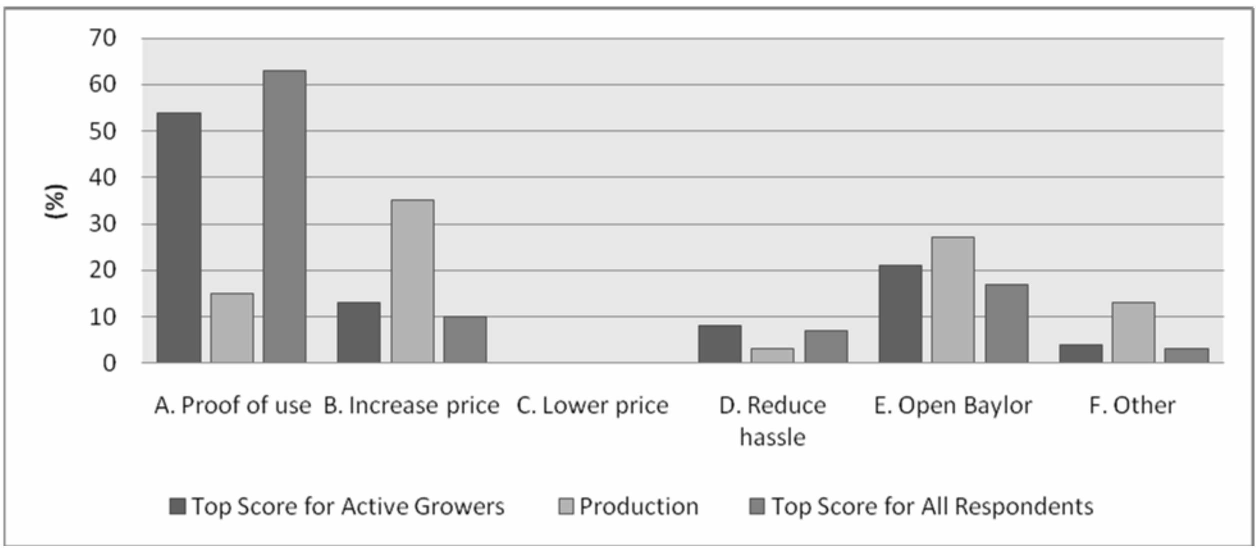


Table 3.1.22: If some Baylor grounds were opened, would you lease them?

	Active Clam Growers		All Respondents
	Top Score (%)	Production (%)	Top Score (%)
A. Yes	48	38	44
B. No	36	60	36
C. Don't know	16	2	19
Total		100	

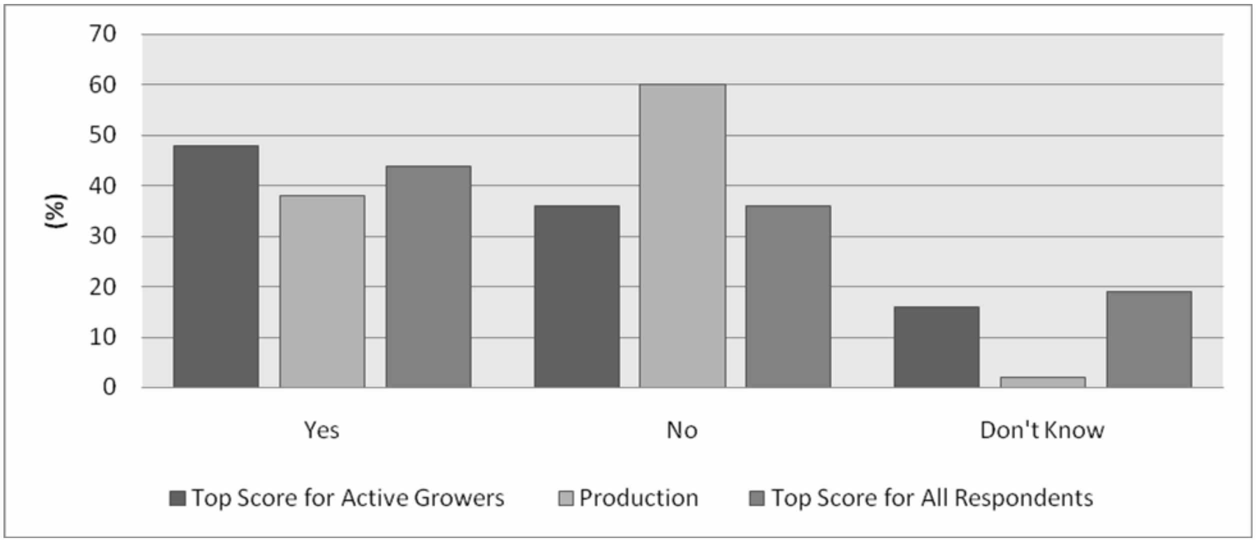


Table 3.1.23: Would you support opening some Baylor grounds for private shellfish aquaculture?

	Active Clam Growers		All Respondents
	Top Score (%)	Production (%)	Top Score (%)
A. Yes	50	44	49
B. No	33	54	37
C. Don't know	17	2	14
Total		100	

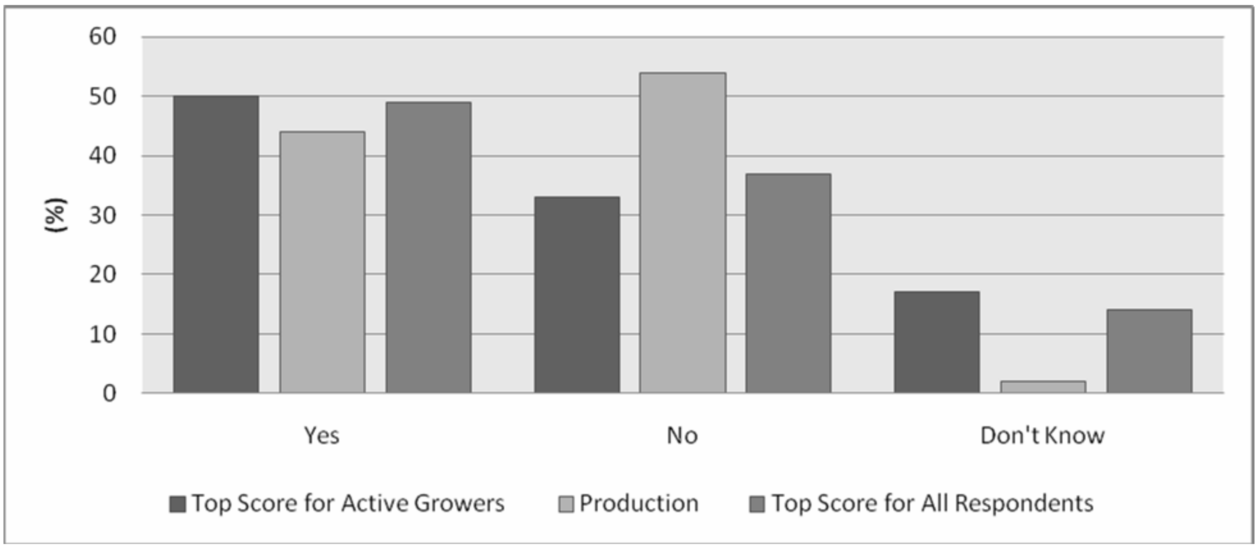


Table 3.1.24: How could state agencies best assist clam growers (1 for best assistance, 2 for second best, etc.)

	Active Clam Growers			All Respondents	
	Top Score (%)	Mean	Production (%)	Top Score (%)	Mean
A. Assistance with marketing and the development of value added products	32	2.33	19	26	2.55
B. Assist in minimizing conflicts with surrounding landowners and recreational users	14	2.67	4	13	2.58
C. Assist with research and demonstration projects	0	5.08	0	0	5
D. Enforce 'proof of use' requirements to ensure that private leased grounds are being used for clam production	18	3.06	4	13	3.11
E. Assist with seed production by hatcheries	4	4.25	1	8	3.88
F. Provide educational programs for developing the future industry	4	4.42	1	3	4.63
G. Protect water quality	29	1.94	70	37	1.88
	Total		99		

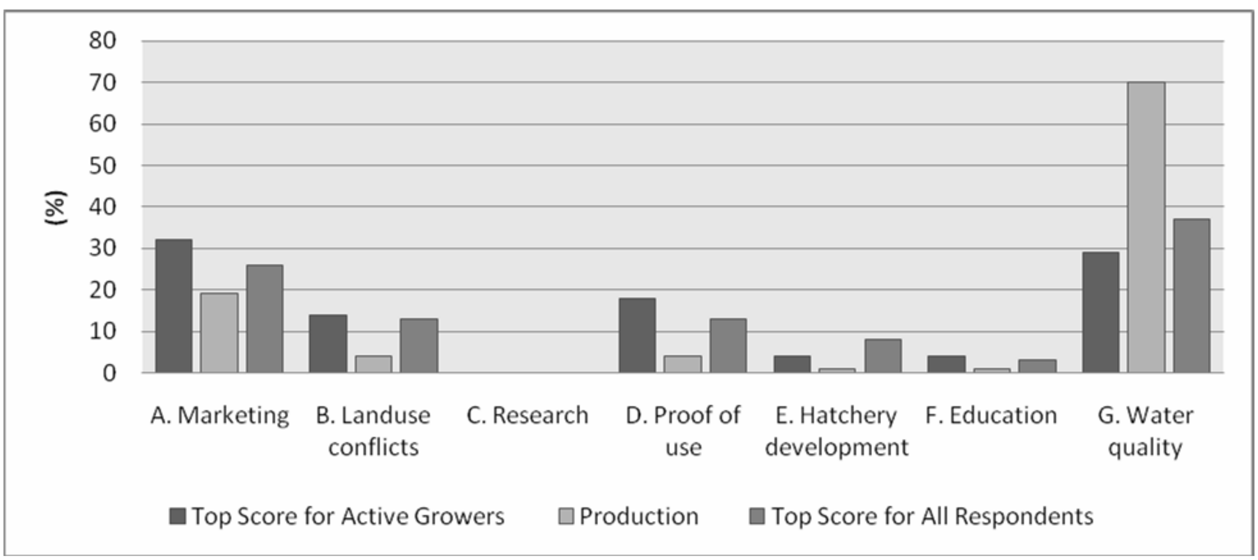


Table 3.1.25: How much of a contract price increase would it take for you to double your current output if you could sell your clams for a fixed contract price?

	Active Clam Growers		All Respondents
	Top Score (%)	Production (%)	Top Score (%)
A. $0.01 (in addition to current price or contracted price)	7	37	8
B. $0.03	15	1	11
C. $0.05	33	9	32
D. $0.10	15	3	11
E. $0.15	0	0	0
F. $0.20	7	4	5
G. I wouldn't increase my output due to other constraints	15*	43	16
H. Other (please specify)	7	4	16
	Total	100	

* These respondents constraints included seed cost, ground availability and labor

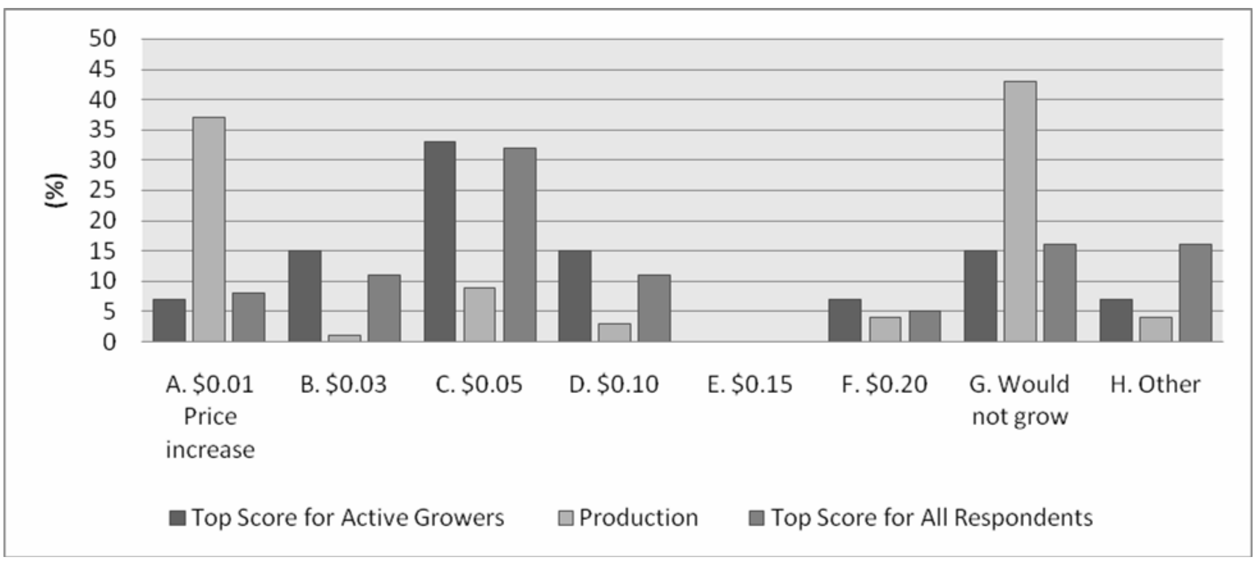


Table 3.1.26: If Virginia clam producers were to double their quantity from 200 million clams in 2006 to 400 million, how would it impact the price you receive?

	Active Clam Growers		All Respondents
	Top Score (%)	Production (%)	Top Score (%)
A. no change in price	21	9	20
B. $0.01 drop in price	8	27	7
C. $0.03 drop in price	46	20	50
D. $0.05 drop in price	21	38	20
E. $0.07 drop in price	0	0	0
F. $0.09 drop in price	0	0	0
G. $0.11 drop in price	4	3	3
H. Other (please specify)	0	0	0
Total		96	

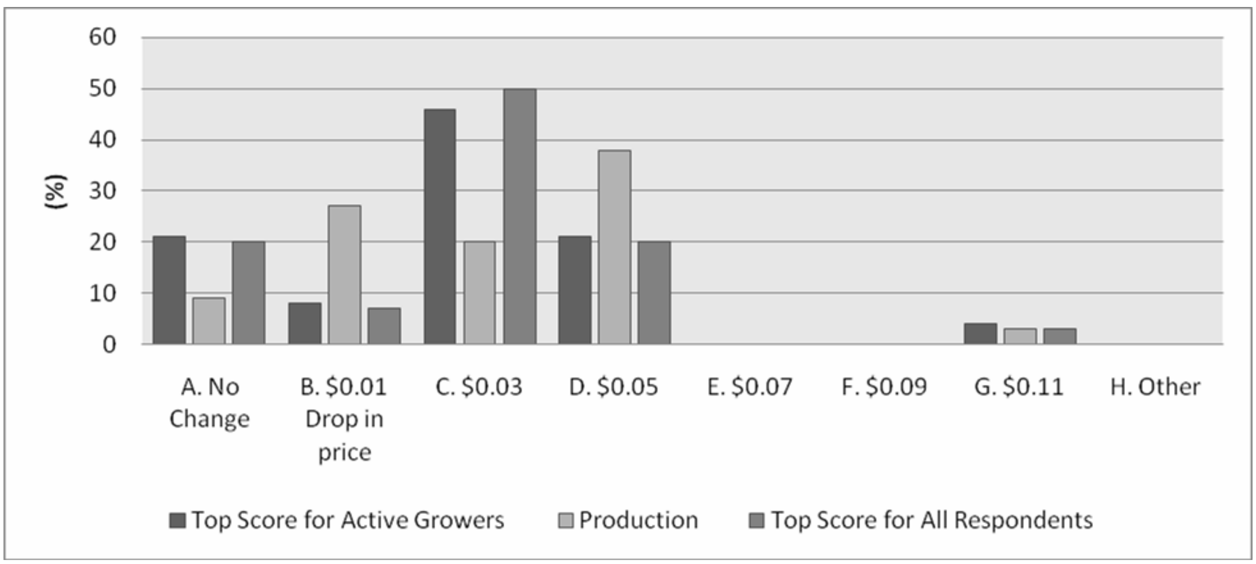
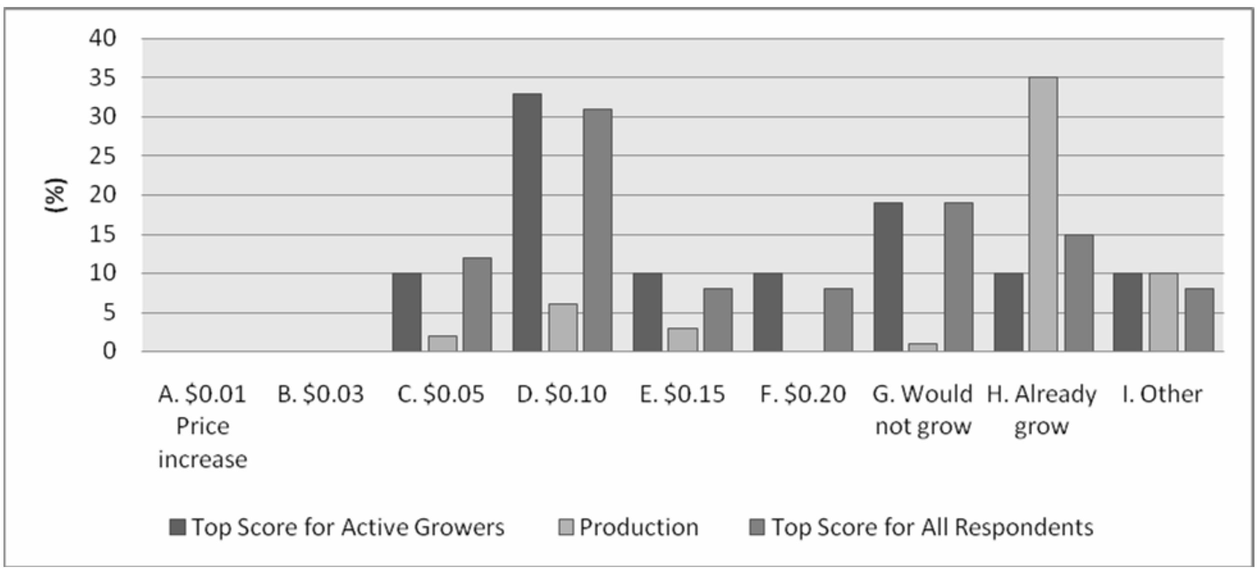


Table 3.1.27: If you do not grow oysters, what increase above the current prices would it take for you to start producing oysters commercially?

	Active Clam Growers		All Respondents
	Top Score (%)	Production (%)	Top Score (%)
A. $0.01 (increase above current prices)	0	0	0
B. $0.03	0	0	0
C. $0.05	10	2	12
D. $0.10	33	6	31
E. $0.15	10	3	8
F. $0.20	10	0	8
G. I wouldn't grow oysters commercially due to other constraints	19	1	19
H. I am already growing oysters commercially	10	35	15
I. Other (please specify)	10	10	8
Total		57	



Current Commercial Clam Production

Table 3.1.28: Please indicate your clam production and average market price for 2007 and an estimate for 2008

Variety	2007		2008 (Estimate)	
	Average price / clam	Total # sold	Average price / clam	Total # sold
Smaller than 1 inch	.113	102,592,300	.111	104,515,000
Larger than 1 inch	.147	70,649,035	.145	89,675,000

3.2. Introduction to Policy Evaluation

In this section we discuss several policy alternatives and explain the impacts of policies on prices and outputs from partial equilibrium responses. We attempt to explain likely outcomes based on qualitative or quantitative evidence including the responses to the grower survey and the evaluation framework described in the previous section. We only attempt to quantify policy alternatives where we feel that our survey results and/or results from existing studies allow us to be confident about quantitative conclusions.

3.3. Policy Evaluation: Redefinition and/or Clarification of Leasing Policy

3.3.1. Resurveying Baylor grounds

The survey we conducted with oyster and clam growers provides some insights into whether producers think there is a need for resurveying the Baylor grounds. However, the responses to similar questions relating to resurveying the Baylor grounds were often quite different between oyster and clam growers. Therefore, in this section we summarize the results relevant to the Baylor ground issue separately for oyster growers and clam growers.

Results from relevant survey questions in oyster section

There were three questions that were relevant to the issue of resurveying Baylor grounds in the "Questions for Oyster Growers" section of the survey. Question 1 asked oyster growers to rank the factors that constrain their ability to expand their current oyster operations. The responses of active oyster growers suggest that the "availability of grounds" was one of the least important of the constraints. Only 4 percent of growers (accounting for 10% of production) identified this option as the most important (Table 3.1.1). The most important constraint appeared to be the availability / cost of seed, which was the top score of 50 percent of oyster growers (accounting for 53% of production). It should be noted that the survey was administered during a year when seed supply was particularly tight.

When asked directly whether they would lease former Baylor grounds to increase their oyster production, forty-one percent of active oyster growers (accounting for 42% of market production) said yes, while 33 percent replied no (accounting for 39% of the market) (see Table 3.1.12). A fourth of all producers (only representing 8% of production) did not know if they would lease Baylor grounds if it were opened up to private leases. A larger percentage of growers supported opening some Baylor grounds for private shellfish aquaculture (See Table 3.1.13). Fifty-two percent of active oyster growers (accounting for 63% of production) said yes, 30 percent (accounting for 10% of production) said no, and 19 percent (accounting for 17% of production) said they did not know. Since growers frequently produce both clams and oysters, the favorable response to opening Baylor could also be related to the perceived need for additional ground for clam production.

Results from relevant survey questions in clam section

Three questions similar to those described in the oyster section were asked in the "Questions for Clam Growers" section of the survey. Clam growers ranked the factors that most constrain their ability to expand their current operations (see Table 3.1.18). Twenty-five percent of growers (accounting for 37% of production) identified the "availability of grounds" as the most important. This was the most frequently cited constraint. When asked whether they would lease Baylor grounds to increase their clam production, if some Baylor grounds were opened for private use, forty-eight percent of active clam growers (accounting for 38% of market production) replied yes, 36 percent (accounting for 60% of the market) said no (Table 3.1.22). Sixteen percent (accounting for 2% of production) said they did not know if they would lease Baylor grounds if it were opened up to private leases. These responses suggest that there may be a relatively significant group of clam growers (who account for a relatively small share of current production) looking for avenues to expand production. Unsurprisingly, half of active clam growers (accounting for 44% of production) supported opening some Baylor grounds for private shellfish production (see Table 3.1.23). A third (54% of production) would not support opening up Baylor grounds.

Discussion on resurveying Baylor grounds

Survey results suggest that oyster growers would largely support resurveying the Baylor grounds. Nonetheless, many of those surveyed suggested they would not lease Baylor grounds to increase their oyster production. Furthermore, the availability of grounds appears to be of relatively low importance to oyster growers compared to other constraints on expanding their operations. Clam growers on the other hand appear to place greater importance on the availability of grounds. The clam and oyster growers are split over whether they support opening up Baylor grounds with a slight majority favoring.

Will resurveying the Baylor grounds help to significantly expand aquaculture production in Virginia? Our interpretation of the survey results is a qualified “maybe.” It does not appear that the availability of grounds is a major constraint for oyster production. This makes sense, given the current size of total oyster production and that oyster production in containers can be grown in relatively small areas. The availability of grounds appears to be a bigger issue for clam growers. Furthermore, it is the small producers (in terms of production) that appear most eager to use Baylor grounds. It is here that we could foresee the resurveying of Baylor grounds potentially expanding clam production in Virginia. The magnitude of this expansion is, however, difficult to quantify.

3.3.2. Reforming the leasing system

The survey can also provide some insights into whether growers think there is a need for reforming the leasing system. Like the Baylor grounds section above, the response to this question issue varies between oyster and clam producers.

Results from relevant survey questions in oyster section

Oyster producers indicated that the opportunity to lease grounds was not a major impediment to oyster production.   They ranked the availability of grounds as one of the least constraining factors to expanding their operations (see Table 3.1.1).   When asked how state and federal agencies can best assist oyster growers to expand production, enforcement of 'proof of use' requirements was one of the lowest ranked actions (only 6 percent of respondents, accounting for 2% of production, ranked enforcing proof of use requirements as the most important) (Table 3.1.7).   The highest ranked option for state/federal assistance was assisting with seed production by aiding the development of hatcheries. When ranking options on what state agencies could do to improve the current leasing system in Virginia, seventeen percent of respondents (accounting for 40% of production) chose the 'other' option and typically specified that they thought no changes were needed for the current lease system (Table 3.1.11).

Results from relevant survey questions in clam section

As discussed above, clam growers identified the availability of grounds as the highest ranked factor constraining current production. Unlike the oyster section, the clam section of the survey asked growers directly if they thought changes to the current leasing system are needed (see Table 3.1.20). Somewhat surprisingly, sixty percent of respondents answered "no" (accounting for 85% of production). But if changes were to be made to the leasing program, 54% of respondents (accounting for 15% of production) ranked "enforcing 'proof of use' requirements" as most important (Table 3.1.21). Although only 13 percent of respondents ranked "increase the lease price" as the most important, these 13 percent accounted for 35 percent of clam production. When asked how state and federal agencies can best assist clam growers, relatively few identified enforcement of 'proof of use' requirements to ensure that leased grounds are being used for clam production. The top response from clam growers on how government agencies could assist the industry was to help protect water quality (29 percent of respondents, accounting for 70% of production) (Table 3.1.24).

Discussion on reforming the lease system

There are two primary ways in which the current leasing system could be altered to more efficiently allocate subaqueous bottoms for the purpose of aquaculture. First, the "use it, or lose it" nature of the original law could be strictly enforced. This would mean that those lease-holders who no longer actively perform aquaculture on their leases would need to start an aquaculture operation or let others begin renting the property for aquaculture production. The second alternative would be to adjust the rental price mechanism of the leases.

Overall it appears that availability of grounds is not the most important constraint to oyster growers. Clam growers on the other hand view availability of grounds as being an important constraint to their ability to expand their operations. However when directly asked if the current leasing system should be changed, most growers said “no” (Table 3.1.20). These growers accounted for 85 percent of clam production. Smaller producers, however, appear more supportive of changing lease policy. When asked what could be done to improve the lease system, small clam growers appeared to want enforcement of “proof of use” requirements, whereas big growers were more supportive of increasing the lease price. Overall, changing the lease system could potentially expand clam production in Virginia by allowing current small growers to expand their operations. However, it appears that there are additional factors constraining growers at this time so it is unclear the magnitude of the expansion that would occur from reforming the lease system.

3.3.3. Establishing Shellfish Enterprise Zones

Shellfish enterprise zones can provide protection for oyster and clam growers by reducing uncertainty about water quality, regulatory pressure, and conflicts with waterfront property owners. The ‘proof of use’ conflicts for both oyster and clam growers were previously discussed but land use conflicts require further evaluation. This section describes the survey responses in two separate sections focusing on oyster and clam growers.

Results from relevant survey questions in oyster section

Permitting issues and land use conflicts concern active growers with 12 percent (1% of total production) listing it as their number one constraint (Table 3.1.1). Thirteen percent of active oyster growers (accounting for 4% of total production) listed possible conflicts with waterfront property owners and recreational users as their top reason when considering expanding to a new site (Table 3.1.2).

Regarding state and federal assistance for oyster growers, assistance in minimizing conflicts with surrounding landowners and recreational users was selected by 9 percent (5 percent of active growers) as their top choice for enhancing the industry (Table 3.1.7). As mentioned earlier, active growers ranked enforcing the 'proof of use' requirements on leased bottom as the most important (30 percent) way for state agencies to improve the current leasing system. Reducing the time and hassle of changing or acquiring leases was listed second with 22 percent of active oyster growers (Table 3.1.11).

Results from relevant survey questions in clam section

For active clam growers, permitting issues and land use conflicts ranked low with only 7 percent (3 percent of production) choosing it as their most important constraint (Table 3.1.18). Possible conflicts with waterfront property owners and recreational users ranked lowest with only 4 percent of active clam growers citing it as their most important factor in determining where to lease a new site (Table 3.1.19). In terms of assistance to clam growers, minimizing conflicts with surrounding landowners and recreational users elicited 14 percent of growers (representing 4 percent of production) to rank it as the best way for state agencies to assist (Table 3.1.24).

Discussion on shellfish enterprise zones

As seen in the previous sections, land use conflicts and permitting issues are not the most important issues for oyster growers. A shellfish enterprise zone would provide legal protection for land use conflicts and also provide additional water quality regulations, which is currently one of the most important issues to both oyster and clam growers. Overall, oyster growers had stronger response to questions about land use conflicts than clam growers. The clam growers appear to have established sites primarily on the Eastern Shore where population densities are lower, thus not experiencing the same level of conflict from landowners. Oyster growers however feel pressure from landowners and appear to have a greater need for regulations against nuisance lawsuits. The large producers for both clam and oyster aquaculture are currently constrained by other factors such as water quality and availability of seed, while only a handful of small growers appear to need assistance with land use conflicts. The state should be aware that even though there are land use conflicts, respondents were generally opposed to creating enterprise zones based on their concern that more regulations would create a greater hassle for watermen.

3.3.4. Developing aquaculture "bill-of-rights" disclosure statements

While not explicitly addressed in the survey, another alternative to evaluating the land use conflicts is the establishment of an aquaculture "bill-of-rights" disclosure statement. An aquaculture "bill-of-rights" would address recent concerns about conflicts with waterfront property owners for growers who meet certain prescribed production standards. Specifically, it would provide a legal basis for shellfish growers to deflect complaints about noise or visual disamenities associated with their normal commercial operations. An aquaculture bill-of-rights could be designed similarly to the Right-to-Farm Acts by providing growers with the security of knowing the state of Virginia is supportive of their operations.

An aquaculture bill-of-rights would provide more security for growers and, as opposed to enterprise zones, would not increase the amount of regulations for watermen. In order for growers to use the bill-of-rights, they could be required to demonstrate a set of best management practices outlined by the state. One concern with an aquaculture bill of rights is that it may not provide the legal precedence growers would need if a land use conflict were taken to court. Maryland's aquaculture bill-of-rights is relatively new and has yet to be tested in a legal environment, hence the need for caution in creating such a document.

3.4. Policy Evaluation: Research and Development

Active oyster growers identified several areas where research and development could aid their operations. The availability of seed is a major constraint to expansion with 50 percent of active oyster growers listing it as the number one constraint (Table 3.1.1). Active grower respondents also listed seed production most often (38 percent) as the area where government assistance would be helpful (Table 3.1.7).

Breeding programs to enhance growth rates and reduce disease are also important. Twelve percent of active oyster growers listed disease mortality as the most important constraint to expansion (Table 3.1.1). Active growers listed yield verification (field trials for genetic lines) most often (32 percent) as the way in which state agencies could best support research and development (Table 3.1.9). Oyster growers cited this as the single most important research agenda state/federal agencies could pursue to assist the industry. Better access to triploid seed was most often listed (32 percent) by active growers as the most important way government could help seed production (Table 3.1.8) while long-term breeding and genetic research was listed second (19 percent). Because triploid seed oysters are infertile, they can invest more energy into growth and exceed the growth of fertile diploid oysters (Nell 2002; cited in Miller 2008).

We focus on three research and development options for active oyster growers: 1) reducing the cost of hatchery seed; 2) reducing disease susceptibility and mortality; and 3) increasing growth rates. We estimate the resulting effects on oyster returns for a representative grower who uses floats and a representative grower using cages to produce oysters (Miller 2008). Oyster revenues and costs for differing seed prices, mortality levels, and growout rates are estimated for a 10-year cycle of repeated seed plantings using the model developed by Miller (2008). Oysters are initially planted in March (floats) or April (cages) and harvested based on the assumed time to maturity for each scenario. Oysters are immediately replanted the month following harvest except that replanting cannot occur in November, December, January, February (cage or float aquaculture), or March (in case of cage aquaculture) due to unsuitable growing conditions (Miller 2008). Net revenues (gross revenues minus variable production costs) are estimated for each cycle and discounted to present values using a real annual discount rate of 5%. The process is repeated until 10 years have elapsed. If a cycle is incomplete at the end of the investment period, that cycle is eliminated from the estimate of benefits. Upfront investment costs (land, dock, buildings, equipment, etc.) described in Miller (2008) are summed and subtracted from the present value of investment revenues. Specific assumptions and results for cage and float aquaculture are described in the following sections.

For each type of oyster production systems, a sensitivity index is created. Sensitivity indices (S.I.) are calculated to compare the responsiveness of a oyster aquaculture operations return on investment (internal reate of return) to changes in mortality (Table 3.4.1). The higher the sensitivity index, the more sensitive the aquaculture operation financial position is to a change in the change factor (seed cost, mortality, or growth rates).

The S.I. for mortality is defined as:

$$S.I. = \frac{\%\ \Delta\ IRR}{\%\ \Delta\ mortality}$$

All S.I.'s are calculated relative to the baseline levels of growout mortality and IRR.

Cage aquaculture

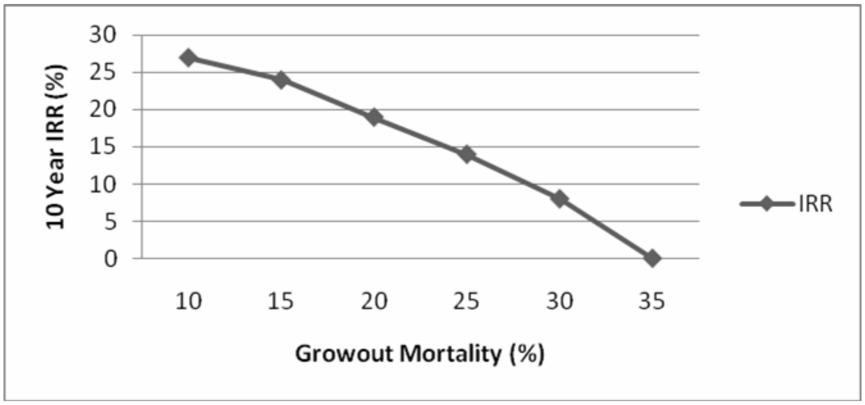
The baseline for the representative cage aquaculture investment assumes:

- 30% mortality rate
- A seed price of $7.00 per 1000.
- A wholesale halfshell market price of $0.28 and a wholesale shucked market price of $0.15.
- Other costs include labor, nursery, cage, marketing and overhead.
- The oyster growout time (from 0.5 to 3 inches) averages 14 months. The harvest distribution is 25% at 12 months, 50% at 14 months, and 25% at 16 months[17].

Varying the mortality rates from 10% to 35% caused the internal rate of return to vary from 27% to 0%. The internal rate of return declined at an increasing rate with increasing mortality (Figure 3.4.1.). S.I.'s vary from -3.6 to –6 indicating high responsiveness of IRR to reduced mortality [every 1% reduction in grow out mortality results in a 3.6 to 6% increase in rate of return (Table 3.4.1)].

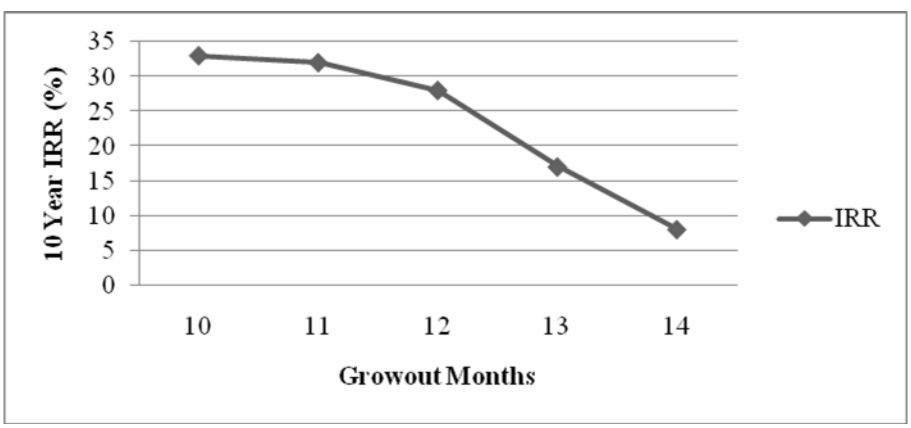
[17] Miller uses a 8-month overall range on growout (25% at 10 months, 50% at 14 months, and 25% at 18 months. We tighten the overall range to four months in order to be able to evaluate a wider range of scenarios.

Figure 3.4.1 Cage Aquaculture: IRR Response to Mortality Rate



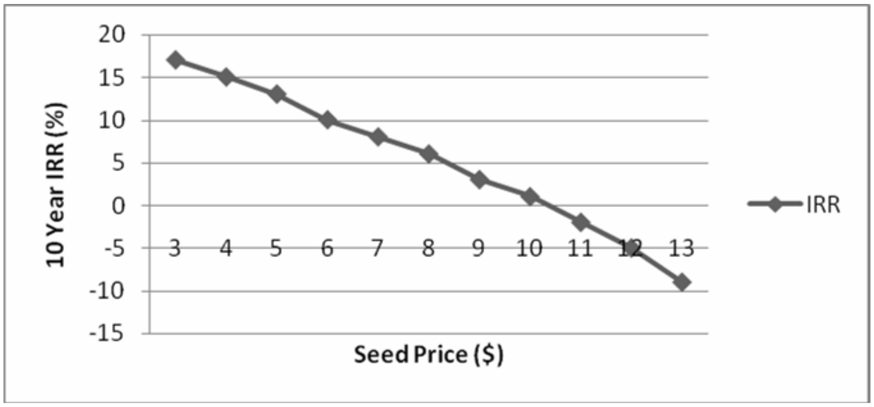
The average grow-out months ranged from 10 to 14 with a two month distribution (25% mature two months earlier and 25% two months later than the average time). The expected 10 year internal rate of return ranged from 33% to 8% over a four month range in average growout times (Figure 3.4.2). The S.I. for growout ranges from -10.8 to -17.5 indicating extremely high sensitivity of net returns to growout time (Table 3.4.1).

Figure 3.4.2 Cage Aquaculture: IRR Response to Increasing Grow-out Period



Varying oyster seed costs from $3.00 to $12.00 caused the estimated 10 year internal rate of return to range from 17% to -9%. A 15% drop in seed prices ($7.00 to $6.00 per 1000) would raise the IRR by three percentage points (from 6 to 9%) (Figure 3.4.3). IRR is sensitive to seed costs as indicated by S.I.'s greater than 2 (Table 3.4.1).

Figure 3.4.3 Cage Aquaculture: IRR Response to Increasing Seed Costs



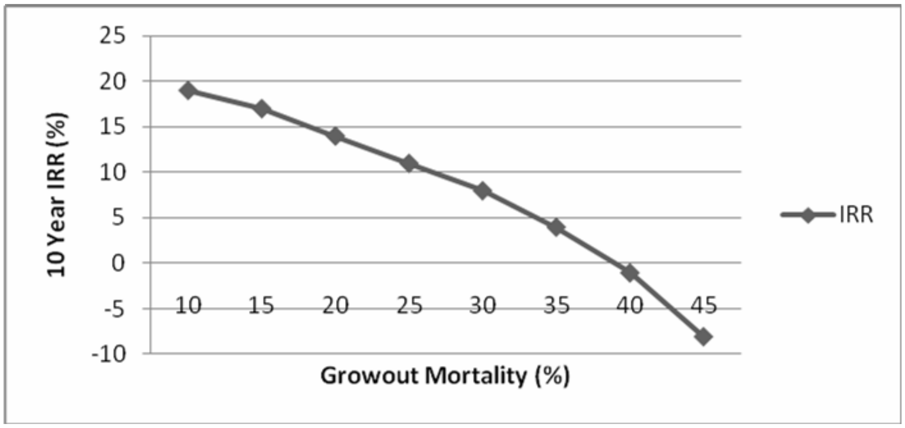
Float aquaculture

The baseline for the representative float aquaculture investment assumes:

- 25% mortality rate
- A seed price of $7.00 per 1000
- The wholesale halfshell market price per oyster of $0.38 and a wholesale market shucked price of $0.15. The wholesale halfshell price is higher for oyster from float aquaculture compared to cage aquaculture because the growers are participating in more direct marketing.
- The oyster growout time (from 0.5 to 3 inches) averaged 12 months with a distribution of 25% ready at 10 months, 50% at 12 months and 25% at 14 months.
- Other costs include labor, nursery, cage, marketing and overhead.

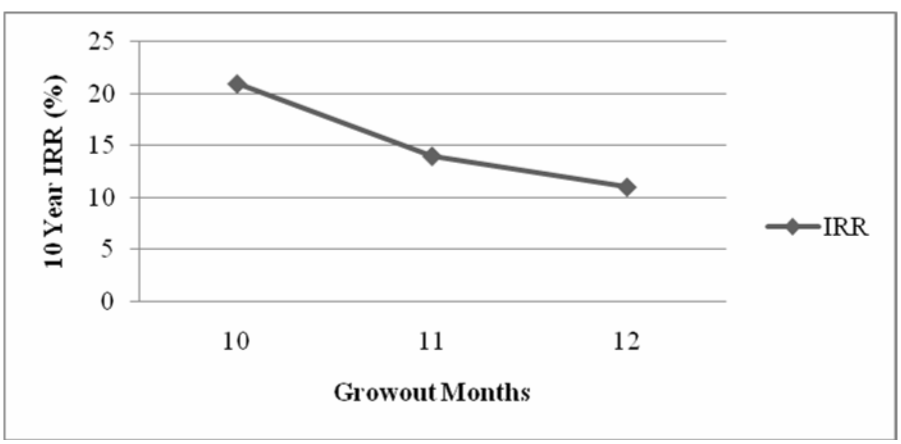
Mortality rates are varied from 10% to 45% in five-percent intervals. The estimated 10- year internal rate of return ranges from 19% to -8%. The IRR decreases at an increasing rate with increases in mortality (Figure 3.4.4).

Figure 3.4.4 Float Aquaculture: IRR Changes with Growout Mortality Rate



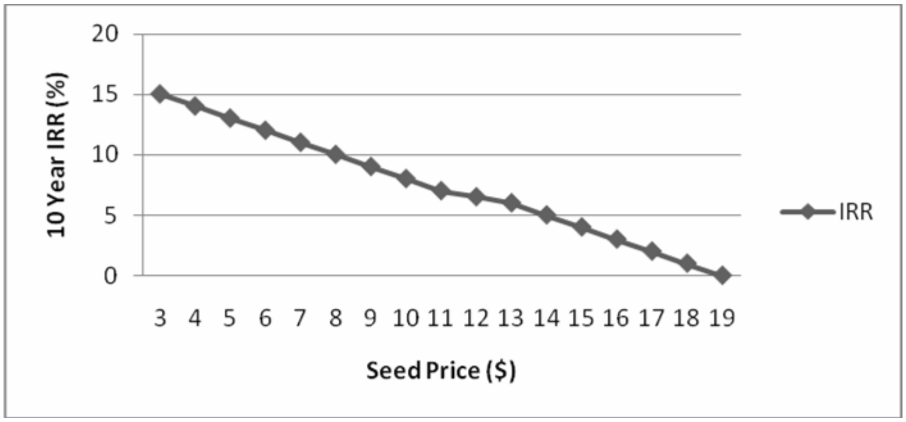
The average growout months vary from 10 to 12 months with a 2-month distribution (25% mature two months earlier than average and 25% two months later than average). The expected 10 year internal rate of return ranges from 21% to 11% over a two-month increase in the average growout period (Figure 3.4.5).

Figure 3.4.5 Float Aquaculture: IRR Changes with Growout Period



The expected 10-year internal rate of return varies from 15% to 0% as seed price increases from $3 to $19 per 1,000 (Figure 3.4.6). A one dollar drop in seed price increases the IRR by around 1%. IRR is less sensitive to seed costs compared to other parameters.

Figure 3.4.6 Float Aquaculture: IRR Changes with Cost of Oyster Seed



Discussion

Profitability of cage and float aquaculture is sensitive to reductions in growout period, mortality, and seed costs as indicated by S.I. values greater than 1 in most cases (Table 3.4.1). Both float and cage aquaculture are most responsive to reductions in growout period, followed by reductions in mortality, and seed price. Cage aquaculture is more responsive to changes in growth and seed parameters than is float aquaculture. These results provide strong confirming evidence of the high potential returns to the oyster industry from research that could reduce mortality and provide even modest improvements in oyster growth rates.

This analysis is short-run and does not consider any price responses to increasing oyster supplies. If research results were adopted widely in other areas beyond Virginia's coastal waters, oyster supplies might increase sufficiently that prices would fall and negate some of the benefits to producers of the increased production efficiency. However, consumers would still reap the benefits of increased oyster supplies.

Table 3.4.1 Average S.I. of IRR Related to Mortality, Growout Period, and Seed Price

	Mortality	Growout period	Seed price
Cage aquaculture:			
Range	3.6-6.0	10.9-17.5	1.8-5.1
Average	4.4	14.5	2.4
Float aquaculture:			
Range	1.2-2.2	3.3-5.5	0.6
Average	1.6	4.4	0.6

3.5. Policy Evaluation: Financial Incentives to Stimulate Commercial Production

In section 2.2.3, we outlined three different types of programs that could increase returns to commercial shellfish production in Virginia. One possibility would be a subsidy program that would either reduce the cost of inputs or make a direct payment based on production to each aquaculture grower. A second possibility would be a program that seeks to enhance the marketability of shellfish through branding or through the development of an industry ecolabel. Finally, a third as approach would be to pay aquaculture operations for providing water quality services. Our analysis initially abstracts from the means to increasing returns and instead asks a broader question: if short run output price were to increase (by whatever means), what might happen to shellfish production and long-run market prices?

We use information from the survey to provide insights about likely changes in quantities and prices from efforts to increase returns to shellfish production. We also illustrate a more sophisticated model of the oyster market which uses our survey results on oyster supply together with estimates from the literature on oyster demand in order to estimate market impacts from increased shellfish returns. This in-depth analysis focuses on oysters because the oyster aquaculture industry is still relatively small, while the clam industry has expanded under existing prices. In addition, oysters provide an additional benefit not provided by clams, namely water filtration, which might serve as the basis for supplemental payments to oyster aquaculture.

Clam industry

Survey respondents indicated willingness to expand production if prices increased (Table 3.1.25). Respondents representing 37% of capacity indicated that a $0.01 increase (8% of current average price) would be required to double output while respondents representing 17% of production indicated that increases of $0.03 to $0.20 per clam would be needed. Thirty-two percent of respondents who don't currently grow clams indicated they would enter production for prices increases ranging from $0.03 to $0.20 (Table 3.1.6).

Clam producers are less optimistic about effects on prices of expanding production. Producers representing 85% of production predicted price declines of $0.01 to $0.05 (8 to 38% of current average price) if output doubled (Table 3.1.26).

Oyster industry

Producer respondents representing the major share of current production indicated willingness to double production for $0.05 to $0.10 price increases (18 to 30 percent of the current $0.28 average price). Specifically 24% of active producers representing 47% of production indicated that they would double production with a $0.10 per oyster price increase, while 17% of active producers representing 29% of production indicated a $0.05 increase would be required (Table 3.1.4). In addition, 43% of respondents who do not currently grow oysters indicated a willingness to enter production for price increases of $0.05 to $0.10 above current levels (Table 3.1.27).

Growers are also optimistic that increased production would have a minimal impact on prices. Respondents representing 41% of oyster production indicated doubling output would have no impact on prices while respondents representing 30% of production indicated a $0.05 price decline (18% of current average price) (Table 3.1.5).

3.5.1. Economic and Environmental Impacts from Value-Added Activities

In this section we use the model of oyster supply and demand to simulate the economic and environmental impacts from a series of hypothetical programs that would seek to increase the value of Virginia's oysters. Much of our analysis is based on a model of the supply and demand for Virginia oysters that we developed by combining the results from our grower survey with a review of the literature on modeling oyster demand. A full description of that model is provided in appendix 2. Our analysis in this section takes a partial equilibrium perspective. We predict how various ways of transferring income to oyster growers would affect the market price of oysters, the number of aquaculture oysters raised, and the removal of nitrogen (N) and phosphorous (P) from Virginia's coastal waters.

We consider three types of programs that would increase returns to growers. One possibility would be a subsidy program to restore the oyster fishery. This would involve making a direct payment per/oyster to each aquaculture grower. A second possibility would be a program that seeks to enhance the marketability of oysters through branding or through the development of an industry ecolabel. Finally, a third way to transfer income to oyster growers would be to pay aquaculture operations for their removal of nitrogen (N) and phosphorous (P) from the Virginia's coastal waters especially the Chesapeake Bay and its estuaries. Since nutrients are the primary water quality management objective in the Chesapeake Bay, these services are called "payment for nutrient assimilation services" or PNAS.

Recall that questions #4 and #15 of the survey allow us to predict how growers would respond to a uniform increase in the price they received for oysters. We use this information to predict how a direct subsidy, branding and ecolabeling, or a PNAS program would affect the market price of oysters, the number of aquaculture oysters raised, and the removal of N and P from the Bay through biomass harvest and denitrification. There are two important sources of uncertainty that we address as part of our analysis. First, there is uncertainty in our estimates for how growers would respond to a future price increase. While some growers would be able to increase their production in the short run, others face significant non-price barriers to expanding their operations, including disease, landowner conflicts, and difficulty in obtaining seed. Uncertainty about the extent to which these non-price barriers will actually constrain growers is reflected in the bounds on the supply response depicted in Figure A.2.3.

The second important source of uncertainty in our analysis is the residual demand for Virginia oysters. Most of the growers who responded to our survey felt that doubling the Virginia's oyster production would have virtually no effect on prices. While no recent studies have been able to identify the demand for oysters econometrically, an earlier study by Shabman and Capps (1984) suggests a price flexibility of -0.11.[18] Since oyster harvests have crashed since their study period (1960-1980) it seems reasonable to treat the Shabman-Capps estimate for the price flexibility as an upper bound on the absolute magnitude of demand responsiveness. Therefore, we address uncertainty about the demand response to an increase in oyster production

[18] A "price flexibility" of -0.11 implies that a 1% increase in the quantity of oysters harvested would decrease prices by -0.11%.

by analyzing the sensitivity of our results to two extreme cases: a price flexibility of -0.11 and a price flexibility of 0.

We use the bounds on our supply and demand models to simulate the economic and environmental consequences from a series of hypothetical increases in the gross returns to oyster aquaculture—from 0.1 cents per oyster to 5 cents per oyster. The simulation process consists of three steps. First, for each of eight different increases in the rate of return, we simulate how the increase in gross returns would ultimately affect the market price of oysters and the total number of oysters produced in Virginia's coastal waters. Next, we use the filtration rates provided in Miller (2008) to convert our prediction for the total number of aquaculture oysters raised into an estimate for the pounds of N and P removed from the Bay on an annual basis (for a summary of the method, see discussion in section 3.5.2). Finally, we calculate the cumulative value of transfers made to growers. In the case of a PNAS program or a direct subsidy, this "value transfer" represents the amount of money paid to growers from public funds. It provides a lower bound on the cost of operating a payment-based program because it excludes administrative costs including any potential costs of verifying that oysters have actually been raised in aquaculture operations located on the Chesapeake Bay or other Virginia coastal waters. In the case of a program that uses branding or ecolabeling to increase the marketability of the Chesapeake oyster, the value transfers are best interpreted as the "gross value added" by the program. The value added is "gross" in the sense that it does not reflect the cost of obtaining certification or the cost of advertising and promoting a new brand or a new ecolabel.

Figure 3.5.1 provides a conceptual illustration of how we calculate the new market price and quantity in the extreme case where demand is perfectly elastic. Prior to the program, the average market price is p_0 and the total quantity produced is q_0. Introduction of a subsidy or

PNAS program in figure 3.5.1a drives a wedge between the (horizontal) demand curve and our estimated supply response, increasing the oyster harvest to q_1. The payment per oyster is defined by $p_1 - p_0$. Figure 3.5.1b illustrates how the same increases in price and quantity could stem from a branding or ecolabeling program that increases the demand for oysters. The point is that, if demand is perfectly elastic, branding, ecolabeling, direct subsidies to rebuild the fishery, and payments to growers for nutrient assimilation would all serve to increase the market price and quantity of oysters. Therefore, we can evaluate the economic and environmental implications of these increases without having to tie our calculations to one particular type of program. We proceed by using the model of oyster supply developed in Appendix 2 to calculate bounds on the new market price and quantity. These bounds are based on our estimates for upper and lower bounds on the supply response. The resulting quantities, filtration rates, and value transfers allow us to evaluate the sensitivity of our simulation results to the uncertainty in our estimates for the market supply. Table 3.5.1 summarizes our results.

Figure 3.5.1a: Calculating the Supply Response with Perfectly Elastic Demand (direct subsidy or payments for assimilation services)

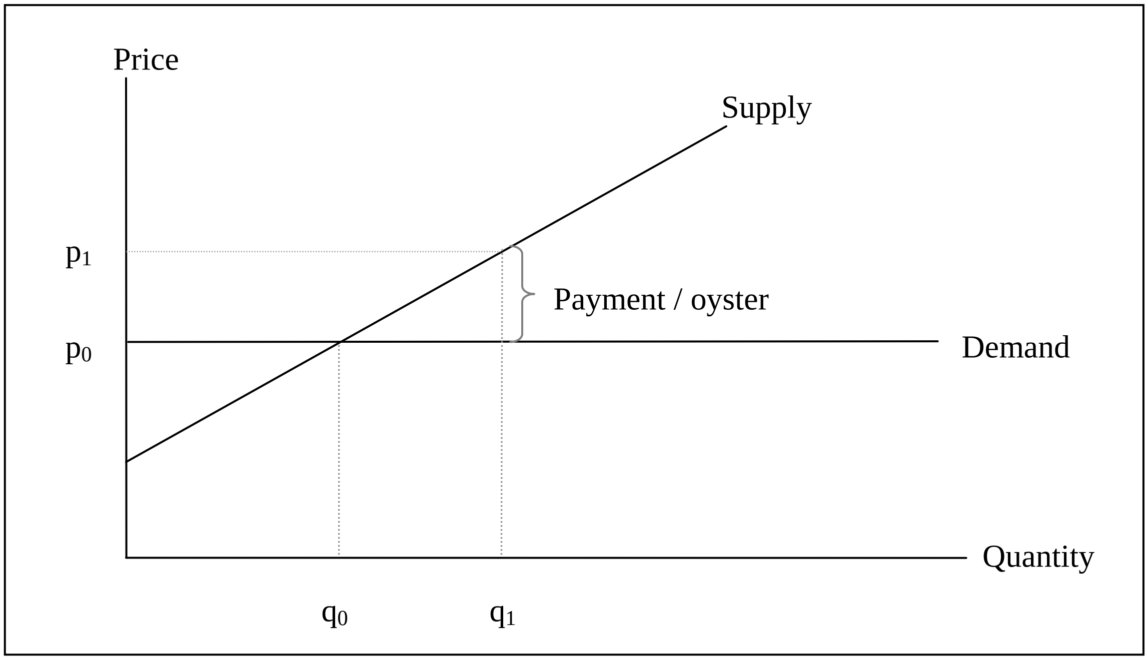


Figure 3.5.1b: Calculating the Supply Response with Perfectly Elastic Demand (branding or ecolabeling)

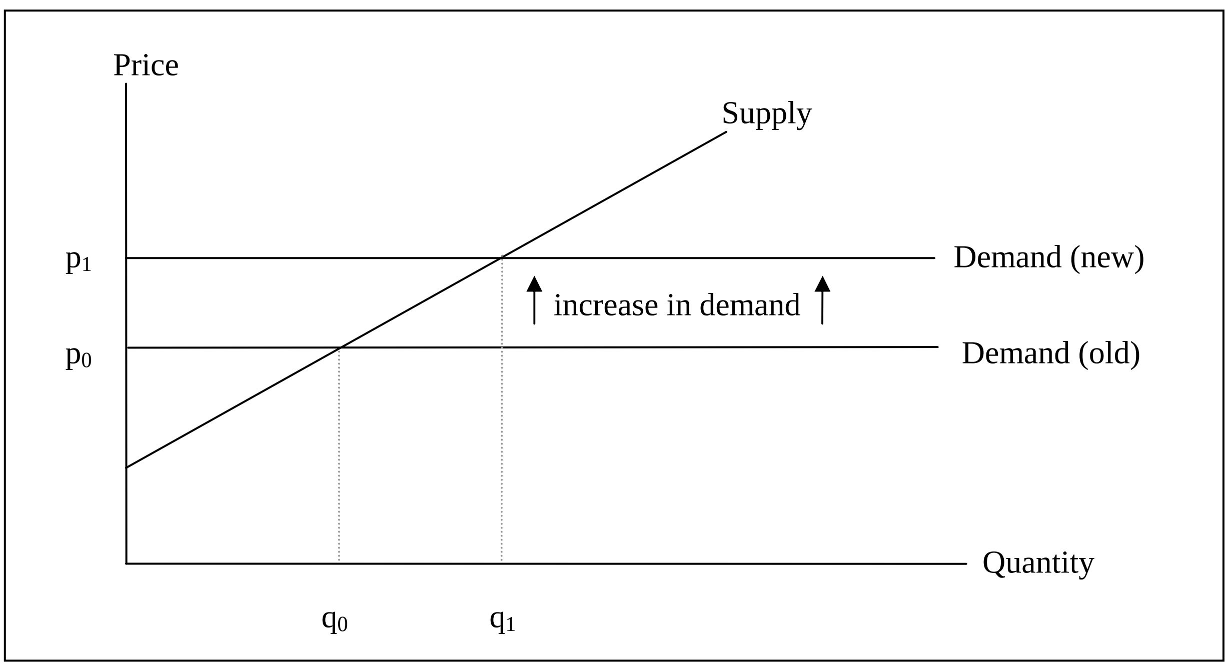


Table 3.5.1: Bounds on Production, Nutrient Assimilation, and Value Transfers in the case of Perfectly Elastic Demand

payment / oyster	price change		oysters (million)		N (1000 lbs)		P (1000 lbs)		Value ($1000)	
	min	max	min	max	min	max	min	max	min	max
0.0	0.0	0.0	16.2	16.2	8.6	8.6	0.66	0.66	0	0
0.1	0.1	0.1	16.4	16.4	8.7	8.7	0.67	0.67	16	16
0.5	0.5	0.5	17.2	17.2	9.1	9.1	0.71	0.71	86	86
1.0	1.0	1.0	18.2	18.2	9.6	9.6	0.75	0.75	182	182
2.0	2.0	2.0	19.9	20.3	10.5	10.7	0.82	0.83	398	405
3.0	3.0	3.0	21.6	22.3	11.4	11.8	0.88	0.91	648	669
4.0	4.0	4.0	23.3	24.3	12.3	12.8	0.95	1.00	931	973
5.0	5.0	5.0	25.0	26.4	13.2	13.9	1.02	1.08	1,248	1,318

Note: payments are expressed in cents/oyster.

The *max* and *min* scenarios in the table correspond to the simulation results based on our estimates for upper and lower bounds on the supply response (see Appendix 2 for additional detail). Since the demand curve in Figure 3.5.1 is horizontal, the value transfers are fully capitalized into the market price of oysters. That is, the price change equals the transfer rate. A transfer of 0.5 cents per oyster would increase the market supply by approximately 1 million oysters, filtering approximately 9.1 thousand pounds of N and 710 pounds of P every year. This would represent an increase of 500 pounds of N and 50 pounds of P from current levels. The cumulative value of transfers to the industry would be approximately $86,000. The increase in price is sufficiently small that our survey results indicate that all major growers would be able to increase their production as desired. This is why there is no difference between the *min* and *max* values for production, filtration, and program costs in the third row of the table.

As the transfer rate increases, the *min* and *max* estimates begin to diverge as non-price constraints prevent some growers from increasing their production as much as they would like. With a transfer rate of 5 cents, our results indicate that the market supply of oysters would rise between 42% and 46% above current levels. In this case, growers would filter between 13.2 and 13.9 thousand pounds of N annually, and between 1,020 and 1,080 pounds of P annually. The total value of transfers would lie between \$1.2 and \$1.3 million. However, these figures will overstate the actual increases in production, filtration, and returns to growers to the extent that the increase in production decreases the market price of oysters. As the oyster harvest increases, some growers may have to accept a lower price.

Figure 3.5.2a provides a conceptual illustration of how we simulate the change in total oyster production in the extreme case where the price flexibility of the demand for oysters is -0.11. As before, the value transfer drives a wedge between supply and demand, increasing oyster production to q_1. However, since the demand for oysters is downward sloping, the increase in production decreases the market price of oysters to p_2. This partially offsets the price increase received by growers. As a result, growers increase their production by less than in figure 3.5.1a. Figure 3.5.2b parallels figure 3.5.1b in demonstrating that the same changes in price and quantity could follow from an increase in demand due to ecolabeling or branding. The results from running simulations for these “less than perfectly elastic demand” scenarios are reported in table 3.5.2.

Overall, the pattern of results in table 3.5.2 is very similar to table 3.5.1. The main difference is that the increase in the market price of oysters ($p_1 - p_0$ in figure 3.5.2) is less than when the demand is perfectly elastic. For example, our simulation results indicate that a transfer rate of 3 cents per oyster would increase the market price by 2.2 cents. With a smaller net price increase, growers have less of an incentive to increase their production and the total number of oysters harvested, the total pounds of N and P filtered, and the total value of transfers to growers are all lower than in table 3.5.1.

Figure 3.5.2a: Calculating the Supply Response with Price Flexibility = -0.11 (direct subsidy or payments for assimilation)

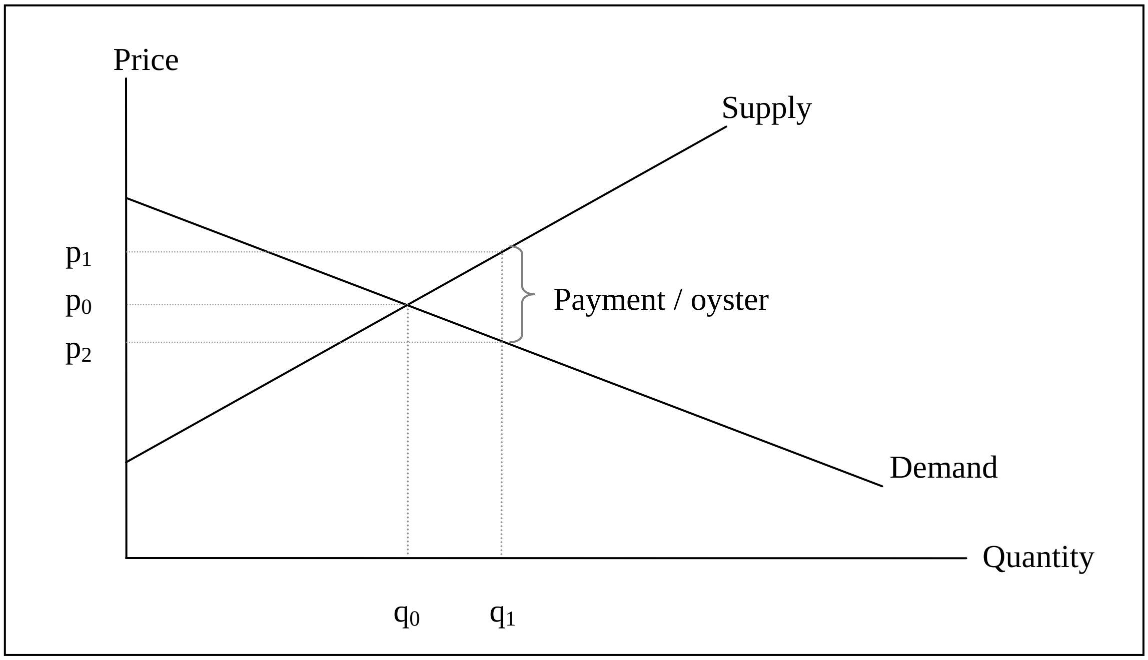


Figure 3.5.2b: Calculating the Supply Response with Price Flexibility = -0.11 (branding or ecolabeling)

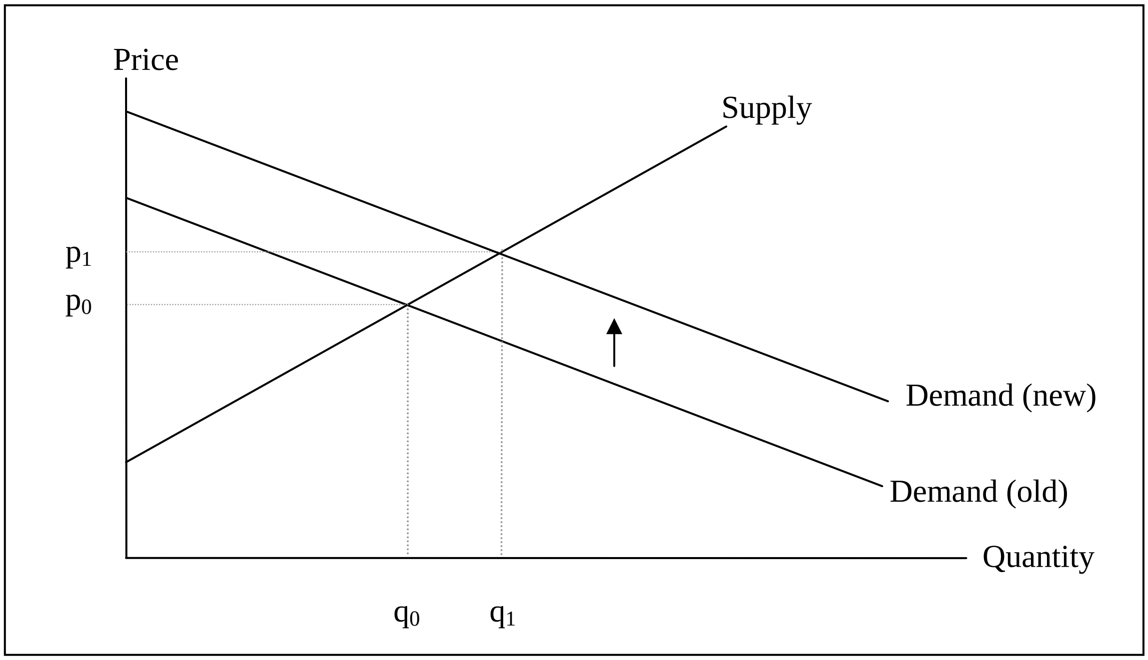


Table 3.5.2: Bounds on Production, Nutrient Assimilation, and Total Program Costs: Price Flexibility = -.11

payment / oyster	price change		oysters (million)		N (1000 lbs)		P (1000 lbs)		Value ($1000)	
	min	max	min	max	min	max	min	max	min	max
0.0	0.0	0.0	16.2	16.2	8.6	8.6	0.66	0.66	0	0
0.1	0.1	0.1	16.3	16.3	8.6	8.6	0.67	0.67	16	16
0.5	0.4	0.4	16.9	16.9	8.9	8.9	0.69	0.69	85	85
1.0	0.7	0.7	17.7	17.7	9.3	9.3	0.72	0.72	177	177
2.0	1.5	1.5	19.0	19.2	10.1	10.1	0.78	0.79	381	383
3.0	2.2	2.3	20.3	20.7	10.7	10.9	0.83	0.85	610	620
4.0	2.9	3.0	21.6	22.2	11.4	11.7	0.89	0.91	865	886
5.0	3.7	3.8	22.9	23.6	12.1	12.5	0.94	0.97	1,147	1,182

Table 3.5.3 combines the results from tables 3.5.1 and 3.5.2 to report bounds that reflect our uncertainty in both supply and demand. The lower bounds come from the *min* columns of table 3.5.2 and the upper bounds come from the *max* column of table 3.5.1. The range of estimates is remarkably narrow. This reflects the relatively small range of transfer rates we

consider. The survey results indicate that relatively few growers will face constraints to expanding their production in response to the relatively small price changes considered in our simulations. This can be seen by comparing the *min* and *max* columns within tables 3.5.1 and 3.5.2, or by observing that there is very little difference between the upper and lower bounds on the predicted supply response for price increases between 0 and 5 cents. Likewise, the Shabman-Capps estimate for the price flexibility implies a relatively small price response to the increases in oyster production predicted by our model. This can be seen by comparing the results from tables 3.5.1 and 3.5.2.

Table 3.5.3: Bounds on Production, Nutrient Assimilation, and Total Program Costs

payment / oyster	price change		oysters (million)		**N** (1000 lbs)		**P** (1000 lbs)		Value ($1000)	
	min	max	min	max	min	max	min	max	min	max
0.0	0.0	0.0	16.2	16.2	8.6	8.6	0.66	0.66	0	0
0.1	0.1	0.1	16.3	16.4	8.6	8.7	0.67	0.67	16	16
0.5	0.4	0.5	16.9	17.2	8.9	9.1	0.69	0.71	85	86
1.0	0.7	1.0	17.7	18.2	9.3	9.6	0.72	0.75	177	182
2.0	1.4	2.0	19.0	20.3	10.1	10.7	0.78	0.83	381	405
3.0	2.2	3.0	20.3	22.3	10.7	11.8	0.83	0.91	610	669
4.0	2.9	4.0	21.6	24.3	11.4	12.8	0.89	1.00	865	973
5.0	3.6	5.0	22.9	26.4	12.1	13.9	0.94	1.08	1,147	1,318

Finally, it is important to highlight two caveats to our final results in table 3.5.3. Most importantly, our analysis holds constant all other market forces that have the potential to affect oyster production and market prices. Extreme weather, changes in the number of oysters grown in other regions on the East Coast, health concerns, changes in consumer tastes, elimination of current barriers to expansion, and advances in research and development all have the potential to have dramatic impacts on the prices and quantities of oysters grown in the Bay. These impacts could dominate the changes in harvests reported in table 3.5.3 and alter the cost of operating a PNAS or direct subsidy program for oyster growers.

A second caveat is that our results in tables 3.5.1, 3.5.2, and 3.5.3 are based on new estimates for nutrient assimilation rates which are low compared to those reported in the published literature (Newell, 2004; Newell et al., 2005). Our assimilation rates are drawn from Miller (2008). He extends the existing literature by recognizing that oysters grown in floats and cages tend to have a higher meat-to-shell ratio than oysters grown on bottom. Since nutrient assimilation occurs partly through biomass accumulation in the oyster's shell, the recognition that aquaculture oysters are typically grown in floats and cages would be consistent with a lower rate of assimilation than reported in previous studies which have been based on oysters grown on the bottom. Nevertheless, the observation that Newell (2004) and Newell et al. (2005) report higher assimilation rates raises the possibility that our estimates for the amounts of N and P removed which are reported in tables 3.5.1, 3.5.2, and 3.5.3 may be conservatively low. That is, we may be understating the magnitude of nutrient assimilation services provided by commercial aquaculture.

3.5.2. Hypothetical payment for nutrient assimilation service

In this section we use a firm level bioeconomic simulation model constructed by Miller (2008) to estimate the total amount of N and P removed from Bay waters by a representative oyster aquaculture operation. Then we use these results together with the current implicit price of nutrient removal to calculate the payment rate for a hypothetical PNAS program that would compensate aquaculture operations for providing assimilation services.[19]

[19] For a further explanation of the technical background of the bioeconomic simulation process refer to Appendix 3

A firm level bioeconomic simulation model constructed by Miller (2008) was used to estimate the total amount N and P removed from Bay waters by an oyster aquaculture enterprise. The model estimates economic returns and nutrient removal by oysters, as well as the total costs, revenue and returns of both cage and float oyster aquaculture enterprises under operational conditions specified by the model user. The model simulates costs and revenues over a 10 year investment period and uses this information to estimate a rate of return on investment. Costs include operating and capital costs. Revenue comes from the sale of meat in both the half-shell and shucked market. If specified by the user, revenue can also include compensation from the removal of nitrogen and phosphorus provided by the oysters.

Estimates of the total annual mass load of phosphorus and nitrogen harvested in the oyster biomass were based on oyster aquaculture field trials conducted by Higgins and Brown (2008). Dry weight of sampled aquacultured oysters were 8.15% N and 0.82% P in the meat tissue and 0.22% N and 0.05% P in the shell. Based on sampled oysters, statistical equations were estimated that related oyster shell length to dry weight of oyster meat and shell. Multiplying nutrient percentage of tissue and shell by dry weight yields the total mass load of N and P contained in oyster biomass.

The total amount of nitrogen removed through denitrification was estimated based on the existing literature (Miller 2008). Jordan (1987) estimated the biodeposition rate (in dry weight) for *C. virginica* under a variety of temperature, seston levels, and animal sizes. Using average concentrations of total nitrogen in the biodeposits and average monthly water temperature measurements, the total monthly mass load of nitrogen being processed by oysters was estimated. A denitrification rate was then used to determine the total amount of N processed into N_2 gas through nitrification and denitrification. Newell et al. (2005) references literature that states 20% to 70% of nitrogen in marine ecosystems is released in the form of N_2 gas through the denitrification process. Within the simulation model, the percentage of TN denitrified can be changed to estimate nitrogen removed from Bay waters.

The bioeconomic simulation model was then used to estimate the total amount of nitrogen and phosphorus removed by an oyster aquaculture facility. In this illustration, an aquaculture cage operation is assumed to be capable of stocking 3,000,000 oysters. Growout time ranges between 10 to 18 months with an average of 14 months. Grow-out mortality is 30 percent. Under this situation, average annual harvest over 10 years is about 1,630,000. Assuming that 30% of the oyster biodeposits are eventually denitrified under the assumptions above, this operation removes an estimated 860 pounds of nitrogen a year though both biomass harvest and denitrification and 67 pounds of phosphorus through biomass harvest. This translates into about 528 pounds of N and 41 pounds of P for every 1,000,000 harvested oysters.

The value of this nutrient removal may be estimated by the cost of removing the same quantity of nutrients using the next best available technology. A variety of studies have estimated the cost to remove nutrients from point and nonpoint sources. The cost ranges from less than a dollar for some agricultural BMP practices to over $1000 per pound from urban stormwater BMPs (Aultman 2007). Under the Virginia point source trading program, DEQ has determined the cost of offsetting point source discharges with nonpoint sources to be $11.06/lb of nitrogen and $5.04/lb of phosphorus (9 VAC 25-829-10 et seq.).

If the oyster aquaculture operation received compensation for the N and P removal services at the price VDEQ is currently charging point sources for exceedences in their wasteload allocation, total average annual revenue for the aquaculture operation identified above would be approximately $9,800 per year or approximately 5 percent of total revenue. This translates into little more than ½ cent in additional revenue per oyster. While a relatively small share of total revenue, the simulation model estimates the additional revenue is sufficient to increase the rate of return on investment by 4 points (from 6% to 10% rate of return). These estimates assume no reduction in market price as growers expand production in response to increased payments per oyster. If market prices fall as a result of increased supplies, the revenue increases would be smaller. The results from our model of Virginia's oyster supply and demand indicate that a payment of ½ cent per oyster would increase production by between 0.7 million and 1 million oysters per year (Table 3.5.3).

4. CONCLUSIONS

Wild oyster and clam harvests have historically been important sources of revenue to Virginia watermen. Wild oyster and clam harvests are down sharply in both Virginia and Maryland portions of the Chesapeake Bay compared to historic peaks in the 1950's and 1960's. Causes of the decline include overharvesting, disease parasites like Dermo (*Perkinsus marinus*) and MSX (*Haplosporidium nelsoni)*, and predators such as cow nose rays. Today wild harvests from the Chesapeake Bay are a relatively small share of U.S. shellfish output, less than 1 percent of oysters and 3 percent of clams.

Diminished oyster and clam harvests pose a concern for commercial growers, watermen, and others who live and work in Bay area communities, which derive substantial income from oyster and clam harvests. Oysters also provide a number of ecological services including filtration of phytoplankton (and seston in general), which improves water clarity, and filtration of nitrogen and phosphorus, which may aid the growth of submerged aquatic vegetation (SAV) and increases habitat for other marine species. The filtration service provided by oysters provides an additional economic motive for state and federal policymakers to increase commercial oyster production.

The commercial oyster and clam aquaculture industries have arisen to restore part of the production shortfall from reduced wild harvests. In 2006, 194 million aquacultured clams were marketed in Virginia together with 3.2 million oysters (oyster harvests rose to 6.6 million in 2007) (Murray and Oesterling, 2008). Given the historic economic importance of oyster and clam production and environmental benefits of oysters, the state of Virginia seeks ways to assist oyster and clam production and faces important policy decisions on how best to accomplish this.

The objective of this report was to evaluate the economic implications of potential management strategies to expand or enhance clam and oyster production in Virginia.

We did not evaluate specific policy options being considered by the Virginia General Assembly, but focused on more general policy changes based on our conversations with policymakers and industry experts. We investigated three types of policy options: (1) proposals to redefine or clarify the current leasing system, (2) proposals to invest state funds in research and development for oyster and clam production, and (3) proposals to create direct economic incentives to boost commercial production. Policy options were evaluated based on results from a survey of oyster and clam producers, a general model of oyster supply and demand, which was specified in part with results from the survey, and information obtained from other sources including a bioeconomic model of oyster growth and mortality developed by Miller (2008). The survey was mailed to 150 growers and 65 responses obtained, which represent an estimated 95% of total production in Virginia.

Results are summarized under the three major policy classifications.

4.1. Redefinition and/or Clarification of Leasing Policy

Resurveying Baylor grounds

Will resurveying the Baylor grounds help to significantly expand aquaculture production in Virginia? Our interpretation of the results of the survey is a qualified "maybe." It does not appear that the availability of grounds is a major constraint for oyster production. This makes sense given how most oyster production is done in containers which do not require a large amount of grounds. Resurveying appears to have more potential to increase clam production. The availability of grounds appears to be a bigger issue for clam growers. Furthermore, it is the small producers (in terms of production) that appear most eager to use Baylor grounds. The magnitude of this expansion is however difficult to quantify.

Reforming the lease system

The current leasing system could be altered in an effort to more efficiently allocate subaqueous bottom for the purpose of aquaculture by strictly enforcing the "use it, or lose it" nature of the original law and by adjusting the rental price mechanism of the leases. Changing the lease system could potentially expand aquaculture production in Virginia by allowing current small growers to expand their operations. However, it appears that there are other factors that are more constraining than the availability of grounds at this time so it is unclear the magnitude of the expansion that would occur from reforming the lease system.

Shellfish enterprise zones

Shellfish enterprise zones can provide protection for oyster and clam growers by reducing uncertainty about water quality, regulatory pressure, and conflicts with waterfront property owners. A shellfish enterprise zone would provide legal protection for growers facing land use conflicts and also provide additional water quality regulations, which is currently one of the most important issues to both oyster and clam growers. However, the state should be aware that even though there are land use conflicts, survey respondents generally did not provide positive feedback to the idea of creating enterprise zones due to the presumption by the respondents that the establishment and use of the SEZ will mean new regulations and additional burdens on them.

Developing aquaculture "bill of rights" disclosure statements

An aquaculture "bill-of-rights" would address recent concerns about conflicts with waterfront property owners for growers who meet certain prescribed production standards. The aquaculture bill-of-rights would provide more security for growers and, as opposed to enterprise zones, do not have the perceived risk of additional regulations. One concern with an aquaculture bill of rights is that it may not provide the legal precedence growers would need if a land use conflict were taken to court. Maryland's aquaculture bill-of-rights is relatively new and has not been tested in a legal environment, suggesting a need for caution if Virginia were to develop such a document.

4.2. Investments in research and development for oyster production

Specific options included research to 1) reduce mortality, 2) reduce growout times, and 3) reduce the cost of seed. Evaluation of research options was based on a bioeconomic model of oyster production in cages and floats developed by Miller (2008). Investment in research is a promising way of assisting oyster aquaculture. In general, percentage improvements in each parameter would result in even greater percentage improvements in profitability of the oyster enterprise. The largest percentage increases in profitability come from reductions in growout period, followed by reductions in mortality, and seed costs, respectively. For example, the S.I. for cage aqaculture growout ranges from -10.9 to -15.8 indicating extermely high sensitivity of net returns to growout time. Cage aquaculture is also more responsive to changes in growth and seed parameters than is float aquaculture.

This analysis does not consider any price responses to increasing oyster supplies. If prices fall as a result of increased supplies, some benefits to producers would be negated, but consumers would still reap benefits of increased oyster supplies.

4.3. Direct Economic Incentives for Commercial Production

Analysis with the oyster supply and demand model shows that direct subsidies, ecolabeling, and payments to aquaculture operations for removal of nitrogen (N) and phosphorous (P) from Virginia's coastal waters have the potential to increase N and P filtration, oyster supplies, and growers' net revenues. Paying growers an equivalent rate to what Virginia Department of Environmental Quality (VDEQ) currently charges point sources for exceeding their wasteload allocations ($11.06/lb of nitrogen and $5.04/lb of phosphorus) would translate into a payment of approximately 0.5 cents per oyster. Assuming a horizontal demand price for oysters, this payment would increase oyster supplies by one million (7%) and N and P filtration by 500 and 42 pounds, respectively, both increases of about 7%. Total payments would be approximately $86,000 not including any administrative costs to establish contracts or verify production practices. A 0.5 cent payment to a representative oyster cage operation capable of stocking 3,000,000 oysters would increase average annual revenue by approximately $9,800 per year or 5 percent of total revenue. The additional revenue is sufficient to increase the rate of return on investment by 4 points (from 6% to 10% rate of return).

Increasing the payment rate to 5 cents would cause the estimated market supply of oysters to rise between 42% and 46% above current levels. In this case, aquacultured oysters would filter an estimated 13 to 14 thousand pounds of N annually (an annual increase of 4,600-5,300 lbs. of N and 360 to 420 lbs of P). The total cost of payments would lie between $1.2 and $1.3 million. Results are not greatly changed by assuming a downward sloping demand curve (price flexibility of -0.11) due to the small range of payment rates considered.

4.4. Future Research

It is clear that the nutrient assimilation services provided by commercial oyster aquaculture provides an economic rationale for public programs that would seek to rebuild and enhance the fishery. If we believe that at least some people who care about water quality in Virginia's coastal waters are uninformed about the assimilation services that oysters provide, market efficiency could be improved by developing an ecolabel that distinguishes Chesapeake aquaculture oysters from those harvested from the bottom and those grown in other regions of the country. Another policy option would be to compensate growers directly for the assimilation services they provide through a per/oyster payment or by establishing a nutrient trading program.

Which of these alternatives would do the most to rebuild the oyster fishery and increase nutrient assimilation? Would consumers be willing to pay more for oysters certified as sustainable by the Marine Stewardship Council? Would Virginians be willing to fund a "payments for nutrient assimilation services" program? If the Commonwealth had $1 million to spend on oysters, which approach would do the most to rebuild the fishery—an ecolabeling program, a payments-for-assimilation program, or some other approach? These are important questions for future research. Understanding the tradeoffs that Virginians are willing to make to help rebuild the oyster fishery and improve water quality is an essential step in developing efficient policies for aquaculture management.

APPENDIX 1: GROWER SURVEY AND COVER LETTER

March 17, 2008

Art Vandalay
Vandalay Industies

Dear Art,

We are writing to ask for your opinion on how the Commonwealth of Virginia and the National Oceanic and Atmospheric Administration (NOAA) can help to enhance the economic viability of oyster and clam fisheries in the Chesapeake Bay. Your responses to the attached aquaculture industry development survey will help guide future shellfish management and research decisions made by Virginia state agencies and NOAA.

This is a one-time follow-up to the annual *Virginia Institute of Marine Science* survey of shellfish aquaculture. The results from our survey will be aggregated and summarized in a report to the *Virginia Department of Environmental Quality*. In addition, *NOAA* will use your input to further develop private oyster aquaculture in this area. We would be happy to provide you with a copy of the report.

Please take a few minutes to complete the attached aquaculture industry development survey and return it in the enclosed self-addressed, stamped envelope. ***Your comments and any information about your individual operation will be kept strictly confidential.*** All responses from growers will be compiled, analyzed, and reported together. If you do not grow oysters or clams, please note this on the first page of the survey and return using the enclosed stamped envelope. Feel free to contact us with any questions or concerns. We value your feedback and look forward to hearing from you!

Best Regards,

Darrell Bosch
Professor
Virginia Tech
bosch@vt.edu

Michael J. Oesterling
Aquaculture Specialist
Virginia Institute of Marine Science
mike@vims.edu Tel: 804.684.7165

Kurt Stephenson
Associate Professor
Virginia Tech
kurts@vt.edu

Questions for Oyster Growers

(If you do not grow oysters, please skip to the clam grower section on page 4)

Part 1: What are the Barriers to Expanding Your Oyster Operation?

1. Which of the following factors constrain your ability to expand your **current oyster operations**? Place a 1 by the most important, a 2 by the second most important, and so on.

_____a) Availability / cost of seed
_____b) Availability of grounds
_____c) Lack of market / low price
_____d) Problems with predators (rays, crabs, etc.)
_____e) Problems with disease (MSX, dermo, etc)
_____f) Permitting issues / land use conflicts
Please list additional constraints you view as important or provide comments (use back of page if necessary)

2. If you were planning to expand your oyster production on a **new site**, what factors would be most important in determining whether you would lease that site? Place a 1 by the most important, a 2 by the second most important, and so on.

_____a) Convenient location (near my existing aquaculture operation or access or boat ramp)
_____b) Possible conflicts with waterfront property owners, recreational users, etc.
_____c) Potential disease and/or predator pressure on the site
_____d) Water quality (pollution from sedimentation, pesticides, etc.)
_____e) Physical characteristics (salinity, bottom condition, flushing rate, etc.)
Please list additional factors you view as important or provide comments

3. If you sell your oysters in the **half shell market**, what limits your expansion? Place a 1 by the most important constraint, a 2 by the second most important, and so on.

_____a) Can't produce more product on a consistent basis
_____b) Lack of time to expand market contacts
_____c) Lack of market potential for expansion
_____d) Not profitable to expand
_____e) Lack of capital
Please list below other constraints or comments on marketing oysters in half shell.

4. If you could contract to sell your oysters for a fixed price in the **half shell market**, how much of a *contract* price **increase** would it take for you to double your current output?

_____a) $0.01 (in addition to current price or contracted price)
_____b) $0.03
_____c) $0.05
_____d) $0.10
_____e) $0.15
_____f) $0.20
_____g) I wouldn't increase my output due to other constraints
_____h) Other (please specify) ____

5. In 2007, Virginia growers planned to sell approximately 6.5 million oysters. If Virginia producers were to **double** this quantity to 13 million, what do you think would happen to the price you receive per oyster?

_____a) No change in price
_____b) $0.01 drop in price
_____c) $0.03 drop in price
_____d) $0.05 drop in price
_____e) $0.10 drop in price
_____f) $0.15 drop in price
_____g) $0.20 drop in price
_____h) Other (please specify) ____

6. If you do not grow **clams** commercially now, what increase above current prices would it take for you to start growing them? (Clam growers reported average prices of $0.14 per clam in 2006).

_____a) $0.01 (increase above current prices)
_____b) $0.03
_____c) $0.05
_____d) $0.10
_____e) $0.15
_____f) $0.20
_____g) I wouldn't grow clams commercially due to other constraints
_____h) I am already growing clams commercially
_____i) Other (please specify) ____

Part 2: How Can We Enhance the Growth of Virginia Oyster Aquaculture?

7. How could state agencies and NOAA (a federal agency) best **assist** oyster growers? Place a 1 by the best assistance, a 2 by the second best, and so on.

_____a) Assist with marketing and the development of value added products
_____b) Assist in minimizing conflicts with surrounding landowners and recreational users
_____c) Fund research and demonstration projects targeting defined industry problems
_____d) Enforce 'proof of use' requirements to ensure that leased grounds are being used for oyster production
_____e) Assist with seed production by aiding the development of hatcheries
_____f) Support educational programs for technical training and extension programs
_____g) Protect and enhance water quality
List other state or NOAA assistance that would be important to you and provide comments.

8. What could state agencies and NOAA do to develop or support **seed/eyed larvae production** in your region? Place a 1 by the best assistance, a 2 by the second best, and so on.

_____a) Assist with training programs for hatchery managers and technicians
_____b) Provide support for long-term breeding and genetic research
_____c) Develop technology for solving hatchery problems
_____d) Support research for new production methods
_____e) Help provide greater access to triploid seed
_____f) Other (please specify)____

9. What could state agencies and NOAA do to provide support for **research and demonstration projects**? Place a 1 by the best assistance, a 2 by the second best, and so on.

_____a) Expand and enhance remote setting systems
_____b) Develop more effieicnt nursery systems
_____c) Develop methods for large-volume material handling
_____d) Support yield verification (field trials for genetic lines)
_____e) Develop new production methods and equipment
_____f) Other (please specify)____

10. What could state agencies and NOAA do to provide support in **providing educational programs**? Place a 1 by the best assistance, a 2 by the second best, and so on.

_____a) 4-H and Youth programs (including high school clubs, FFA, and others)
_____b) Vocational-technical school programs
_____c) Community college programs
_____d) Extension programs
_____f) Other (please
specify)____

11. What could state agencies do to improve the **current leasing system** in Virginia? Place a 1 by the best assistance, a 2 by the second best, and so on.

_____a) Enforce "proof of use" requirements on leased bottoms
_____b) Increase the lease price
_____c) Lower the lease price
_____d) Reduce the time and hassle of changing or acquiring leases
_____e) Open up the Baylor grounds for private leases
_____f) Other (please
specify)____

12. If some **Baylor grounds** were open for private use in your area, would you lease Baylor grounds to increase your oyster production?

_____a) Yes
_____b) No
_____c) Don't know

13. Would you support opening some **Baylor grounds** for private shellfish aquaculture at this time?

_____a) Yes
_____b) No
_____c) Don't know

14. Please use the space below to describe what state agencies and NOAA can do to ensure the economic viability of the aquaculture industry and assist oyster growers **that was not adequately addressed** in the previous questions.

Part 3: Your Commercial Oyster Production

15. Please indicate in the box below your oyster production and average market price for 2007 and an estimate for 2008.

2007		**2008 (Estimate)**	
Average price per market oyster	total # market (non-seed) sold	Average price per market oyster	total # market (non-seed) sold

16. What percent of your total oyster production was grown in containers last year?________%

17. What percentage of your production is typically sold on the half shell market?________%
If you do not sell on the half shell market at all, why not?

Questions for Clam Growers

(If you do not grow clams, please skip to the last page and indicate if you wish to receive a copy of the final report)

Part 4: How Can We Enhance the Growth of Virginia Clam Fisheries?

18. What are the greatest constraints on your ability to expand your **current clam operations**? Place a 1 by the most important, a 2 by the second most important, and so on.

_____a) Availability / cost of seed
_____b) Availability of grounds
_____c) Lack of market
_____d) Problems with predators (rays, crabs, etc.)
_____e) Problems with disease
_____f) Permitting issues / land use conflicts
_____g) Poor or uncertain water quality
Please list additional constraints you view as important and include comments (use back of page if necessary).

19. If you were looking to expand your clam production on a **new site**, what factors would be most important in determining whether you would be willing to lease that site? Place a 1 by the most important, a 2 by the second most important, and so on.

_____a) Convenient location (near my existing aquaculture operation or access or boat ramp)
_____b) Possible conflicts with waterfront property owners, recreational users, etc.
_____c) Potential disease and/or predator pressure on the site
_____d) Water quality (pollution from sedimentation, pesticides, etc.)
_____e) Physical characteristics (salinity, bottom condition, flush rate, etc.)
Please list additional factors you view as important and include comments.

20. Do you think changes to the **current leasing system** are needed?

_____yes
_____no
_____c) Don't know

21. What could state agencies do to improve the **current leasing system** in Virginia? Place a 1 by the best assistance, a 2 by the second best, and so on.

_____a) Enforce "proof of use" requirements on leased bottoms
_____b) Increase the lease price
_____c) Lower the lease price
_____d) Reduce the time and hassle of changing or acquiring leases
_____e) Open up the Baylor grounds for private leases
_____f) Other (please
specify)____

22. If some **Baylor grounds** were open for private use in your area, would you lease Baylor grounds to increase your clam production?

_____a) Yes
_____b) No
_____c) Don't know

23. Would you support opening some **Baylor grounds** for private shellfish aquaculture at this time?
_____a) Yes
_____b) No
_____c) Don't know

24. In your view, how could Virginia state agencies best **assist** clam growers? Place a 1 by the best assistance, a 2 by the second best, and so on.

_____a) Assistance with marketing and the development of value added products
_____b) Assist in minimizing conflicts with surrounding landowners and recreational users
_____c) Assist with research and demonstration projects
_____d) Enforce 'proof of use' requirements to ensure that private leased grounds are being used for clam production
_____e) Assist with seed production by hatcheries
_____f) Provide educational programs for developing the future industry
_____g) Protect water quality

List other state agency assistance to aquaculture that would be important to you and provide comments.

25. If you could contract to sell your clams for a fixed price, how much of a *contract* price **increase** would it take for you to double your current output?

_____a) $0.01 (in addition to current price or contracted price)
_____b) $0.03
_____c) $0.05
_____d) $0.10
_____e) $0.15
_____f) $0.20
_____g) I wouldn't increase my output due to other constraints
_____h) Other (please specify) ____

26. In 2006, Virginia growers sold approximately 200 million clams. If Virginia producers were to **double** this quantity to 400 million, what do you think would be the impact on the price you receive?

_____a) no change in price
_____b) $0.01 drop in price
_____c) $0.03 drop in price
_____d) $0.05 drop in price
_____e) $0.07 drop in price
_____f) $0.09 drop in price
_____g) $0.11 drop in price
_____h) Other (please specify) ____

27. If you do not currently grow **oysters** for the commercial market, what increase above current prices would it take for you to start producing oysters commercially? (Oyster growers reported average prices of $.30 per oyster in 2006).

_____a) $0.01 (increase above current prices)
_____b) $0.03
_____c) $0.05
_____d) $0.10
_____e) $0.15
_____f) $0.20
_____g) I wouldn't grow oysters commercially due to other constraints
_____h) I am already growing oysters commercially
_____i) Other (please specify) ____

Part 5: Your Commercial Clam Production

28. Please indicate in the box below your clam production and average market price for 2007 and an estimate for 2008.

Variety	2007		2008 (Estimate)	
	Average price / clam	Total # sold	Average price / clam	Total # sold
Smaller than 1 inch				
Larger than 1 inch				

_____ Yes, I would like to receive a free electronic copy of the final report on shellfish management alternatives in the Chesapeake Bay. My email address is___________________

Thank you for completing this survey!
Please send survey in the enclosed return envelope or return to:

Mike Oesterling
Virginia Institute of Marine Science
P.O. Box 1346
Gloucester Point, VA 23062

APPENDIX 2: ECONOMIC MODEL OF OYSTER SUPPLY AND DEMAND

Modeling the Supply of Virginia Oysters

Questions #4 and #15 of the survey allow us to estimate how growers would react to a uniform increase in the market price of oysters. After dropping data from survey respondents who did not answer both questions or were not currently growing oysters, we were left with 26 usable observations.[20] Table A.2.1 provides summary statistics for these growers (Question 15 of survey). Growers reported harvesting a total of 8.04 million oysters in 2007. This figure is 20% larger than the expected harvest of 6.59 million reported by VIMS (table 2.1.2). One possible explanation for the difference between these two figures is that using the Virginia Marine Resources Commission mailing list gave us access to some additional growers who were not included in the VIMS survey or who did not respond to the VIMS survey. Another possibility is that some growers had excessively pessimistic expectations when they completed the VIMS survey in early 2007.

Table A.2.1: Virginia's Commercial Oyster Production, 2007-2008

	year	min	max	mean	st. dev.	weighted average	sum
price ($/oyster)	2007	0.16	0.50	0.28	0.08	0.28	
	2008	0.16	0.50	0.29	0.08	0.27	
quantity (million)	2007	0.00	3.20	0.31	0.69		8.04
	2008	0.01	4.80	0.62	1.05		16.18

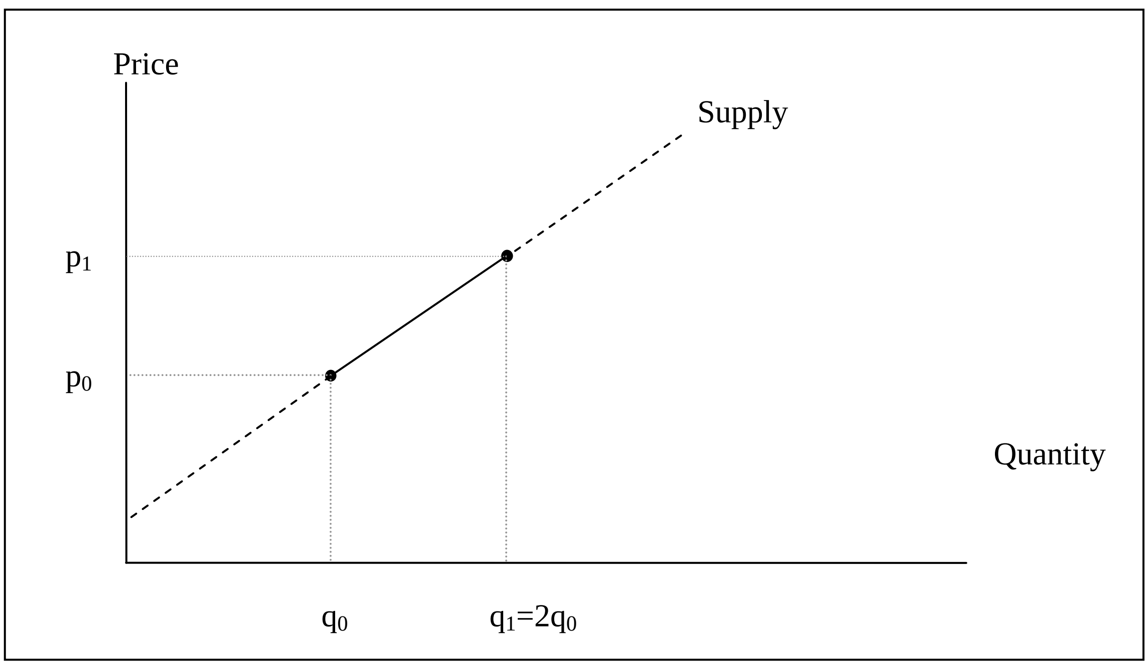
Note: this is the mean of 26 respondents to our survey who were producing oysters.

[20] This excluded two growers who reported their oyster production but did not say how they would respond to a uniform price increase. These two growers accounted for a combined total of 50,000 oysters in 2008. Excluding them will have a negligible effect on our results since 50,000 oysters is less than one half of one percent of Virginia production.

While the average oyster price was 28 cents in 2007, there is considerable variation across individual growers. Some received as much as 50 cents per oyster while others received as little as 16 cents. The most notable trend in the table is that growers expect their production to double in 2008. The increase is consistent with the increase in the number of oysters planted between 2005 and 2006 and between 2006 and 2007 (table 2.1.2).

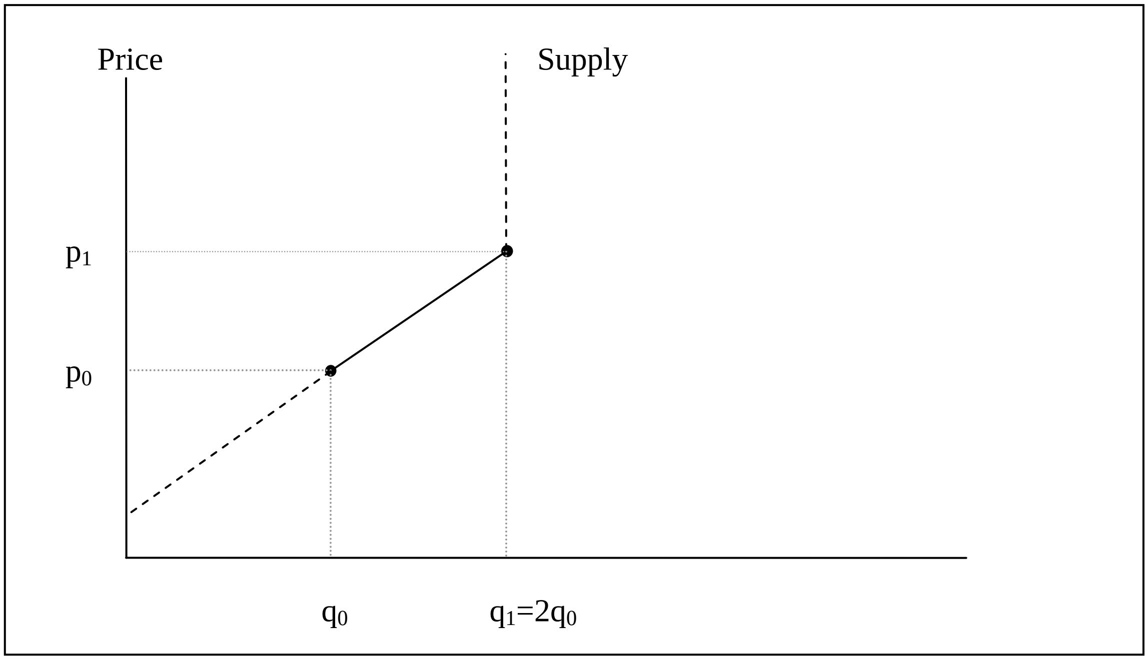
In question #4 each grower reported the price that would induce them to double their current production. For most growers, this price increase was between 5 and 10 cents. We used this information to calculate upper and lower bounds on the extent to which each grower would increase their production in response to an increase in the market price. Figure A.2.1 provides a conceptual illustration of how we calculated the upper bound supply response. The grower's current quantity and price are labeled as q_0 and p_0. The price that would induce them to double their production to $q_1 = 2q_0$ is labeled as p_1. We can use the two points (p_0, q_0) and (p_1, q_1) to take a linear approximation to a grower's supply curve.

Figure A.2.1: Upper Bound on the Grower's Supply Response



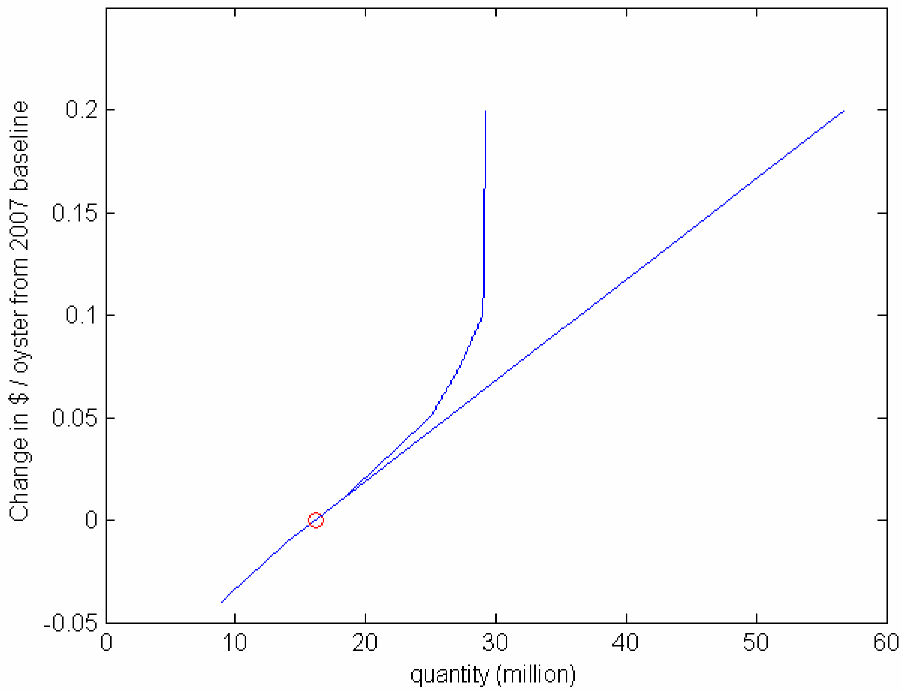
By simply "connecting the dots" in figure A.2.1 we assume that growers have a smooth supply response. This assumption becomes increasingly unrealistic as we continue to increase prices above p_1. Recall that many growers noted in their responses to survey question #1 that there are significant non-price barriers to increasing their production. The most frequently cited examples were disease, landowner conflicts, and the availability of seed. As prices rise above p_1, these constraints will eventually decrease the flexibility of supply, making the supply curve steeper. Therefore, the supply curve in figure A.2.1 should provide an upper bound on the quantity the grower would supply at prices above p_1. Figure A.2.2 illustrates the extreme case where the grower cannot increase their production above q_1, no matter how much price increases. This curve provides a lower bound on the grower's supply response. Together, figures A.2.1 and A.2.2 allows us to place conservative upper and lower bounds on the way we would expect the grower to adjust his production if price were to rise above p_1.

Figure A.2.2: Lower Bound on the Grower's Supply Response



In order to construct the market supply response for the Virginia oyster growing industry, we repeat the exercise in figures A.2.1 and A.2.2 for every grower and then aggregate the results. Figure A.2.3 displays the resulting market supply response curves. The vertical axis measures the increase in price relative to the baseline in 2007. For example, the current weighted average price of 28 cents/oyster would correspond to a price change of 0 on the vertical axis. At this price, growers expect to harvest 16.2 million oysters in 2008. The supply response branches at a quantity of 18.2 million oysters, which corresponds to a 1 cent increase in price. This is the smallest price increase at which some growers say they would be willing to double their production. To derive a lower bound on supply we assume these growers are supply constrained beyond this point, as illustrated in figure A.2.2. As more growers reach the production levels at which they would be constrained, they drive a wedge between the upper and lower bounds on the market supply response in figure A.2.3.

Figure A.2.3: Bounding the Market Supply Response for Virginia Oysters



Note: The lower line represents a scenario in which growers continue to linearly expand production with price increases. The upper line represents a scenario in which an individual grower's supply may become perfectly inelastic above some threshold due to non-price related constraints on their production.

The bounds on the supply response are fairly informative for price increases between 0 and 10 cents. This is the range in which most growers reported they would be willing to double their production. For example, if the price every grower received were to increase by 10 cents, Figure A.2.3 indicates that the Virginia oyster harvest would increase from 16.2 million to somewhere between 29 and 36.5 million oysters. For price increases above 10 cents, the bounds on the supply response are less informative. Another source of uncertainty about the supply response is that 12 clam growers who do not currently grow oysters responded to question #27 by saying that they would enter the market if the price per oyster were to rise above 35 cents. Therefore, the upper and lower bounds in figure A.2.3 may both be underestimates for price increases above 10 cents.

Modeling the Demand for Virginia Oysters

Due to time and budget limitations we were unable to conduct an original survey to estimate the market demand for oysters. Instead, we turn to previous studies to develop our model of the demand for oysters. Previous studies have focused primarily on the national demand. For example, Cheng and Capps (1988) estimate the U.S. retail demand for oysters, Lin and Milon (1993) estimate a double-hurdle model to study the impacts of health risk on oyster demand, and Muth et al. (2002) calibrate an interregional model of oyster demand. Since the Chesapeake Bay accounts for a miniscule share of national production, national studies seem likely to provide a poor approximation to the residual demand for Chesapeake oysters.

We are aware of only three studies which estimate the wholesale demand for oysters at the regional level. All three use NMFS time-series data to estimate the price flexibility of oyster demand: Shabman and Capps (1984), Keithly and Diop (2001), and Lipton et al. (2006).[21] Table A.2.2 summarizes the key features of these studies, and their results. Keithly and Diop estimate demand for the Gulf Coast. Since the Gulf Coast accounts for a large share of national production (table 2.1.1) we rule out using their results for the same reason we avoid using the results from the national studies. The Lipton et al. study also has limitations. It fails to address the classic simultaneous equations problem[22] and it uses time-series data from a 50-year period during which the industry underwent massive structural changes and the Chesapeake went from being the largest producing region in the nation to one of the smallest. These problems make it very difficult to give their estimates an economic interpretation.

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[21] The *price flexibility* is the percentage change in price associated with a 1% increase in the quantity demanded of a particular commodity. In theory, it provides a lower bound on the price elasticity of demand.

[22] The simultaneous equations problem refers to the fact that prices and quantities are generally jointly determined in a market equilibrium. Therefore, it is necessary to have some instrument to break the simultaneity in order to identify the demand or supply curve.

The study by Shabman and Capps acknowledges the basic simultaneous equations issue and uses data from a 20-year period (1960-1980) during which the quantities of oysters harvested from the Chesapeake Bay were fairly stable (table 2.1.1). Their estimated demand flexibility of -0.11 implies that a 1% increase in quantity would be accompanied by a -0.11% decrease in price. This estimate seems likely to provide an upper bound on the magnitude of the price responsiveness to changes in Chesapeake Bay production. This is because Chesapeake oyster populations have crashed since the end of the Shabman-Capps study in 1980.

In our survey, 66% of growers who collectively account for 90% of half-shell production answered question #5 by speculating that there would be no change in price if Virginia's oyster harvest were to double. This estimate seems reasonable. Doubling Virginia's production would not have a large impact on national production or on production along the east coast. Of course, for a sufficiently large increase in quantity, prices would eventually decline. Since quantities will not rise to their 1980 levels in the foreseeable future, it seems reasonable to model the demand for oysters using -0.11 and 0 as bounds on the price flexibility. Given the current market price, a price flexibility of -0.11 would imply that if quantity were to double, price would drop by around 5 cents.

Table A.2.2: Regional Studies of the Demand for Oysters

Study Characteristic	Keithly and Diop (2001)	Lipton et al (2006)	Shabman and Capps (1984)
Price flexibility	-0.43	-0.37	-0.11
Market	Gulf Coast	Chesapeake Bay	Chesapeake Bay
Data source	NMFS	NMFS	NMFS
Years	1981-1997	1950-2003	1960-1980
Temporal variation	quarterly	annual	annual
Econometric method	OLS	OLS	2SLS
Units	lbs meat (million)	lbs meat (million)	lbs meat (million)
Price	ex-vessel $/lb	ex-vessel $/lb	ex-vessel $/lb

APPENDIX 3: TECHNICAL PROCESS OF BIOECONOMIC SIMULATION MODEL

The bioeconomic simulation model estimates nutrient removal from ambient waters from two processes – oyster biomass harvest and chemical reduction through the denitrification of oyster biodeposits. The Eastern oyster, *C. virginica,* is an active filter-feeding bivalve that removes nitrogen bound seston particles—phytoplankton and sediments— from the ambient water column (Newell et al. 2005). Seston particulates enter the oyster gut where they undergo metabolic digestion (Newell et al. 2005). As compared to other bivalve suspension-feeders, such as the hard shell clam *M. mercenaria*, *C. virginica* is unusual in its ability to maintain a high filter-feeding rate for removing and processing seston particles even when seston densities exceed the oyster's nutritional needs (Newell et al. 2005). On average, oysters convert 20% to 90% of food taken into their system into useable material (Newell et al. 2005). Of the ingested material, oysters convert some N and P-embodied algal biomass through metabolic processing into tissue (meat) and a shell.

The remains of ingested particles that are digested are excreted as feces (Newell et al. 2005). Particles lacking nutritional quality or exceeding the capacity of the oyster's stomach are voided as a mucus-bound package known as "pseudofeces." Biodeposits (feces and pseudofeces) that contain organic and inorganic N travel to the benthos where they serve as fodder for microorganisms thriving throughout the aerobic sediment layer (Newell et al. 2005). When reaching the bottom, microorganisms begin a process of breaking down or decomposing portions of the organic N in biodeposits into a useable ammonium (NH_4^+) form needed for nitrification. Inorganic N does not undergo a transformation, as it is already in the ammonium NH_4^+ form. Under aerobic conditions, bacteria, *Nitrosomonas* and *Nitrobacter,* eventually break ammonium NH_4^+ into nitrites (NO_2^-) and nitrates (NO_3^-), the oxidized forms of nitrogen, through a process called nitrification (Novotny 2003). These two compounds, NO_2^- and NO_3^-, either make way into the anaerobic sediment below or are resuspended back into the water column above. A portion of NO_2^- and NO_3^- in the anaerobic sediments undergoes a denitrification process where NO_2^- and NO_3^- are converted into inert N_2 gas (biologically unavailable), which is released into the atmosphere (Newell et al. 2005). The percentage of N denitrified is dependent on biodiversity of the sediment as well as seasonal and physicochemical fluctuations such as temperature, benthic oxygen concentrations, and flow rates (Newell et al. 2005).

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