The Feasibility for Sustainable Provision of Hatchery Products for Oyster Aquaculture in the Chesapeake Bay

Prepared For

The Morgan State University Estuarine Research Center

Prepared By

Robert Wieland
Main Street Economics
P.O. Box 11
Trappe, MD 21673

October 10, 2007

Table of Contents

I. Introduction:

The goal of the research reported here was to examine the feasibility of a program to assist local watermen in producing oysters for harvest. The assistance envisioned is access to hatchery-produced seed oysters, and/or eyed larvae (for remote setting). The study does not address specific engineering questions associated with the hatchery production of seed oysters or larvae. Rather, it focuses on the commercial prospects of various types of oyster aquaculture and the consequent feasibility of sustained demand for oyster seed stock. The reasoning in this approach is that if people can make money producing oysters by one method or another, they will do so. If they cannot, then there will not be much demand for either seed oysters or eyed-larvae.

Spat-on-shell placed on the bottom without any containment is the aquaculture method that has been used for the longest time in the Bay. On leasehold ground in Virginia, this has entailed collecting seed oysters from public bars in the spring and placing these on the growers' leased bottom for later harvest. In Maryland, where private leases are much rarer, most of this collecting of seed oysters has been from protected State Seed Areas, and those collected seed oysters have then been put on public bars for local harvesters.

Since the mid 1960s, disease has decimated the Virginia leased bottom production (along with harvests from public bottom). Those disease pressures gradually worked their way up the Bay and private production in Maryland fell from a high of 80 thousand bushels in 1976 to 2.8 thousand bushels in 1989. It has since fallen to near zero.[1] Harvests from public bars also fell over this period. However, because there was considerable political momentum behind the public provision of seed oysters for public oyster bottom in Maryland, planting wild seed oysters on public bottom remained a large scale activity there until recent years. In recent years, seed oysters and shell with which to replenish State Seed Areas have been too rare to support continued planting of wild seed oysters[2].

While these outcomes were developing in the Bay, scientists and others have undertaken to improve the efficiency of hatchery produced, disease free oysters and larvae. In Virginia, where hatchery production has been supplied largely by private operations, there has been increased production of both larvae for remote setting and seed oysters set on micro-cultch. In Maryland, efforts to expand capacity for spat-on-shell and larvae for remote setting have been focused at the Horn Point Hatchery, a facility associated with the University of Maryland Center for Environmental Science (UMCES).

I discuss below the products produced by hatcheries in Maryland and Virginia and the ways in which oyster production is beginning to change in these two States. This discussion will start with descriptions of the various contained and on-bottom methods used in the Bay to grow oysters and estimates of the costs and returns to each. Following that discussion I describe current trends in Virginia and Maryland and discuss

---

[1] Unpublished MD DNR statistics.
[2] MD DNR Seed and Shell Reports, various years.

institutional and regulatory constraints to expanded aquaculture in Maryland. The paper then concludes with a summary and recommendations.

II. Methods and Costs of Contained and On-bottom Oyster Aquaculture

A. Contained Aquaculture

The contained aquaculture methods considered here include floats and cages on bottom. Both practices use spat set on micro-cultch as seed stock. Those spat may be regular Eastern Oysters (*Crassostrea virginica*) or a triploid version of that oyster. Triploids are created by breeding oysters that have been altered to have an abnormal number of chromosomes with normal oysters. This process creates an infertile oyster that grows much faster, in part because it does not put any energy into reproduction.

Both types of larvae and seed oysters can be purchased from private hatcheries in Virginia. Those hatcheries sell larvae and oysters set on micro-cultch. As discussed below, there has been a large increase in demand for hatchery product from growers in both Virginia and Maryland in recent years and there is uncertainty as to whether or not that hatchery supply will be adequate to expanding demand for hatchery products.

1. Material Costs

Wieland, forthcoming, reports enterprise budgets for float aquaculture and on-bottom cages and cost and returns information for spat-on-shell on bottom. Estimates from that report form the basis for the following description.

Regular (diploid) seed oysters in the range of 2 to 4 mm in size bought from Virginia hatcheries cost between $6.00 and $6.50 per thousand[3]. Triploid seed oysters carry a higher cost, between $7.00 and $7.50 per thousand. Producers estimate between 30 and 40 percent mortalities between the time seed oysters are purchased and market, so a producer wishing to produce around 1 million oysters would need to buy 1.5 million seed oysters.

At 2 to 4 mm, seed oysters are fragile and they require some nurserying before they are ready to place in either floats or cages. This nurserying requires a system that can keep predators at bay and provide food in sufficient quantities for rapid growth. Two different systems are used to do this. The most commonly used method is an "upweller" system. These are basically floating docks that contain several rows of tanks which are connected to a central cavity by means of a tube. These tanks have screened bottoms on which the small seed oysters are placed. Water, carrying food for the seed oysters, is caused to flow up through the screen by drawing water out of the central cavity. Floating upwellers cost anywhere from $3,500 to $7,500.

[3] Prices are nominal 2006 – 2007 prices reported by producers.

As they grow, the seed oysters are screened and separated so that their growth is not limited by the volume of the tanks. Some producers separate growing seed oysters by growth rates, others separate them randomly until their final sort. As the oysters approach a size that can be placed in cages, they must be separated by size to ensure that those that are not large enough to stay in their grow-out container remain in the upweller. A shaker table is useful in this context and those cost between $4,000 and $8,500.

Because it is costly to keep seed oysters in the upweller and because of the nature of their growth with respect to space, growers want to get new oysters out into cages as soon as possible. Generally, this implies moving seed oysters out of the upweller before they are large enough to be contained by the mesh of the cage or float bag. This was reported as being between 3 weeks to 3 months for triploid seed stock for cages on bottom and between one to four months for diploid seed stock for floats.

Under either method of final grow-out, growers use barriers of different mesh size to start the seed oysters in their cages or floats. On bottom cages are typically built of one inch wire mesh and range in size from 3' x 6' x 4" to 3' x 4' x 8". They may be single or double stacked. Some growers place new oysters in finer mesh bags in the cages while others simply line their cages with a smaller mesh material. Cages might be stocked with 3,000 small oysters at the start of their grow-out but at market size, the number of oysters per cage will be reduced to about 1,500.

Floats are made of 5" PVC tubing and tend to be 3'x 6'. Some growers place a single bag on each float, others put several smaller bags on a single float. Bags of different mesh sizes can be used, but the larger the mesh size, the less a problem is created by fouling. Bags are cleaned of fouling by turning them over occasionally (about once per month) and allowing the accumulated material to dry in the sun. A float bag for new seed oysters may be stocked with as many as 20,000 oysters but, by the time the oysters have reached market size, these will have been reduced to around 800 to 1000 per bag.

Taking 1 million as the number of anticipated market oysters and dividing this by the average number of market oysters contained in single cages or floats gives us the total number of cages or floats required. By this measure, it will require about 667 cages and 1,000 floats to grow one million oysters. At about $85/cage and between $40 and $65 per float, total containment equipment for 1 million oysters works out to $56,700 for cages and an average of $52,500 for floats. Producers note that because of the uneven growth rates, not all oysters will grow to market size at the same time. To the extent that the equipment estimate does not account this factor, it over-states containment costs.

An additional piece of equipment required for on-bottom cages is a boat with a gaff and winch to set and retrieve cages from the bottom. These attachments cost between $3,000 and $4,500.

Both floats and cages require lines and hardware that are estimated to cost between $2,407 and $4,364. A final piece of equipment useful for both float and on-bottom cages aquaculture is a sorting table with cleaning attachments. While sorting and cleaning can be done manually, a sorter can process a bushel of oysters in about one minute. Depending on the equipment, sorting tables cost around $8,000.

2. Labor Costs

It is difficult to estimate labor requirements for contained aquaculture from just a few observations. The approach taken here is to use estimates for starting stocks per container and final (market) oysters per container factored by the man hour labor requirements per container to develop a "per million oyster labor cost". Cages, which must be retrieved from a remote site, sorted, and then replaced at their remote site, are estimated to require 1.5 hours per cage to sort. This implies 333 cages times 1.5 hours for the first sort out of the upweller (500 hours), a second sort in which the 333 cages are expanded to 667 cages (750 hours) and a final harvest of 667 cages (1,000 hours) for a total labor requirement of 2,250 hours.

Floats, because they are typically located near the base of operations, take less time in per unit handling. Float sorting time is estimated, based on staffing and labor at one facility, at about ½ hour per float. But, because floats hold less stock than cages, more of them are required for the same number of market oysters. Using the same reasoning as above for the cages, if we start with 50 bags containing about 1 million seed oysters and expand these across six sorts to 1,000 floats with 1,000 oysters each, 1,780 hours are required for sorting and harvest. Adding an estimate of 300 hours over the growing season to tend against fouling generates a float labor estimate of 2,080 hours. To the extent that floats are ever distant from the base of operations, these labor estimates would understate labor requirements.

Labor requirements for both methods of contained oyster aquaculture are substantial. In terms of annualized expenses, labor is the largest cost of production. Moreover, labor requirements are variable over a growing season and across operations. All of the producers who provided information for this study either had hired labor or a partner or both. A conservative labor price of $8/hour is used here as a base price for hired labor. The estimates for labor requirements described above for both floats and cages form the basis for a "low-cost" labor price. Each estimate is doubled for a "high cost" labor estimate for each method. When a grower uses his or her own labor, it is be priced at this lower rate. Residual returns, after netting out material and labor costs would then be presumed to generate more satisfactory returns for the grower's labor and management.

3. Summary Cost Analysis for Floats and Cages

Table 1 gathers the cost estimates for on-bottom cages described above and reports these with estimated useful life for material and equipment. The resulting annualized cost of material and equipment, factored by the production time requirement, is then added with the other costs (labor and seed stock) to generate an estimated cost per million market oysters. Triploid oysters under either contained method are assumed to come to market size in 18 months. Diploid oysters are assumed to take 24 months to market. Thus, for any given cohort of 1 million oysters, annualized costs are carried out 1.5 years for triploid and 2 years for diploid seed stock. High-end equipment costs are paired with low-end labor costs, on the presumption that there is some capital-labor trade-off. Because labor costs are such a substantial part of total costs, total costs using low-end equipment costs are sometimes higher than total costs using high-end equipment costs.

Table 1: Estimated Production Costs for 1 Million Oysters in On-Bottom Cages

Item	Cost		Per Million Product
Triploid seed oysters (1.5 million)	11,250	--	11,250
Diploid seed oysters (1.5 million)	9,750	--	9,750
Labor (low: $8/hr * 2,250)	18,000		18,000
Labor (high: $8/hr * 4,500)	36,000		36,000
		Expected Life	**Annualized Cost**
Bags & barriers (low)	3,400	2 years	1,700
Bags & barriers (high)	6,630	4 years	1,657
Lines, buoys, anchors (low)	2,407	4 years	602
Lines, buoys, etc (high)	4,364	4 years	1,091
Gaff & winch (low)	3,000	5 years	600
Gaff & winch (high)	4,500	5 years	900
Cages (low)	41,625	6 years	6,938
Cages (high)	56,610	6 years	9,435
Floating upweller (low)	3,500	8 years	438
Floating upweller (high)	7,500	8 years	938
Shaker table (low)	4,000	10 years	400
Shaker table (high)	8,500	10 years	850
Sorter/cleaner (low)	0	--	0
Sorter/cleaner	8,000	10 years	800

Table 1 (Source: Project Data, Chesapeake Bay Oyster Company Farm Planner)

With the assumptions enumerated above, the cost estimates per million market oysters are as follows:

	Costs
Low-end (equip) triploid	$52,757
High-end (equip) triploid	$63,266
Low-end (equip) diploid	$59,092
High-end (equip) diploid	$67,105

The oysters that are produced in on-bottom cages are single oysters, shorter and deeper than wild oysters grown on bottom. They are harvested, often, at a smaller size than wild oysters and for these and other reasons, a bushel of market oysters is assumed to have 400 oysters[4]. A more common estimate for wild oysters in Maryland is 300 oysters per bushel[5]. Producers work a number of different markets in their retailing of aquaculture oysters and a range of prices are received. For this valuation we use a market price of $35/bushel. Thus, one million oysters would have a value of $87,500 and net returns would range between $20,400 and $34,743 for high-end diploid and low-end triploid respectively.

On bottom cages as estimated here clearly show scope for positive returns to capital and management.

Float aquaculture, using method-specific cost estimates for material and labor is reported in **Table 2**. Again, I pair high capital costs with low labor costs and vice versa.

<u>Table 2</u>: Estimated Production Costs for 1 Million Oysters in Floats

Item	Cost		Per Million Product
Triploid seed oysters (1.5 million)	11,250	--	11,250
Diploid seed oysters (1.5 million)	9,750	--	9,750
Labor (low: $8/hr * 2,080)	16,640		16,640
Labor (high: $8/hr * 4,160)	33,280		33,280
		Expected Life	**Annualized Cost**
Bags & barriers (low)	2,500	4 years	625
Bags & barriers (high)	2,500	2 years	1250
Lines, buoys, anchors (low)	2,407	4 years	602
Lines, buoys, etc (high)	4,364	4 years	1,091
Floats (low)	40,000	4 years	10,000
Floats (high)	65,000	4 years	16,250
Floating upweller (low)	3,500	8 years	438
Floating upweller (high)	7,500	8 years	938
Shaker table (low)	4,000	10 years	400
Shaker table (high)	8,500	10 years	850
Sorter/cleaner (low)	0	--	0
Sorter/cleaner	8,000	10 years	800

Table 2 (Source: Project Data)

The total cost estimate for a cohort of 1 million market oysters grown in floats is as follows:

	<u>Cost</u>
Low-end (equip) triploid	$62,628
High-end (equip) triploid	$59,659

[4] Additionally, on-bottom cage information is from Virginia, which has a somewhat larger bushel than Maryland.
[5] Wolman, 1990.

Low-end (equip) diploid	$67,160
High-end (equip) diploid	$68,748

Using the same estimates of 400 oysters per bushel and $35/bu, float aquaculture also appears to leave investors a return on their capital and management, though somewhat less than the expected returns for on-bottom cages. Returns are estimated between $18,750 for diploid (high-end) and $27,840 for high-end triploid oysters.

B. Spat-on-Shell on Bottom

As noted in the Introduction, the most common approach taken to oyster culture historically in the Chesapeake Bay has been spat-on-shell on the bottom. Traditionally, these were wild seed oysters collected from areas that had consistently good spat sets. In Virginia, holders of bottom leases would collect seed oysters from seed areas in the spring, place them on their leased bottom and harvest them after they had grown to a marketable size. This practice became impractical for Virginia's private producers in the mid 1960s, as disease reduced the availability of wild seed oysters and planted seed died of disease before growing to market size.

In Maryland, oyster production from leased bottom was never a significant share of the annual harvest. However, a similar practice was employed by state agencies, moving seed oysters from highly productive seed sites to areas where the oysters might grow to size more quickly. From the mid-1960s, Maryland DNR moved seed oysters around the Bay under its "oyster repletion program". While this practice was not bound by the need for a positive return, it too has diminished over the past five years due to the scarcity of seed oysters and a lack of shell with which to replenish seed area bars.

In its contemporary form, spat-on-shell on bottom uses hatchery produced larvae set on shells as a substitute for wild seed oysters. In Virginia, growers are encouraged to try these hatchery disease free spat-on-shell by subsidizing larvae sales and providing funding for some up-front setting costs. While that program is too new to submit to analysis, preliminary information[6] indicates that there is some potential for commercially remunerative production using triploid spat. Whether or not it will be sufficiently remunerative to encourage significant uptake among producers is not yet known.

In Maryland, the use of hatchery-produced seed oysters for on-bottom planting has grown larger than the repletion program that it replaces in terms of oyster planted. These oysters are placed in one of three different categories of sites. Sanctuaries are plantings that are intended to never be harvested. Harvest bars are the same as historical harvest bars. And a third and newer category of site is the managed reserve. Managed reserves are restricted in access such that most of the oysters on a site must be 4 inches or larger before being opened for harvest. Moreover, harvest is restricted to days appointed by the managers.

[6] Melissa Southworth and others, NOAA Chesapeake Bay Office Summer 2007 Quarterly Review of Non-Native Oyster Research

Managed reserves provide a useful test of the potential returns to spat-on-shell using hatchery produced disease-free oysters because there are good records of what has been planted on the sites over time and what has been harvested from them. It should be noted, however, that commercial sustainability is not necessarily the only goal for these managed reserves. Proponents of the method claim environmental benefits from the oyster populations while they are in the water growing and this program provides harvest for divers and shaft tongers who are desired harvester groups.

Maryland's oyster restoration efforts involving hatchery disease-free spat on shell is about seven years old. It is managed by the non-profit organization, Oyster Recovery Partnership (ORP). ORP has been planting seed oysters on sanctuaries, harvest bars and managed reserves since 2001. Some harvest reserves have been opened for harvests for the past three seasons.

The costs of producing oysters for market using spat-on-shell on bottom include:

1) site preparation (removal of any diseased oysters and placement of suitable substrate),
2) producing, transporting and planting spat-on-shell on the site, and
3) harvest costs

Site preparation and planting costs are reported for four different managed reserves in **Table 3.** Costs reported in Table 3 do not include transport costs or harvest costs.

<u>Table 3</u>: Production Costs for Spat-on-shell On Bottom

Planting Year	Managed Reserve	Shell (Bushels)	Shell Costs	Seed Oysters (million)	Seed Costs @$10k/mil.	Summed Shell & Seed
2001	Blunts	87863	$48,792	15	$150,000	$198,792
2002	Blunts	263516	$147,222	18.2	$182,000	$329,222
2003	Blunts	172962	$131,812	35.9	$359,000	$490,812
2001	Bolingbroke	57529	$31,351	15	$150,000	$181,351
2002	Bolingbroke	0		14.93	$149,300	$149,300
2003	Bolingbroke	116399	$88,706	41.2	$412,000	$500,706
2001	Emory Hollow			5	$50,000	$50,000
2002	Emory Hollow			0.653	$6,530	$6,530
2001	Broadneck			5.2	$52,000	$52,000

Table 3 (Sources: Shell Planting volumes and costs, DNR Seed and Shell Reports and ACOE data. Seed oysters and costs, ORP data)

Harvest costs, along with other price and harvest information are presented in **Table 4**. Harvest costs are estimated using actual time spent on site by harvesters times $8/hour. To that product is added a fixed cost for harvest equipment and fuel. Boat and gear costs specific to the two different gear types used at these managed reserves (i.e., divers and shaft tongers) are from Wieland, 2006. Shell costs are from MD DNR Seed and Shell Reports and ACOE (Baltimore) data. Seed production costs are unknown but ORP will provide 1 million spat to some organizations on payment of $10,000 and this figure is used here as a proxy for seed oyster production costs[7]. Harvest unit values are estimated at $30/bu.

Table 4: Production and Harvest Costs with Returns

Harvest Year	Managed Reserve	Production Costs	Harvest Costs	Gross Returns	Cost/Benefit Ratio
2005	Blunts	$198,792	$8,588	$46,719	4.44
2006	Blunts	$329,222	$7,967	$44,790	7.53
2007	Blunts	$490,812	$7,654	$38,490	12.95
2005	Bolingbroke	$181,351	$1,960	$9,585	19.12
2006	Bolingbroke	$149,300	$9,295	$32,078	4.94
2007	Bolingbroke	$500,706	$946	$510	983.63
2005	Emory Hollow	$50,000	$7,662	$29,175	1.98
2006	Emory Hollow	$6,530	$897	$615	12.08
2006	Broadneck	$52,000	$31,385	$53,730	1.55

Table 4 (Source: DNR, ORP and Wieland, 2006)

The final column in Table 4 measures the ratio of total costs to commercial returns from harvests. A number larger than one implies that costs exceed returns by that factor.

Spat-on-shell on bottom requires relatively less labor than the contained systems and it focuses this labor requirement in two relatively brief periods. Its principal drawback is that not a very large portion of what is originally put out is ever harvested. During the same growth phase that cultured seed oysters are being carefully nurseried under the two contained aquaculture approaches, they are washed overboard and deposited into an unprotected environment in the spat-on shell on bottom method. There is generally a large mortality soon after planting and then a more gradual rate of mortality over the three to five years that the oysters are left on the bottom. In addition to this mortality, at harvest, only some portion of the remaining oysters is actually retrieved from the bottom. Divers tend to clean a bar more completely and shaft tongs leave more oysters behind[8].

The spat-on-shell model as practiced in Maryland has been adaptive, changing as resources have expanded and as new techniques have come on line. Continued efficiency gains in setting and transporting seed oysters are likely and more cost effective means for preparing the bottom to receive seed oysters are possible. However, these gains will be

[7] Given the lower material and handling costs of seed oysters set on micro-cultch, the difference between the market price for single seed oysters ($6,000/million) and spat-on-shell ($10,000/million) does not seem large enough. It is used with this caveat.

[8] See Lenihan

muted by the large mortalities and inefficient harvest methods associated with Maryland's oyster restoration model, at least with respect to cost-recovery.

C. The Market for Hatchery Products

While hatcheries in Virginia supply the market in both Virginia and Maryland for triploid and diploid larvae for remote setting and seed oysters set on micro-cultch, this market has been turbulent in recent years. In Virginia, there has been a considerable increase in demand for larvae for remote setting, due to State programs aimed at encouraging growers to try this alternative to wild seed oysters for on-bottom, uncontained aquaculture. The short-term result of this increased demand has been shortages and disrupted supply for some producers. In the longer term, hatchery capacity is being expanded in Virginia, but it remains unclear whether this expanded capacity will keep pace with increased demand for hatchery products.

Virginia's experiment in public support for remote setting of spat-on-shell will help to determine whether or not Virginia's hatcheries keep pace with increasing demand for hatchery product. If growers find that they can profit from growing seed oysters that they set in their own setting tanks, demand for larvae can be expected to grow and hatcheries may not be able to keep up with both larvae and seed oyster demand. If growers find that mortalities and an inability to harvest a sufficient fraction of what they put out keeping them from earning sufficient returns, demand for larvae for remote setting will drop off.

With respect to seed oysters set on micro-cultch, there appears to be growing demand in Virginia for such seed stock and production capacity for these products have also expanded. Some Maryland growers produce their own larvae for setting on micro-cultch, but others must procure their seed stock from Virginia. Maryland does not have hatchery capacity or the institutional framework to regularly supply demand for seed oysters on micro-cultch.

With respect to spat-on-shell in Maryland, almost all the production of those hatchery products comes from Horn Point Hatchery (HPH). HPH has supplied spat-on-shell to several buyers at a price of $10,000 per million. However, most of their production is used by ORP on oyster restoration sites and harvest bars. Because HPH is a publicly-owned operation whose functional purpose is to satisfy demand from ORP, it is doubtful that it could, at the same time, fulfill a role as a supplier to private growers. Private growers in Maryland are, therefore, largely dependent on Virginia hatcheries.

Between the Potomac River and the Magothy River, an area that might be served by hatchery products produced under the project, there are about 263 active leases on about 2,000 acres of estuarine bottom. These leases can be transferred for a $5 fee to the State at the discretion of the current holders. This represents a significant share of the total leased bottom in the State.

III. Assessing the Findings for Oyster Aquaculture

A. Regulatory and Institutional Issues

Before considering the findings from the enterprise budgets with respect to the feasibility of providing hatchery product to growers/harvesters in a sustainable fashion, it is necessary to examine some regulatory and institutional issues that face oyster aquaculturalists in Maryland. These include some important factors that help to explain why private oyster aquaculture has not prospered in Maryland to date.

Maryland's Chesapeake Bay oyster bottom was surveyed in 1913 to delineate natural oyster bars from "barren bottom". Part of the objective of that effort was to identify potential resource for investors who wanted to grow oysters on leased bottom. The idea behind this was that existing public oyster bars would not be leased but barren bottom could be. Kennedy and Breisch, 1981, document the problems that ensued from this effort. After several rounds of legislative action in the early 1900s, Maryland's lease laws were undermined by severe limits on lease size (5 acres) and provisions that greatly weakened tenure on such leases (three witnesses claiming that they knew of oysters growing naturally on a leased site could undo the lease). More recently, since the 1960s, various counties in the State have banned or placed moratoria on new bottom leases in county waters[9].

While regulatory constraints have limited the development of Maryland's on-bottom aquaculture, I noted in the introduction that there was some private leasehold production in the state in the mid 1970s. MD DNR statistics show this private production falling to zero since then, as disease has spread through the Bay and devastated all oyster stocks. However, because of an abeyance on lease rents in recent years, many of the leases held in the 1990s are still effective, even if no production is currently being generated by them. Many of those leases are in the effective working range of Morgan State Estuarine Research Center. Moreover, leases are transferable.

Since the research supporting this study found several private producers whose combined product would form a significant share of a very bad harvest season such as 2004, zero measures for private oyster production must be viewed with caution. But, the private production examined in this study was from float aquaculture which does not require a bottom lease. Rather, most float aquaculture in Maryland's portion of the Bay utilizes a "water column" lease, which is associated with riparian rights and existing docks and piers.

With some claim to riparian rights, an applicant for a water column lease must apply for a joint federal/state tidal wetland permit with the Maryland Department of the Environment

[9] Fortunately for the project none of the counties near the Morgan State Estuarine Center have moratoria on bottom leases.

(MDE). This requires five copies of extensive documentation of the project and is circulated among the relevant agencies by MDE. The applicant will also have to obtain requisite County Planning and Zoning permits and to participate in public review of the project. Final approval of the wetlands permit requires the water quality certification. This requires extensive water testing and takes between 18 months and 3 years to complete.

There is no charge for filing the necessary applications for a water column lease, but, if awarded, these carry an annual fee of $80/acre and additional, one-time fees for the license can range from $250 to $1,000, depending on the size of the project. MDE bears the costs of water quality sampling and MD DNR will pay the publication charges for advertising a lease proposal. The considerable time required to meet the regulatory and permitting requirements for water column leases may limit investor interest in this approach. Additionally, charging 22 times the lease rent for a water column lease relative to a bottom lease (ignoring the abeyance) can be seen as a disincentive for investment.

B. Prospects for Sustainable Demand for Hatchery Products

A fundamental goal of the research undertaken for this report was to assess the feasibility of providing hatchery products for oyster production. In order to address this question in a comprehensive way, the project has considered three different oyster growing methods relevant to the contemporary Chesapeake Bay market. By the analysis applied, it has been shown that contained oyster aquaculture carries considerable promise for generating returns to capital and management, and thus might be a feasible source of demand for hatchery-produced larvae or seed stock over the longer term. Both contained systems enjoyed higher predicted returns using triploid seed stock, so it might be expected that demand for those will outpace demand for diploid seed stock.

While these findings are based on limited information analyzed under a number of simplifying assumptions, they have the desirable characteristic of tracking recent developments in the marketplace. A report on the shellfish aquaculture industry in Virginia (VIMS, 2007) shows seed oyster sales from hatcheries doubling from 2005 (20.4 million) to 2007 (41.2 million[10]). In that same report, oysters sold by aquaculturalists are shown to have risen at an even faster rate over the same period. While the increase in seed oysters sold can be attributed to aquaculturalists using a contained method, it is less clear where the additional market oysters from aquaculturalists are coming from. Those figures may include an increase in spat-on-shell production.

Maryland has less readily available information on its oyster aquaculture industry, but the two operations reviewed under this study had several years behind them and appeared to be earning a return for their owners or to be on track to do so. Given the regulatory and other obstacles to this investment, it is impressive that private growers have put their own capital at risk in these ways.

[10] 2007 is an estimate.

While Maryland's hatchery produced spat-on-shell efforts are shown to generate returns that are much lower than costs, other efforts with spat-on-shell appear to be generating different results. Recent efforts in Virginia have focused on encouraging private leaseholders to experiment with remote setting of larvae on shell as a source of seed stock for spat on shell. Those experiments have not yet generated a published report, but preliminary information indicates that triploid seed stock can bring positive returns to growers. Verification from the market that this is the case awaits a conclusion of the program; at which time, if this is a viable approach, producers will maintain it without the support of public subsidies for setting equipment.

Mike Congrove (VIMS, unpublished), has developed a spat-on-shell calculator based on Virginia data that predicts that, at survival rates of 12.5 percent coupled with harvest rates of 75 percent, a private return of 35 percent and better is possible. That rate compares favorably with the losses reported in **Table 4**. But it does not rise to the levels predicted for either on-bottom cages or triploid stock in floats.

In considering these three different methods of oyster aquaculture and their regulatory and institutional constraints, it is clear that there are political economy issues at play which will have a tremendous effect on prospects for sustainably supplying hatchery products.

Whether or not the public sector investments in put-and-take activities via public harvest bars and managed reserves will continue over time is an important political economy question. Under the examination of costs and returns to the various oyster grow out methods, diploid spat-on-shell on bottom is by far less remunerative than either of the two contained systems (using diploid oysters). Yet, if one ignores the costs of putting spat-on-shell seed oysters on the bottom, the returns to harvesters are greatest under that approach. The question is whether it is a good idea to ignore the costs of putting hatchery produced spat-on-shell on the bottom. Much of the funding for this effort has originated from the federal budget and it is not clear that this funding can be expected to flow in perpetuity.

While the option remains to harvest oysters placed on the bottom at no cost to harvesters, the contained oyster aquaculture methods will be relatively less attractive to those harvesters. If, on the other hand, those options become limited, there might be greater interest in either of the two contained grow out systems. Moreover, a shift in the use of restoration resources to encourage greater investment in contained aquaculture methods could generate greater interest in those systems. Examples of policies that might encourage greater investment in contained oyster aquaculture are discussed in the Summary and Recommendations section, below.

IV. Summary and Recommendations

The Chesapeake Bay oyster fishery is currently a small remnant of the historical fishery. By any measure, the public fishery has collapsed, reducing the possibility for watermen to make a living off of the oyster resource. Restoration efforts in Maryland, which have focused on replacing the wild seed oyster repletion program with a hatchery-produced seed program, have not generated sustainable benefits. In light of these factors, alternative approaches to producing oysters are getting closer attention.

This study has examined three different oyster production methods, including: cages on bottom, floats, and spat-on-shell on bottom. It has also looked at the impact of using triploid seed stock, as opposed to the more commonly used diploid seed stock. Cost and returns information for private producers were gathered using structured interviews with producers. These interviews included trips to the growing sites and first-hand observation of oyster growing methods.

Cost information on publicly-supported spat-on-shell on bottom activities were gleaned from ORP, DNR and ACOE data. Setting costs could not be ascertained with certainty, due to a lack of available information. In place of cost information, a "price" representing the dollar payment for which ORP/HPH will allow others access to 1 million seed oysters was used as a proxy for costs.

In analyzing these three different oyster production methods with respect to costs and returns, it was shown that the "contained systems" (i.e., cages and floats) showed some promise for providing returns to capital and management. Spat-on-shell on the bottom was shown to require ongoing infusions of funds for continued operation. Given these findings, it appears likely that oyster production in the Chesapeake Bay will increasingly come from growers who manage production privately or in groups.

While State and Federal restoration policies as currently constituted do not incorporate some of the information discussed in this report, these policies are currently under review and are likely to change. Given this uncertain medium-term policy framework, the only factors that can be brought to bear on the question of sustained demand for hatchery products are those relating to private costs of production and commercial returns from harvests. Considering production methods in terms of private costs and returns, harvests of oysters placed on the bottom by government and non-profit agencies brings the highest rate of return to harvesters. However, as noted throughout this document, it is not clear that those operations will continue indefinitely.

The second most remunerative method of growing oysters was by private production, using triploid seed stock grown in containers. Although cages on bottom generated somewhat higher returns than floats, both methods provided returns to capital and management. Contained aquaculture using diploid seed stock also generated a positive return, but somewhat less than those to triploid seed stock. The problem for cages in Maryland, however, is that there is no standard definition of this process incorporated into a general (on-bottom structures) permit. Therefore, obtaining all the required permits for this method may constitute a binding constraint on investment. However, these policies may change in the near future.

Demand for hatchery produced oyster seed stock is clearly rising robustly in Virginia. Much of the aquacultural production that generates this demand utilizes contained aquaculture systems, primarily on-bottom cages. Moreover, much of this production occurs in mesohaline reaches of Virginia's waters, at salinities similar to those found lower in Maryland's tributaries. Successful aquacultural production in Virginia might be expected to have a demonstration effect for potential aquaculturalists in Maryland.

The major Maryland supplier of hatchery produced oyster seed stock, HPH, has narrowed its focus to producing larvae for local setting on whole shell. With no other large-scale suppliers in the State, it is not clear that there will be sufficient availability of oyster seed stock set on micro-cultch for any nascent contained aquaculture industry. While some producers in Maryland have shown a capability to produce their own larvae for setting on micro-cultch, it is not likely that self-supply of seed stock will be widespread.

Given these findings, it is recommended that the project proceed in such a way as to encourage the methods that are most likely to succeed on commercial grounds. This will be fraught with difficulty, to the extent that many of the potential clients will object to such a policy for cultural reasons. However, in any industry faced with change, there are always innovators who are willing to try new ways to achieve their goals. By focusing on such individuals, a project to supply hatchery products to oyster growers could help to advance the process. In addition, support for producers using contained oyster growing systems might place Morgan State Estuarine Research Center in a better position to influence public oyster policy for the betterment of these innovative solutions.

If policy-makers consider the value of increased production from private operations, they may decide to utilize a greater portion of restoration resources to encourage this development. Examples of policies that might encourage greater investment in oyster aquaculture include:

1. Improved access to bottom leases throughout both State and County waters (i.e., removing moratoria on bottom leases, mapping available bottom for leases and marketing them, limiting the time and money costs of acquiring leases, among others),
2. Development of a general permit for on-bottom cages, reducing the time and money costs of achieving regulatory compliance for that grow-out method,
3. Develop a judicious use of restoration funding for both private and public agency costs associated with oyster aquaculture permitting and water quality certification,
4. Develop crop insurance for aquacultural output with a particular focus on disease losses,

5. Undertake greater extension and training in contained oyster aquaculture systems,
6. Ensure an enabling environment for branding and marketing aquaculture product, and
7. Improve the enforcement of oyster property rights by expanding policing and increasing the punishment for ignoring those rights.

Whether these or similar policy changes will be adopted in the near future cannot be known. However, the State of Maryland has convened an Oyster Advisory Commission and charged it with developing proposals to improve the sustainability of oyster restoration efforts in Maryland's portion of the Chesapeake Bay. A concern for sustainability in conjunction with information regarding costs and returns to the various oyster restoration practices to date might be expected to generate a change in policy. Whether such recommendations will then be supported by the State legislature is another question.

Literature Cited

Kennedy, V.S. and L.L.Breisch. 1981 Maryland's Oysters: Research and Management. Maryland Sea Grant Publication UM-SG-TS-81-04.

Lenihan, H.S. & C.H. Peterson. 2004. Conserving Oyster Reef Habitat by Switching from Dredging and Tonging to Diver-Harvesting. Fish. Bull. 102:298–305.

Maryland DNR. (various years) Shellfish Operations: Oyster Propagation Activities. Annapolis.

VIMS 2007 . Virginia Shellfish Aquaculture Situation and Outlook Report. VIMS Marine Resource Report 2007-2.

Wieland, R. 2006. Operating Costs in the Chesapeake Bay Oyster Fishery. NOAA Chesapeake Bay Office Non-Native Oyster Research Program Report.

________ forthcoming. Costs and Returns to Oyster Aquaculture in the Chesapeake Bay. NOAA Chesapeake Bay Office Non-Native Oyster Research Program Report.

Wolman, M.G. 1990. Recommendations of the Governor's Committee to Review State Policy for Funding Maryland's Chesapeake Fisheries - The Role of the State of Maryland in Oyster Fisheries Management. MD. Y3. Oy 98:2/W/990