A Framework for Native Oyster Aquaculture Development in Maryland

A report submitted to:

The Maryland Oyster Advisory Commission

The Keith Campbell Foundation for the Environment

and

The NOAA Chesapeake Bay Office

CRC Report Number 08-166

December 2008

Acknowledgments

This report was prepared by a steering committee comprised of Dr. Mark Luckenbach (Virginia Institute of Marine Science), Dr. Doug Lipton (University of Maryland, Sea Grant Extension Programs), Donald Webster (University of Maryland Cooperative Extension), Stephan Abel (Oyster Recovery Partnership), Tommy Zinn (Calvert County Waterman's Association), Tommy Leggett (Chesapeake Bay Foundation and private oyster aquaculturist), Dr. Edwin Rhodes (Phillips Seafood Co.) and Dr. Kevin Sellner (Chesapeake Research Consortium). Additional expertise was provided by participants at a workshop held on Kent Island on November 6 - 7, 2008. Presenters and participants at the workshop are listed in the Appendix.

Funding for this effort was provided by the Keith Campbell Foundation for the Environment (KCF) and the NOAA Chesapeake Bay Office (NCBO). We specifically thank Verna Harrison, Executive Director of the KCF and Peyton Robertson, Director of NCBO for their roles in identifying the need for such a plan and the input into the issues that needed to be addressed.

The Campbell Foundation

NOAA CHESAPEAKE BAY

Suggested Citation:
Luckenbach, M., D. Lipton, D. Webster, S. Abel, T. Zinn, T. Leggett, E. Rhodes, and K.G. Sellner. 2008. A Framework for Native Oyster Aquaculture Development in Maryland. CRC Publ. No. 08-166, Edgewater, MD. 38 pp.

A Framework for Native Oyster Aquaculture Development in Maryland

Purpose of the Plan

Maryland has a rich history of support for a public access fishery for oysters and other commercial species. In recent decades that fishery has declined dramatically due to stress from a variety of sources including the presence of two parasite-induced diseases. Along with this decline have come serious impacts on watermen and their communities which have depended upon the oyster harvest. Efforts to restore this public fishery have met with only limited success and, at best, will require long time periods of substantial investment of public funds. The Maryland Oyster Advisory Committee (MD OAC) has endorsed the development of private aquaculture of oysters to increase production and provide new opportunity for watermen.

The goal of this document is to provide a framework that helps chart a course for the development of a profitable, sustainable and environmentally-responsible, private oyster aquaculture industry in Maryland. Though the emphasis here is on private aquaculture, there are many components to this framework, including public sector involvement, which will directly impact both the short-term and long-term success of oyster aquaculture within the state. In this framework we outline important initial steps needed to enable and support the development of native oyster aquaculture in Maryland. These include recommendations for statutory and regulatory changes to support the development of private aquaculture. The plan also addresses the need for public support for research and development, training, and extension. It addresses the issue of seed production, the roles of public and private hatcheries, and the opportunities and limitations provided by commercial hatcheries in other states. This framework outlines strategies for cultivating oysters which draw upon lessons from oyster aquaculture elsewhere, with appropriate consideration of conditions in Maryland. An important goal of this effort is to provide potential oyster culturists with an economic tool to assist them in the planning and development of a viable oyster aquaculture business. Finally, as an important early step in charting this course, it includes recommendations for demonstration projects to provide “proof-of-concept” and training opportunities.

This report focuses on cultivation of the native oyster, *Crassostrea virginica*. In doing so, we do not make any prejudgments about the potential role of other oysters species, in particular *C. ariakensis* which is currently being considered for use in Chesapeake Bay. Rather, we recognize that aquaculture based on this non-native oyster species would face different sets of challenges, including different disease threats (such as, Bonamiosus), different environmental constraints (reduced tolerance of low dissolve oxygen, increased predator susceptibility, and reduced tolerance of aerial exposure), and different economic considerations (importation and quarantine of brood stock), which are beyond the scope of this document. Additionally, the regulatory framework required for the development of an industry based upon a non-native species is unclear at this point.

This framework is intended to (1) provide information to the MD OAC and through that body to the Secretary of Natural Resources, the Governor, and the General

Assembly about the needs for developing oyster aquaculture, (2) inform resource managers, the oyster industry, and the public about the opportunities for native oyster aquaculture, and (3) provide tools to help guide practitioners. It is not intended to supersede the efforts underway in various state agencies and the interagency Aquaculture Coordinating Council to promote the development of oyster aquaculture in Maryland. Rather it seeks to inform the MD OAC about those efforts while highlighting issues that have been important in the development of shellfish aquaculture industry in other regions.

The aquaculture industry that this framework seeks to develop is not intended to replace the public fishery, but to offer new opportunities. It stems from the recognition that aquaculture is well suited to take advantage of hatchery technology and selective breeding techniques to produce oysters in the changing conditions within Maryland tidal waters and that traditional watermen are well poised to benefit from this to enhance their businesses.

Approach to Developing the Framework

This framework is the collective effort of numerous individuals with a range of experience in oyster aquaculture, restoration, and ecology in Chesapeake Bay. A steering committee developed the overall structure of the framework with help from numerous experts inside and outside of the Chesapeake region. We then convened a two-day workshop on November 6 – 7, 2008 in Grasonville, MD with 37 attendees to provide a nationwide, broad perspective in further developing the plan. At this workshop, case studies of shellfish aquaculture development from other regions of the country were presented and important issues for oyster aquaculture development were discussed by the group. The steering committee then incorporated the findings from these discussions into the framework.

Background

Decline of the Wild Fishery

The decline of the oyster fishery in Chesapeake Bay and its causes have been well documented and discussed (Rothschild et al. 1994, Hargis and Haven 1999). Prominent among the causes have been overharvest, disease, habitat destruction, and poor water quality. Efforts to restore wild populations have met with some localized success, but have failed to achieve widespread enhancement of the fishery. There are critical lessons from these experiences for the development of oyster aquaculture in Maryland. First, there are multiple stressors acting on wild oyster populations that reduce the effectiveness of restoration efforts which focus on only one or a few of these stresses simultaneously. Aquaculture provides the opportunity for greater control over some of the stresses. Second, despite the need to identify specific local stresses on oyster populations, the pattern of dramatic decline in wild oyster populations has been observed worldwide for numerous oyster species (Beck et al. in review); concurrently, aquaculture has largely replaced wild-caught fisheries for oysters throughout the world.

Aquaculture Production

According to statistics provided by the Food and Agricultural Organization (FAO), 4.7 million tons of oysters valued at $3.2 billion were produced in aquaculture worldwide in 2006. U.S. oyster aquaculture production has grown steadily in recent decades (http://msstate.edu/dept/crec/aquashellfish.html). By region, U.S. oyster aquaculture production is dominated by the Pacific coast states where production in 2006 exceeded 94 million pounds at a value of over $84 million. These figures represent substantial growth over prior years, although we are reluctant to calculate the precise level of growth due to concerns about data quality[1]. Nevertheless, the existence of an industry of this magnitude exhibiting substantial growth clearly indicates that aquaculture of oysters, under the appropriate circumstances, can be a profitable enterprise. Recent successes in Virginia and Maryland have established the technical and biological feasibility of culturing native oysters in Chesapeake Bay, even in the face of the endemic oyster diseases. The objective of this report is to identify combinations of governmental actions, operational approaches, and economic circumstances for profitable oyster aquaculture in Maryland's portion of Chesapeake Bay and surrounding waters.

Selective Breeding and Disease Resistance
Following decades of active selective breeding, strains of *Crassostrea virginica* have been developed that exhibit resistance to MSX, tolerance to Dermo, and rapid growth rates (Burreson 1991, Ragone Calvo et al. 2003, Encomio et al. 2005). While the utility of these strains for restoration of wild populations remains uncertain, their value in aquaculture has been well established in recent years. By combining the use of these strains with appropriate site selection and growing techniques (Luckenbach et al. 1999), both commercial oyster growers and non-commercial oyster gardeners have repeatedly been successful in culturing oysters in disease-endemic areas throughout Chesapeake Bay over the past decade. Recently, the use of triploid oysters from these selected strains have produced higher yields and enhanced commercial success.

[1] The concern is that improved reporting results in higher numbers from year to year as opposed to actual growth in the industry.

Strategies for Culturing Oysters in Maryland

Developing strategies for oyster cultivation must begin with a clear understanding of current limitations on oyster growth and survival in various regions of the Bay and build on approaches that overcome these limitations. Two of the biggest challenges facing commercial production of wild oysters in Maryland are (1) disease mortality in high and mid salinity regions and (2) low recruitment in low salinity areas. While there may be multiple approaches towards overcoming these limitations, the use of hatchery technology to produce seed with desired characteristics (e.g., disease tolerance and rapid growth) or seed for areas with low recruitment is the common denominator among them. Though we do not presume to know all of the details of the approaches that will be used by successful oyster aquaculture ventures in Maryland—those will depend upon entrepreneurial innovation by the culturists—we outline three generic approaches towards culturing oysters below. In a later section, we provide case study output from a user-friendly economic tool that details costs and potential profits for these scenarios, as well as familiarizing the readers with the user-friendly tool which can be used to evaluate the economics of an oyster farm operation.

Spat-on-Shell, Bottom Oyster Cultivation
Approaches for setting hatchery-reared larvae onto oyster shells (termed *spat-on-shell*) and planting them onto appropriate bottom habitats for grow-out are well established (Jones and Jones 1988). Over the past 25 years, state-run hatcheries both in Maryland (University of Maryland's Horn Point Hatchery) and Virginia (the Virginia Institute of Marine Science's Gloucester Point) have developed these capabilities, refined their techniques, and demonstrated

the efficacy of this approach for growing oysters in some regions of the bay. In Maryland, spat-on-shell has been employed by the Oyster Recovery Partnership to establish sanctuaries, managed reserves, and harvest bars using oyster spat produced at the Horn Point Hatchery. These efforts have demonstrated the technical success of this approach in areas with low to moderate disease pressure, but privatization and commercialization of growing oysters in this manner has yet to be realized in Maryland, largely as a result of a number of regulatory and societal barriers addressed below. Within the past three years in Virginia, and over several years in other U.S. areas, public-private partnerships and private industry alone have begun to use this approach towards culturing oysters and the early indications are positive (see Box 1). The use of *triploid* oysters (that is, native oysters that have been produced to contain an extra set of chromosomes) is enhancing growth rate, permitting this approach to be successful even in areas with moderately high disease pressure.

This approach assumes that the small oysters experience high rates of mortality from predation, sedimentation, and physical damage, but that by planting spat-on-shell at sufficiently high densities, survival will be sufficient to support a profitable harvest by traditional gear. As noted above, recent improvements in survival and growth rates have been achieved through selective breeding and the use of triploids, making it possible to grow oysters with this approach in disease endemic areas. Threats from disease and predation by cownose rays may nevertheless limit the use of this technique in many high salinity regions.

Box 1. Spat-on-shell oyster cultivation in Virginia.

Spat-on-shell bottom cultivation of oysters has expanded significantly since 2006. In one effort, partially funded by the NOAA Chesapeake Bay Office, the Virginia Institute of Marine Science and the Virginia Marine Resources Commission partnered with private industry to test this form of oyster cultivation. Over 130 million spat-on-shell were planted at 22 sanctuary and public reefs and 9 private leases. Estimated survival from small spat to market size varied from 8 – 30% across the sites, with most of the mortality occurring shortly after planting from predation and overcrowding rather than disease. Michael Congrove, project manager for the effort, developed a bio-economics model for spat-on-shell cultivation from the results of this project which indicates that this form of cultivation can be profitable when survival rates from spat to market size exceed 10% (Congrove 2008).

Oyster spat attached to a shell prior to planting and a typical cluster of oysters harvested from the planting (photo by M. Congrove).

In a similar, though entirely private, effort Bevans Oyster Company and Cowart Seafood Corporation since 2006 have done bottom planting of spat-on-shell using selectively-bred, disease tolerant strains of triploid native oysters. Setting oysters at a target density of 20 spat/shell and planting at a density of 250-500 bushels/acre, oysters are taking about 18-24 months to reach market size at their grow-out sites. To date, they have experienced little disease mortality with this approach and A.J. Erskine, Aquaculture Manager for the joint venture, reports that predation and the limited availability of the selectively-bred, triploid larvae are the greatest impediments they face.

A critical feature for successful spat-on-shell cultivation of oysters is the selection of firm bottom, preferably with an underlying base of shell. The shells with oyster spat attached need to be planted on a base of shell (or other material) that will ensure they do not become buried in the sediment. Elevating this base above the surrounding sediments reduces mortality from siltation and enhances oyster growth rate. This is precisely the type of habitat that is provided by natural oyster bars and so the suggestion has been advanced in recent years in both Maryland and Virginia that unproductive public oyster bars be made available for private leasing and planting in this manner. This suggestion usually raises concern among wild harvesters about the loss of public fishing grounds. Alternatively, private industry can lease sedimentary bottom habitat (preferably sands rather than mud) and *prepare* the bottom by planting a base of clean shells prior the placement of spat-on-shell. This approach was employed for nearly a century in Virginia by private growers who planted wild seed on leased bottom, but is recently made more difficult by the reduced availability of oyster shell.

Finally, this approach is predicated on keeping production and harvest costs low. Because the oysters grow in clusters on the bottom, the assumption is that the majority of them will be more suited for the shucked market than the half-shell live market. This assumption is incorporated into the economic model for this type of oyster culture presented below, but it is possible that with improved handling techniques, the use of triploid oysters and brand marketing oysters grown in this manner could be marketed as more lucrative live product.

Intensive Oyster Cultivation - Bottom Cages

More intensive approaches to culturing oysters seek to reduce losses to predation by growing oysters in protective cages, either on the bottom or suspended in the water column (discussed below). These approaches are more labor and capital intensive and thus generally seek to produce oysters for the half-shell live market. Hatchery-reared oyster larvae are generally settled onto small shell fragments so that they grow as single oysters more suitable for the live market. Small juvenile oysters are then reared in land-based, flow-through seawater tanks or near-shore floating nursery systems until oysters grow to an appropriate size (approximately 1 inch) for planting in cages on or just above the bottom. The bottom cages are covered with mesh that is sufficiently small to exclude larger predators (e.g., blue crabs and cownose rays) but large enough to allow for adequate flow to support high oyster growth rates. The cages themselves can vary in dimensions, but are usually constructed to facilitate deployment and retrieval via a power winch aboard a vessel customized for this purpose (see Box 2).

The requirements for appropriate bottom habitat for this method of cultivating oysters are less restrictive than those for spat-on-shell cultivation. The bottom needs to be firm enough that the cages do not sink deeply into the sediment, but a base of exposed shell is not necessarily required. In fact, R. Rheault from Moonstone Oyster Farms in Rhode Island profitably grows oysters in bottom cages placed on fine, sulfidic mud, thereby minimizing user conflicts that occur with other bottom types. The efficacy of this approach and its limitations for culturing oysters in Maryland should be explored.

A significant limitation of this approach is the higher cost of production relative to more extensive bottom cultivation techniques and wild-capture fisheries. This

Box 2. Intensive Oyster Cultivation Using Bottom Cages in Virginia

In addition to spat-on-shell culture described in Box 1, Bevans Oyster Company and Cowart Seafood Corporation in Virginia are raising single oysters in cages on the bottom. They begin with selectively-bred, disease-tolerant, triploid native oyster larvae, settle them onto shell fragments, and then rear them in a floating upweller system (FLUPSY, see figure below) until they are about 1 inch in size. The FLUPSY can produce 10 – 12 million plantable oyster seed in a growing season.

Photo by A.J. Erskine

Oyster seed are placed into cages and deployed onto bottom leases using a power winch and customized vessel (see figure below). Two hundred cages are deployed per acre and tethered to surface buoys. The cages are retrieved periodically to spread the growing oysters into more bags. Harvest occurs between 12-24 months after removal from the upweller and the oysters are used both for the half-shell and shucked markets. According to Erskine, the operation is currently profitable, but given the high initial investment and ongoing operational costs, it will be important in the future to cut costs through achieving an economy of scale.

Photo by A.J. Erskine

challenge is most likely to be overcome through improvements in production practices, enhanced production efficiency through economies of scale, the production of a higher proportion of oysters for the live half-shell market, and product marketing. Additionally, the high initial capital costs associated with building nursery systems, bottom cages, and customizing a vessel will limit the accessibility of this approach to traditional oyster harvesters without access to sufficient capital resources.

Intensive Oyster Cultivation - Suspended Culture and Intertidal Rack and Bag Culture

This cultivation method is similar to the bottom cage approach described above with the exception that oysters are elevated in the water column, either in floats or fixed rack systems, to enhance growth rate. It is predicated on rapid growth to market size and, as such, is most applicable in high salinity, disease-endemic areas. These areas provide for rapid growth, but at the risk of disease mortality. Use of oysters selected for disease tolerance and rapid growth, together with good growing techniques, has been shown to be an effective strategy for culturing oysters in high salinity regions of the Bay (Luckenbach et al. 1999). Currently, these techniques are being employed by several small-scale commercial operations in the bay, including the Circle C Oyster Ranchers Association and Marinetics, Inc. in Maryland, and literally hundreds of non-commercial oyster gardeners. Recent increased use of triploid oysters in Virginia has increased yield (see example in Box 3).

Limitations of this technique include high initial capital costs, conflicts with other users of the water column, visual impacts, and the need for land access for near-shore operations. Additionally, the high cost of growing oysters in this manner dictates that

Box 3. Rack and Bag Oyster Culture

Tommy Leggett, owner of Chessie Seafood, is a former commercial waterman who now grows oysters in a *rack-and-bag* system similar to that used in France and elsewhere. Since 1995, he has run a one-man, part-time operation on the weekends, which has an annual production target of 50,000 oysters. Working on one acre of his 27 acre lease in the York River, Leggett grows single oysters for the half shell market. He purchases about 100,000 oyster seed annually from commercial hatcheries in Virginia, New York, and/or Maine and places them into mesh bags at an initial density of 1,000 oysters per bag, splitting them into more bags as they grow.

Photo by T. Leggett

Photo by Rosa Doughty

In the past, Leggett has been able to begin harvesting these oysters in one year and achieve a 50% yield from the crop before they reach two years old and disease becomes a problem. The loss of up to half of the oysters in a year's crop to predators and disease may seem high, but a 50% yield from seed to market is comparable that achieved by the very successful oyster culture industry in Washington state and the hard clam culture industry in Virginia. Over the past two years, however, he has been raising triploid native oysters and thus far seen faster growth rate and survival of over 90% of his oysters. He markets his oysters to local restaurants where he receives $0.35 a piece. Obtaining a consistent supply of high quality oyster seed has been one of his greatest challenges.

the oysters be marketed as a half-shell or other value-added product. An important lesson from successful oyster culture operations of this type in the U.S. is the need for brand-specific product marketing. The fact that individual, aquacultured *C. virginica* wholesale prices range from $0.20 to $0.75 apiece, depending upon where they are grown and where they are sold, makes the point that a good marketing strategy can do more to affect profitability than shaving a few cents off the production cost of an oyster grown in this manner.

Hatchery Capacity and Seed Production

Each of the approaches towards culturing oysters outlined above is dependent upon hatchery-produced seed. Though publicly-funded hatcheries can play a role in research and development and in demonstration projects, they cannot meet the needs of a private aquaculture industry for several reasons. If private oyster aquaculture is successful in Maryland, demand for seed will quickly exceed the capacity of a state-run hatchery. Moreover, as private hatcheries within the state begin to produce oyster seed, both for their own grow-out and for sale to other growers, state-run hatcheries pose undesired competition. Shellfish aquaculture industry experts at the workshop were unanimous in their advice that private hatcheries, driven by market demand, provide the best opportunity meeting the needs of a thriving oyster culture industry.

Current Hatchery Capacity
A current lack of a reliable supply of high quality oyster seed, especially selectively-bred, triploid oysters, is frequently cited by oyster aquaculturists in Virginia as a limiting factor; new growers in Maryland would face similar limitations. Currently, there is one private commercial oyster hatchery in Maryland that produces seed for its own vertically integrated operation and external sale to others. Three commercial hatcheries in Virginia currently produce seed from selected strains of native oysters; but only one of these produces seed for sale beyond their own use. At least two other private hatcheries are currently under construction in Virginia, but whether or not these companies will use the seed they produce exclusively to meet their own grow-out needs or sell seed to others is currently unknown. Numerous commercial shellfish hatcheries are in operation in other states along the U.S. Atlantic coast (see http://www.ecsga.org/libraryitems/hatcheries.htm for a current listing). Sixteen of these hatcheries currently report that they produce oyster seed. A few of these hatcheries have worked with growers from the Chesapeake Bay region to produce seed from stocks selected for growing in disease endemic areas. As demand for oyster seed from Maryland increases, this capacity among out-of-state hatcheries could increase. However, it appears evident that the development of a robust oyster aquaculture industry in Maryland will be dependent upon expanded commercial hatchery capacity within the Chesapeake Bay region, if not within Maryland itself.

Limitations to and Incentives for Increased Hatchery Capacity
The high capital costs, technical training, and relatively long spin-up time required for successful hatchery production pose significant impediments to the development of new hatcheries within the region. Facilitating the expansion of private oyster hatcheries in Maryland will require a clear, consistent, and manageable regulatory framework, including discharge permits, zoning requirements, and the like. Additionally, the state should consider financial incentive programs, including low interest or state-backed loans and tax incentives. The state of Maine has a Seed Grant Program, providing $12,500 in renewable start-up funds that has been successful in assisting start-up hatcheries. Federal programs are also in place to assist this capacity-building, through NOAA (e.g., Fishery Finance Program) and USDA. Perhaps the most cost effective approach is for the state to purchase some of its oyster seed for restoration from private hatcheries. This approach would help to ensure that an entrepreneur who invests in developing a hatchery will have an initial market for seed or larvae.

Paths to Profitability – An Economic Analysis Tool for Oyster Aquaculture

For oyster aquaculture in Maryland to be economically viable, it will have to provide a competitive return on investment and compensate factors of production at their opportunity cost. For example, a waterman's time devoted to an oyster aquaculture operation should be compensated at a level at least equal to what he could earn if that time were spent fishing or another alternative form of employment. If it is clear that oyster aquaculture in Maryland can be profitable, and a regulatory framework is in place to allow for that production, it is likely that a substantial oyster aquaculture industry will develop within the state.

Aquaculture production takes place in a world of uncertainty and variability. Often the difference between financial success and failure is the ability of the aquaculture manager to incorporate this knowledge of uncertainty and variability into management decisions. This is particularly important in the adoption of a relatively new technology where there is limited experience and performance parameters are often based on laboratory experiments or pilot systems that may vary considerably from commercial applications. Even with a substantial aquaculture industry to draw information from, production cost and return data are not readily available, and even when they are, there is uncertainty in applying them to growth conditions in Maryland's portion of Chesapeake Bay.

Accounting for the above, we need a flexible tool to analyze a variety of oyster aquaculture production systems and accommodate the uncertainty around our knowledge of growth, survival, input costs, and output prices. Aquasim is a Monte Carlo-based financial simulator that has been used for evaluating the economic potential of other species such as hybrid striped bass (Lipton and Gempesaw 1997; Gempesaw et al. 1996) and offshore aquaculture in Korea (Lipton and Kim 2007). The key elements needed to apply Aquasim to oyster aquaculture in Maryland are an understanding of the production model used by culturists, the biologically-relevant input values (growth and mortality), input values for production costs, and prices received for products (shucked meats and live, half-shell oysters).

There is obviously little direct information available from an oyster aquaculture industry in Maryland available to parameterize the economic model, so we gathered information from participants at the November workshop. The participants included individuals with experience in the commercial aquaculture of oysters and other shellfish from around the U.S.: the Pacific Northwest, the Gulf coast, New England, and the mid-Atlantic region, including commercial shellfish culturists from Virginia and Maryland. Additionally, the workshop had participation by relevant state and federal agencies, Maryland watermen, and research and extension faculty from the University of Maryland (see Appendix I for a full list of the workshop participants). Presentations by oyster industry experts and the subsequent breakout group discussions were consistent in stating that oyster aquaculture production could be profitable in Maryland if the opportunity was afforded to the industry to experiment with different production techniques and business models. From these experts, we captured the likely financial conditions that would be encountered in implementing a range of aquaculture business models, from extensive spat-on-shell bottom cultivation to more intensive bottom cage culture to suspended culture in floats.

Another way of thinking about extensive versus intensive aquaculture approaches is to examine the tradeoff that the grower is making in terms of capital and labor investment (higher in intensive systems) in relation to oyster growth and mortality (higher in intensive systems). Only through experimentation, demonstration, or observation of industry practices is one able to determine which of these approaches is superior, and under what circumstances. It is likely that all approaches will play a role in a successful Maryland oyster aquaculture industry, reflecting the heterogeneity of growing conditions and segmentation of the oyster market.

For illustrative purposes, we demonstrate an example of a profitable operation for each of the production approaches outlined above, realizing that there may be many alternative examples that could be profitable as well. To accomplish this, we use the financial simulation model Aquasim to follow a representative firm through ten years of operation. To better represent our current uncertainty about firm performance and the oyster market, we parameterize the model with probability distributions of the input parameters based on expert opinion gathered at the workshop. The model produces detailed cash-flow and financial performance analysis for the representative firms. The best indicator of financial success to use for comparisons is the net present value of the operation over ten years. Net present value is the sum of the discounted stream of yearly net revenue estimates. A real discount rate of 3% is used, and the discounting formula means that net revenues are weighted more heavily the earlier in the ten year process they occur. A firm that has -$100,000 in the first year of operation and $100,000 in the subsequent 9 years will have a net present value (at 3%) of $658,845. We also provide the coefficient of variation of the net present value to illustrate the relative risk. The coefficient of variation is the ratio of the standard deviation of an estimate to its mean. The larger the coefficient of variation is, the greater the risk (and potential reward) of the outcome.

Our goals in adapting this model to and parameterizing it for various business models for oyster aquaculture in Maryland are two-fold. First, by providing a "snapshot" or single case of a profitable operational scenario for each of the three production approaches outlined above, we are able in this document to provide some appreciation for the potential viability of such operations in Maryland. Second, it is our hope the Aquasim model will be used guide specific aquaculture start-up operations in Maryland in the future. Access to the model as a tool for analysis of specific oyster aquaculture operations is available at http://www.arec.umd.edu/Extension/Coastal%20and%20Marine%20Resources/index.cfm or by contacting Dr. Doug Lipton at University of Maryland Sea Grant Extension Program.

Path to Profitability – Spat-on-Shell Bottom Cultivation

In this scenario, eyed larvae are obtained from a hatchery and set on bags of shell in remote setting tanks. The bags are opened and the shell is planted on leased bottom. The oysters are harvested from the bottom by traditional means such as a power dredge when they reach market size.

The major characteristic of this operation is that it requires very little capital investment, particularly for an existing waterman who has a fishing vessel. Oysters experience high planting mortality and are subject to predation, disease, and poaching. There is little labor involved between planting the oysters and harvest. The oysters produced may be better suited to a shucked market because of clumping and other factors, and thus, will receive a lower average price than oysters for the half-shell market.

There are several steps prior to the planting of spat-on-shell which will determine the ultimate cost of planting. Competent eyed larvae must be obtained from a hatchery and transported to the setting location. Transport of eyed larvae is inexpensive; the major cost in this step will be obtaining, transporting, and bagging shell. Once the setting process is completed, bagged shell must be transported to the planting grounds. A variety of options exist for how this seed will be obtained. A grower might buy spat-on-shell from a hatchery/nursery producer or the grower might perform the setting himself. Another variable that will impact costs is the size of seed that is planted, with larger seed having a higher cost per seed, but also is expected to have a higher survival rate than smaller seed. Yet another factor is whether the grower will purchase selected strains of seed (e.g., DEBY) or triploids. Either of these options would increase seed cost, again with the expectations of faster growth and/or survival. We do not attempt to model all these options. Here we model a scenario in which spat-on-shell are planted on the bottom at an average cost to the grower of $0.03 a piece, but the cost is allowed to vary in the model due to the wide range in options and uncertainty so that the standard deviation is $0.015. This price reflects the cost of all the components required to produce the spat-on-shell: larvae, shell, setting system, nursery stage, transportation, and planting.

Once the seed are planted, the critical factors for profitability, other than the market price, are the time needed to reach market size and the overall survival to market. These will depend on what strain (or if triploids) are planted, where they are planted, and the realized environmental conditions such as salinity and temperature. There is also an interaction between time to market size and survival that is exacerbated by disease issues. For purposes of this analysis, we used a period of 26 months for average time to market from the time the oysters are planted. An additional year to market makes these operations unprofitable under all but the most extreme possible conditions in terms of survival and market price. Survival from planting to harvest is allowed to vary greatly, but averages 40% with a range that varies for any crop from a low of 15% to a high of 65%.

The final key assumption is expected market price. As stated earlier, a significant portion of this production is likely to enter the shucked oyster market which has a lower per oyster value than the half-shell market. Some culling may take place to allow marketing of some oysters for the half-shell market. Therefore, we used an average price of $0.15 per oyster, and the price varied with a standard deviation of $0.06.

The simulation is for a grow-out operation that plants 1.5 million seed per year. From a financing perspective, this requires two years of investment at an average of $45,000 per year in seed prior to any cash return. Cash flow requirements, including other related expenditures, require that about $120,000 be available to the operation prior to any positive revenue stream, making this an unlikely enterprise for an individual waterman without significant financial support in the form of low interest loans and/or loan guarantees. With appropriate financing, this operation had an 86% success rate. The net present value after 10 years of operation was approximately $284,000, with a coefficient of variation approximating 41%. Note that the scale of this operation is relatively small compared to bottom cultivation operations in Virginia described in Box 1, so the expectation exists that net present value can realistically be increased by increasing the scale of the operation.

Path to Profitability – Bottom Cage Culture
By increasing the investment in capital and labor, it is possible to increase the survival and shorten the time to market for oysters. On-bottom cages protect oysters from predation as well as keep the oysters slightly higher in the water column allowing increased feeding and growth. Marketability also improves because individual seed can be planted, as opposed to spat-on-shell, making the oysters better suited for sale in the higher value half-shell market.

Cage culture is modeled by using the base scenario for spat-on-shell on bottom from above and adding cage costs and labor costs as advised by the expert panels from the workshop. Additionally, modifications based on workshop results are made to the assumptions about time to market, survival, and the market price. For purposes of this exercise, it was assumed that seed costs would remain the same under the different scenarios. Time from placement of seed in cages to market was estimated at 18 months. Survival rate from planting to market was estimated to average 65%. Survival was modeled using a triangular probability distribution with a minimum survival rate of 40% and a maximum of 70%. The market price was assumed to be higher than the spat-on-shell bottom cultured oysters. To allow for a mixed market of half-shell and shucked oysters, the average price was assumed to be $0.20 with a standard deviation of $0.04.

As would be expected, this scenario requires even greater financing for the same level of planting as the spat-on-shell bottom cultivation scenario. This is due to the increased requirement to buy or build cages to contain the oysters and the need to compensate labor prior to any positive cash flow. However, with a faster time to positive cash flow, the higher survival and higher market price lead to a higher net present value for the ten-year operation of almost $830,000 with only a 9.4% coefficient of variation.

Path to Profitability – Suspended Culture
The most intensive oyster aquaculture method provides even greater protection for the oysters and faster growth by maintaining the crop at or near the surface. Labor costs increase because grow-out structures have to be handled more often to deal with fouling conditions.

We assumed the same survival rates for floating structures as we did for on-bottom cages. The initial costs of the grow-out structures are higher, as are monthly labor costs, which we assumed to be as high as $5,000 per month. The major difference in this scenario was assuming that product would reach market size in 14 months from the time of planting. This shorter grow-out period helps to negate some of the higher input costs such as labor and has significantly positive impacts on cash flow and financing needs. We also assumed that all of the production from this type of operation would be geared toward the half-shell oyster market, so we assumed a market price of $0.30 with a standard deviation of $0.06.

An oyster aquaculture operation that can achieve the assumed performance numbers portrayed here could outperform the other technologies. The 10-year net present value of this operation was $1.1 million with a coefficient of variation of 9.5%.

Paths to Profitability – Summary
There are a variety of options available for an industry to follow to achieve financial success in oyster aquaculture. Evidence from other regions has demonstrated that any of the scenarios presented above can be

profitable if performance is similar to the ranges specified in the operating and pricing assumptions. While the results are positive (see Table 1 for summary), it should be pointed out that the net present value estimates are returns to management. In other words, they do not explicitly account for compensation for the management time provided by an individual or group of individuals that is required to create the enterprise and run it on a day-to-day basis.

Table 1. Major differences in assumptions for profitable scenarios of three oyster production methods and the expected outcome.

Input Variable	Bottom Culture	Bottom Cage Culture	Surface Culture
Time to Market	26 months	18 months	14 months
Survival (Minimum)	15%	40%	40%
Survival (Maximum)	65%	70%	70%
Survival (Most Likely)	40%	65%	65%
Market Price (Mean)	$0.15	$0.20	$0.30
Market Price (std dev.)	$0.06	$0.04	$0.06
Outcome			
Net Present Value	$284,000	$830,000	$1,100,000
Coefficient of Variation	41%	9.4%	9.5%

All of the operations modeled require significant financing to carry the operations through to the period of positive cash flow. Under-financing has been one of the major causes of failure for aquaculture operations in general. Thus, it will be essential to work carefully with perspective growers and the financing sector to ensure that the level of financing required to achieve success in this industry is clearly understood. It should also be understood that not all operations will achieve the performance standards suggested here, and some business failures will occur as a necessary component of market operation. Finally, the scenarios presented here are just examples of profitable operations and outcomes. It is expected that actual operations will vary greatly in methods of operation and in finding the appropriate scale in which to operate.

Public Sector Role

Beyond the role of providing incentives for the start-up of private hatcheries, there are other clear roles for government in developing and sustaining a robust oyster aquaculture industry in Maryland. There is an ongoing role for the state and federal government for research and development, particularly in the areas of selective breeding, broodstock maintenance, and disease dynamics. Over time, as the Maryland industry develops, it is reasonable to expect that it would become a partner in supporting such activities as the maintenance of selected broodstocks (partnering with the USDA molluscan breeding program, for instance) and applied research on culture techniques, as has occurred with the Pacific Shellfish Institute (http://www.pacshell.org) and more recently with the East Coast Shellfish Growers Association (http://www.ecsga.org). In the area of disease diagnostics, there is the opportunity for private business to supply this service as a robust industry develops (as has occurred in the Pacific Northwest and Maine); however, it will be important that state standards be developed for private disease testing laboratories. The approach taken in the Pacific Northwest and Florida is to seek certification of private disease diagnostic laboratories by the USDA's Animal & Plant Health Inspection Service (APHIS). Publicly-funded research programs will be needed to support more detailed studies on emerging disease outbreaks and epizootics (see Box 4 for an example).

Aquaculture, as an agricultural industry, is eligible for several USDA programs, including low interest loans and disaster relief. A pilot program within that agency provides federal crop insurance for hard clam aquaculture; a similar program for oyster aquaculture has been under consideration for several years, but is not yet available.

As with any successful agriculture or aquaculture industry, there is an important government role in providing extension and outreach. Important components of this role include on-site troubleshooting, training programs, and demonstration projects.

Perhaps the most important role for government in the development and maintenance of a viable oyster aquaculture industry is the need for adequate protection by law enforcement officials from theft of oysters and equipment. Virtually every state in the U.S. that has a viable shellfish aquaculture industry has had to wrestle with this problem. It has usually been a particularly difficult issue to address because (1) there is often a cultural background among some individuals in the wild fishery, that shellfish are there for the taking by anyone, (2) natural resource police are generally understaffed for patrolling extensive water bodies, and (3) there is a tendency by some prosecutors and judges to underrate the severity of natural resource crimes (which the theft of private aquaculture products is not, but it is often treated as such). This latter issue has been addressed in Florida by legislation that designates aquacultured organisms as private property. In Maryland, there is broad recognition of a current problem with illegal harvesting in oyster sanctuaries and the implications that presents for security of private oyster aquaculture. An integrated approach towards addressing this issue, involving clear property rights designation, enhanced enforcement efforts, improved ability to distinguish between cultured and wild-caught product, education programs, and stronger sanctions for offenders, will be required if the state is to provide a climate in which oyster aquaculture can be pursued profitably.

Demonstration Projects

Demonstration projects have played important roles in shellfish aquaculture development from Maine to the Gulf coast and in the Pacific Northwest. Maryland has had a history of industry demonstration projects related to oysters, from application of remote setting technology in the 1980's to recent projects using hatchery seed for large-scale restoration. The development of improved oyster strains and the recent successes in oyster aquaculture in the Virginia portion of Chesapeake Bay outlined above suggest that the initiation of several demonstration projects in Maryland could further spur the development of the oyster aquaculture industry. There are several components that we suggest should be part of any demonstration project: (1) industry involvement, (2) appropriate scaling to provide meaningful lessons for industry, (3) an active outreach component, and (4) adequate data collection and analysis to evaluate success and provide appropriate input values to the Aquisim economic model. Though extension and research faculty must guard against divulging specific sales and marketing information that could be proprietary, costs and returns from these projects can be aggregated and used for assessing the financial viability of oyster aquaculture businesses.

Spat-on-Shell Bottom Cultivation

Traditionally, the use of wild spat has been used for production of oysters on leased bottom. As disease epizootics spread throughout the 1980's and 90's, this activity generally ceased. With the availability of hatchery-produced, selected oyster strains, and triploids, there is a need to test the efficacy of this approach in several areas of state waters. First, we recommend a project in a high salinity region where significant disease pressure exists. This project should be designed to validate recent industry successes in Virginia growing spat-on-shell in disease endemic areas. We recommend the use of more than one strain of native oysters and triploids in these field verification trials.

We further recommend field demonstration projects in areas of low disease pressure, where little natural recruitment occurs. Local wild oyster stocks may be appropriate broodstocks for hatchery spat production in these areas and consideration should be given to including triploid as well as diploid spat-on-shell in the trials. Such projects can demonstrate the potential for viable oyster aquaculture in areas that do not support a natural fishery. In addition to these projects, we suggest that remote setting systems be encouraged in a wide range of salinities that would allow scientists and growers to develop criteria for application across a spectrum of production ranges.

A few projects along these lines have recently been initiated by the Oyster Recovery Partnership and the Maryland Sea Grant Cooperative Extension Program with groups of watermen to demonstrate the advantages of oyster aquaculture. A key factor in these projects has been the investment and ownership that the watermen have experienced, something that has been missing in the traditional public oyster bar model. We recommend expansion of such projects to include more watermen in more regions. With increased ownership will come an increasing need for watermen to participate in and assist in the protection of the product. This is seen as an important step in the transition from a hunting and gathering industry to an agrarian one.

Bottom Caged and Suspended Culture

We similarly recommend implementation of demonstration projects for more intensive culture approaches, including bottom cages and surface floats, while remaining open-minded about the inclusion of new or innovative production methods not currently used in the Chesapeake region. These should be designed in cooperation with industry producers and include mid and high salinity regions that would demonstrate their viability in the face of varying disease pressure. While several operations currently exist that could be used in cooperative projects, the proposed designation of Aquaculture Enterprise Zones by the Aquaculture Coordinating Council in several locations of the bay would provide opportunity to engage growers in several areas in these types of projects.

Statutory and Regulatory Framework for Oyster Aquaculture Development

Aquaculture represents a fundamentally different approach to seafood production than wild-capture fisheries. As such, new regulatory frameworks are required that go beyond simply developing a leasing program. Our objectives in this report are to identify those areas for which the development of policies and regulations have been required virtually everywhere sustainable shellfish aquaculture has developed in the U.S. and to highlight the key elements that need to be addressed within these regulations. Specific regulatory actions for achieving these strategies (e.g., establishment of enterprise zones vs. private leases or specific seed importation rules) are not addressed here, because details are the purview of appropriate state agencies. In some cases, specific revisions to state regulations are currently being considered by state agencies and interagency working groups within Maryland. The intent of this document is to provide a clear statement of the issues which policies and regulations must address to support the development of an economically-viable, ecologically-sustainable, and socially-acceptable oyster aquaculture industry in Maryland.

Grow-out Leases

There is a widely recognize need to revise Maryland's bottom leasing laws and regulations. Towards that end, the Maryland Aquaculture Coordinating Council, in response to administration request, has recommended revisions to specific laws and the enactment of specific regulations that would promote the development of shellfish aquaculture on both bottom and water column leases. Here we identify some of the key issues related to bottom and water column leases which have been important in the development of shellfish aquaculture elsewhere in the U.S. and discuss their applicability to oyster aquaculture development in Maryland.

Bottom Leases

Bottom leases in Maryland have traditionally been limited to "barren" bottom, that is, areas where neither oyster or clam populations exist at commercially exploitable densities. In the case of oysters, these areas have been determined from surveys originally carried out approximately one hundred years ago. Much of that area no longer supports significant wild populations of oysters and its status for leasing needs to be re-evaluated under current conditions.

Water Column Leases

Current use of the water column for oyster aquaculture in Maryland is permitted through a joint permit application process which provides state and federal permits for the structures used in the culture operation, comparable to the permit one would need to construct a pier. While this process has worked in Maryland, Virginia, and other states, especially in the early stages of oyster aquaculture development, it is cumbersome and often restrictive of aquaculture. Unlike a pier, once established an aquaculture operation is a dynamic process with growing animals and often changing structure requirements throughout the growing cycle. The development of a water column lease specifically for oyster aquaculture, which permits the specified use with constraints on the type and amount of structures, but allows for more flexibility in operation, would benefit the growth of this industry within the state. Careful consideration will need to be given to the type of approved structures for cultivating oysters in the water column in order to meet the needs of the aquaculture industry, while minimizing user conflicts and impacts on viewsheds.

Lease Size

Limits on the size of individual leases and on the number of leases that an individual may hold have important consequences for aquaculture development. A number of public interest reasons exist to limit lease sizes, among them reducing conflicts with other resource users, minimizing visual impacts (for water column leases), increasing the number of individuals that have the opportunity to participate in aquaculture, and diversifying the base of the industry. It is important to bear in mind, however, that constraints on lease size can affect the efficiency, productivity, and profitability of an aquaculture operation. Ensuring success in the market place and establishing Maryland as a leading producer of cultured oysters will require careful consideration of the lease size and number limits.

Eligibility

Often the right to lease public resources for the purpose of cultivating shellfish is granted exclusively to individual citizens of a state, with corporations excluded. The public interest in this area is to offer the opportunity for many of the state's citizens to participate in the industry and to limit the ability of a single entity to monopolize much of the available resource. Robust and sustainable shellfish aquaculture industries, however, generally require the involvement of some larger industry members that operate hatcheries, supply seed to others in the industry, and provide marketing opportunities (e.g., oyster aquaculture in the Pacific Northwest and clam aquaculture in Virginia). This role is generally filled by companies with long-standing histories in the seafood business, even if the leases are held in individual family member names. Maryland's current policy of excluding corporations from holding leases should be re-examined to determine if it is in the best interest for the industry and the citizens of the state.

Terms and Conditions

The right to use public property for commercial purposes conveys an obligation on the part of the user to meet terms and conditions that protect the public interest. Among the terms frequently set for the use of both bottom and water column leases for shellfish aquaculture is one of "use it or lose it" which mandates a specified level of activity required to maintain the lease. Annual reporting of activity, production levels, and compliance with lease terms provide a basis not only for assessing this use, but also yield critical data for supporting the continued growth of the industry.

Land-based Infrastructure and Permitting

The need for comprehensive land-use, planning, and zoning to include considerations of future aquaculture growth has been recently demonstrated for the shellfish aquaculture industry in the Pacific Northwest and the clam aquaculture industry in Virginia. As oyster aquaculture expands in Maryland, it is likely that additional private sector hatcheries, nurseries, and setting facilities will be established. These operations are all dependent upon a reliable supply of high quality estuarine water. They not only withdraw water from the estuary, but also discharge water after use. County zoning restrictions, state water discharge regulations, navigational issues, and aesthetic considerations all need to be considered in the siting of these critical facilities. Strategies which coordinate across these needs should be developed within the state. Additionally, operating permits should address which shellfish species and perhaps which stocks of specific species may be held in these facilities. In this regard, consultation should be considered with Coastal Zone Management officials and advisory committees, which frequently interface with county planning and zoning officials.

Seed Importation, Permitting, and Testing
Production of oyster larvae and seed for aquaculture in Maryland need not necessarily be limited to Maryland waters. Opportunities exist to obtain larvae and seed from hatcheries elsewhere on the Atlantic, Gulf, and Pacific coasts of the U.S. and taking advantage of these opportunities may speed the development of oyster aquaculture within the state. However, the movement of oyster seed between different bodies of water can spread new pathogens, different strains of existing pathogens, shellfish predators (e.g., flatworms or predatory gastropod egg cases), and other unwanted organisms. Policies and procedures related to origins, handling techniques and disease testing requirements for the importation of oyster seed into Maryland are in place and should be constantly evaluated for efficacy. These policies and the regulations which support them need to be flexible enough to respond to emerging issues (see Box 4).

Currently, importation of oyster seed from hatcheries in the mid-Atlantic is minimally constrained in Maryland. Wild oyster seed must be inspected prior to movement for drills and other organisms by the Natural Resource Police. For seed from outside the region, the Department of Natural Resources develops specific certification criteria based upon the known organisms that exist at the point of origin and requires documentation appropriate to the potential threats.

The lack of shellfish disease diagnostic services in Maryland, comparable to those provided in Virginia or for fish diseases in Maryland, has been a limitation for private growers within the state. Development of

Box 4. Lessons from the Management of QPX Disease in Virginia Clams.

Mortalities observed among cultured hard clams in Virginia in July 2001 were at first unexplained. Histological examinations revealed the presence of a disease-causing organism called QPX (phylum Labyrinthulomycota) that was formerly unreported in Virginia, but was reported to have caused mortality in hard clams in eastern Canada and Massachusetts. All of the clams involved in the mortality events in Virginia were imported as seed from a hatchery in Florida, where QPX was also previously unreported.

Investigations by Lisa Ragone Calvo and Eugene Burreson at VIMS and Susan Ford at Rutgers University revealed that clam seed arriving from Florida was not infected with QPX. Rather, clams from Florida and other southern stocks were more susceptible to QPX which was already present in Virginia. They conducted experiments which revealed that clams from genetic stocks from Virginia northward were less susceptible to QPX (see Ragone Calvo and Burreson 2002). Quick action was taken by the state to ban the use of clam seed produced from stocks originating south of Virginia. Importantly, the regulation did not ban the importation of clam seed from this region, since these locations did harbor the disease. It banned seed produced from Florida broodstock, because of its susceptibility to disease. This was an important distinction for the Virginia clam industry which continues to rely upon seed produced in Florida hatcheries that now use Virginia broodstock.

The lessons in this for oyster aquaculture development in Maryland are two-fold. First, state-supported, state-of-the-art disease diagnostic capabilities were required to diagnose the initial problem and determine its source of origin. Second, flexibility in the state’s program for managing the importation of shellfish seed allowed the proper regulations to be quickly established that protected the industry, but did not unduly restrict the use of hatchery seed from an entire region. Establishing similar capabilities and flexibility in Maryland will be important for aiding a developing oyster culture industry.

this capacity, either through expansion of existing state programs or the involvement of private disease diagnostic services, will be required for growth of this industry within Maryland.

Harvest Regulations

Regulations that have been developed for managing wild shellfish stocks, such as size restrictions, bushel limits, gear restrictions, and seasonal, daily, and time of day harvest restrictions are all inappropriate for managing private, hatchery-based aquaculture. Specific exemptions from harvest restrictions that are related to the management of wild stocks are necessary for the development of a viable shellfish aquaculture industry. In regions where both a wild fishery and a culture industry exist for the same species, this can pose significant challenges for law enforcement officials faced with enforcing differing sets of regulations for the different industries. Nevertheless, addressing this issue is not optional; economically viable shellfish aquaculture cannot be sustained if the harvest of its crops is constrained by regulations designed to manage wild stocks. Every state in the U.S. with a viable shellfish aquaculture industry has found it necessary to address this issue. In Florida, the legislative designation of aquacultured organisms as private property served the dual purpose of establishing a basis for exempting them from fisheries regulations and strengthening the industry's protection from theft. The need for this exemption should not be confused with the need to manage the harvest of wild oysters that may have been transplanted as part of a more extensively managed fisheries program.

All harvest restrictions related to public health should apply to aquaculture operations.

Maryland's natural resource laws and regulations related to oyster harvest have been promulgated almost exclusively for managing wild stocks. Yet, they are currently applied to cultured stocks, largely to simplify enforcement and prevent natural stocks from being sold as privately-produced animals. This can result in lost markets, inefficient harvest schedules, and reduced ability of an aquaculturist to manage their own crops. It is important that the state recognize that fishery-based size restrictions on harvest, developed to ensure the viability of wild spawning stocks, have little meaning when applied to cultured stocks, for which continuous hatchery production is dependent upon the economic viability of the industry. Further, there is no basis for applying regulations related to time, day, or season of harvest that have been developed in an attempt to reduce overexploitation of wild stocks to the harvest of privately-owned, hatchery-produced aquaculture stocks.

Regulations that would allow the sale of any size aquaculture product were recommended by the Maryland Aquaculture Coordinating Council at the request of the legislature but have yet to be finalized. It will be necessary for the state to address this issue in a comprehensive manner before private, hatchery-based oyster aquaculture can thrive in Maryland.

Best Management Practices

Both the State and the industry have an interest in ensuring that oyster aquaculture develops in Maryland in a manner that is environmentally responsible and socially acceptable. Consequently, the development of guidelines for aquaculture practices is critical. Effective Best Management Practices (BMPs) must address a range of issues related to environmental stewardship, maintenance of clean water, waste management, minimizing resource conflicts with other users, aesthetic considerations, disease management, genetic integrity of shellfish stocks, and regulatory compliance by industry. Some of these guidelines, such as leasing and permitting requirements, will necessarily be mandated by the State. In the case of other issues, such as aesthetics, waste removal, and environmental stewardship, BMPs may be developed in a voluntary, bottom-up mode by the industry or in a mandated, top-down mode by the State. There is wide variance in how these have been developed in other areas of the country. Some states (e.g., Florida, see http://www.floridaaquaculture.com/publications/Issue_58.pdf) have taken a top-down approach and mandated most BMPs, while other states (e.g., Washington state, see http://www.pcsga.org/pub/uploads/EPS.pdf) have developed more industry-driven BMPs and Codes of Practice. Some states (e.g., Florida and Rhode Island) require that shellfish aquaculturists purchase security bonds to ensure compliance, especially with gear removal issues; however, opinions among industry and other experts as to the effectiveness of this requirement are mixed. The important point is that buy-in and compliance to a comprehensive suite of practices governing the industry needs to begin at the earliest stages of shellfish aquaculture development. Developing *Best Management Goals or Outcomes* that allow for innovation and improvements in culture practices to meet those goals is generally preferable to mandating specific practices which may only be the best available at the time. BMP plans should be "living documents" which accommodate changing conditions and culture practices.

The Maryland Aquaculture Coordinating Council has developed a comprehensive set of BMPs for aquaculture within the state, including a detailed section on shellfish aquaculture (see Appendix II). These BMPs provide a thorough list of the key issues and indicate which are addressed by current regulations and others that currently require voluntary compliance by shellfish growers. Any of the voluntary guidelines could be made mandatory if the state deems it necessary to ensure appropriate development of the industry. The current BMPs are also meant to be "living" practices and have already been modified to address a specific issue mandated by the legislature.

Regulatory Streamlining

Several state and federal agencies have jurisdictions and responsibilities in the oversight of aquaculture conducted in public waters. These diverse responsibilities generally mean that a prospective aquaculturist must obtain numerous permits before initiating a business. A consistent theme among shellfish aquaculturist from across the country at the November workshop was the need for efficient, "one stop shopping" in the permit application process. The industry recognizes the need for multiple jurisdictions and multiple permits, but it advocates for a simple, streamlined process for procuring those permits. The state of Florida has implemented a particularly efficient system in which a prospective aquaculturist submits a single permit application through the Division of Aquaculture in the State Department of Agriculture and Consumer Services (see http://www.floridaaquaculture.com) and that department serves as the lead agency in shepherding the application through the other appropriate agencies. Oyster aquaculture development in Maryland would be well served by a similar approach with a single agency taking the lead in helping individuals obtain the required permits.

References

Beck, M.W., R. Brumbaugh, L. Airoldi, A. Carranza, L. Coen, C. Crawford, O. Defeo, G. Edgar, B. Hancock, M. Kay, H. Lenihan, M. Luckenbach, C. Toropova, and G. Zhang. (Submitted to Science). Oyster reefs at risk globally and recommendations for ecosystem revitalization.

Burreson, E.M. 1991. Effects of *Perkinsus marinus* infection in the eastern oyster, *Crassostrea virginica:* I. Susceptibility of native and MSX-resistant stocks. J. Shellfish Res. 10**:**417–423.

Congrove, M.S. 2008. A Bio-Economic Feasibility Model for Remote Setting: Potential for Oyster Aquaculture in Virginia. MS Thesis, College of William and Mary, Gloucester Point, VA.

Encomio, V.G., S.M. Strickler, S.K. Allen, Jr., and F.-L. Chu. 2005. Performance of "natural Dermo-resistant" oyster stocks—survival, disease, growth, condition and energy reserves. J. Shellfish Res. 24:143-155.

Gempesaw, C.M., D.W. Lipton, and J.R. Bacon. 1996. Aquasim PC: A financial risk management tool for aquaculture farm managers. Proceedings, 6th International Conference on Computers in Agriculture.

Hargis, W.J., Jr. and D.S. Haven. 1999. Chesapeake oyster reefs, their importance, destruction and guidelines for restoring them. Pages 5-23 i*n:* M.W. Luckenbach, R. Mann, and J.A. Wesson (eds.), Oyster Reef Habitat Restoration: A Synopsis and Synthesis of Approaches. Virginia Institute of Marine Science Press, Gloucester Point, VA.

Jones, G. and B. Jones. 1988. Advances in the remote setting of oyster larvae. British Columbia Ministry of Environment, Marine Resources Branch, Info. Report # ISSN 0-7718-8627-6, 88p.

Lipton, D.W. and C.M. Gempesaw. 1997. Chapter 12. Economics and Marketing. Pages 315-328 *in*: R.M. Harrell (ed.), Striped Bass and Other Morone Culture. Developments in Aquaculture and Fisheries Science 30. Elsevier, New York.

Lipton, D.W. and D.H. Kim. 2007. Assessing the economic viability of offshore aquaculture in Korea: An evaluation based on rock bream, *Oplegnathus fasciatus*, production. J. World Aquaculture Soc. 38(4):506-515.

Luckenbach, M.W., F.X. O'Beirn, and J. Taylor. 1999. An introduction to culturing oysters in Virginia. VIMS Publication Center, Gloucester Point, VA.

Ragone Calvo, L.M. and E.M. Burreson. 2002. QPX susceptibility in hard clams varies with geographic origin of brood stock. Virginia Sea Grant Publication VSG-02-18, Gloucester Point, VA.

Ragone Calvo, L.M., G.W. Calvo, and E.M. Burreson. 2003. Dual disease resistance in a selectively bred eastern oyster, *Crassostrea virginica*, strain tested in Chesapeake Bay. Aquaculture 220:69–87.

Rothschild, B.J., J.S. Ault, P. Goulletquer, and M. Heral. 1994. Decline in the Chesapeake Bay oyster population: A century of habitat destruction and overfishing. Mar. Ecol. Prog. Ser. 111:29-39.

Also see: http://www.mdsg.umces.edu/programs/extension/aquaculture/oysters/background/

Appendix I. Participants for the CRC-convened workshop 'Developing a Framework for Sustainable Native Oyster Aquaculture in Maryland', November 6-7, 2008, Grasonville, MD.

Speakers

Michael Rubino	NOAA Aquaculture Program
William Dewey	Taylor Shellfish, WA
Paul Zajecik	FL Department of Agriculture
Robert Rheault	Moonstone Oyster Farm, ME; President, East Coast Shellfish Growers Association
Skip Bennett	Island Creek Oyster Farms, MA
Michael Peirson	Cherrystone AquaFarms, VA
A.J. Erskin	Bevan and Cowart Seafoods, VA
Robert Parkinson	St. Thomas Creek Oysters, MD

Attendees

Kate Naughton	National Marine Fisheries Service
Max Mayeaux	Plant and Animal Systems, USDA
Peyton Robertson	NOAA Chesapeake Bay Office
Tom O'Connell	MD Department of Natural Resources
Kathy Brohawn	MD Department of the Environment
Karl Roscher	MD Department of Agriculture
Erin Butler	MD Dept of Health & Mental Hygiene
Stephanie Reynolds	Chesapeake Bay Foundation
Beth Bachur	US Army Corps of Engineers, Baltimore District
Ben Parks	Maryland Watermen's Association
Larry Simns	Maryland Watermen's Association
Luke Breza	Great Eastern Chincoteague Shellfish
Ernie Burns	oyster grower
F William Sieling	Chesapeake Bay Seafood Industries Association
Larry Jennings	Coastal Conservation Association
Don Meritt	University of Maryland
Doldon Moore	Maryland Board of Public Works
Ken Paynter	University of Maryland
Mike Naylor	MD Department of Natural Resources
Gef Flimlin	NJ Cooperative Extension
Peter Bergstrom	NOAA Chesapeake Bay Office
Steve McHenry	MARBIDCO
Jon Farrington	Wells Cove Shellfish Nursery
Steve Allen	Oyster Recovery Program

Steering Committee
Attendees

Stephan Abel	Oyster Recovery Program
Douglas Lipton	MD Marine Extension
Mark Luckenbach	VIMS
Edward Rhodes	Phillips Seafood Co.
Kevin Sellner	Chesapeake Research Consortium
Donald Webster	MD Marine Extension

Appendix II. Excerpts from the MD BMP manual pertaining to shellfish aquaculture: General Introduction and Section III.

BEST MANAGEMENT PRACTICES
A MANUAL FOR MARYLAND AQUACULTURE

*** * * * ***

Developed by the

Maryland Aquaculture Coordinating Council

July 2007

*** * * ***

INTRODUCTION

Aquaculture, or the production of aquatic plants and animals, has been a part of Maryland's history for over a century. The industry currently consists of a diverse array of products ranging from traditional shellfish such as oysters to aquatic plants for use in water gardens and shoreline stabilization. Several businesses have been developed that raise finfish and shellfish in innovative systems and aimed at non-traditional markets. In addition, the use of aquaculture products for the restoration of depleted or disrupted natural populations has been an area of increasing research and interest in recent years, and is seen as a potential area for increasing opportunity for the future. This would provide enhanced economic activity while assisting in the environmental modification.

Legislation enacted during 2005 created the Maryland Aquaculture Review Board (MARB), which provides regular interagency review of permits and issues across departmental lines. The Maryland Aquaculture Coordinating Council (MACC) was also created, comprising seventeen designated members from industry, academia, regulatory, and political categories. Among the tasks the MACC was charged with was the development of Best Management Practices (BMP) for all forms of aquaculture.

To address this, the MACC created six subcommittees. These were chaired by MACC members, with additional membership provided by council members, as well as knowledgeable individuals able to provide insight into development of the BMPs. During the summer and fall of 2006, these subcommittees met and formulated drafts. Subcommittee meetings were open to the public for input by non-subcommittee members, and to ensure that citizen comments and concerns were heard and considered for incorporation into the BMPs.

These BMPs are formed from existing state and federal laws and regulations, as well as voluntary measures that are recommended. Their purpose is to provide producers with a base of knowledge regarding expectations in the development of their businesses. In all, they comprise a roadmap for those entering the aquaculture industry to follow as they grow businesses in the state. Since another task of the MACC is the regular and periodic review of all laws and regulations pertaining to aquaculture, these BMPs will be reviewed and revised as a part of this process so that they reflect current practice. It is hoped that they will aid the industry in continuing to grow while maintaining a position of environmental compatibility.

SPECIES

The development of BMPs was not driven by production of specific species, except for the section on Shellfish Aquaculture. The reason is that shellfish culture is largely driven by the use of publicly owned waters and bottom. Therefore, there is a reason for adopting practices that take into account the multiple uses of these waters, as well as the social and historical basis of their use in aquaculture.

For all others, the various sections contained in these BMPs will be sufficient to provide guidance for efficient and profitable production while safeguarding the environment and providing for welfare of the animals. It should be clear that aquaculture production is no different than most other forms of animal agriculture. Production and ultimate profitability largely rest upon ensuring that animals are kept healthy and in a suitable environment to promote growth.

The practice of commercial aquaculture contains several inherent objectives for the grower. These are to:

- Increase survival
- Maximize growth rates
- Develop product uniformity
- Protect from predators
- Manage health
- Grow according to market demand
- Develop product continuity

While restoration aquaculture has some differences, it must take into account the basis for all aquaculture production, which is to enhance the survival of young plants and animals in greater numbers than would be found in natural reproduction.

It is clear, therefore, that the use of BMPs can aid in fostering successful aquaculture operations. They represent the results of science, technology, and innovation in many areas - from construction of impoundments to final shipping of the products. If followed, they can aid the aquaculturist in creating and managing a business that will be financially successful while preventing conflicts with neighbors or other users of the waters, and in providing operations that will coexist within the local environment with minimal impact.

DEFINITION

Best Management Practices are defined as methods of operating an aquaculture business to minimize, so far as practicable, pollution or environmental disruption. A key feature of aquaculture production is the reliance on clean water. Whether in the production of shellfish, finfish, or other aquatic life forms, water quality is a key parameter in the economic success of the business. In addition, aquaculture producers recognize the relationship between their production and the natural resources of the state. These BMPs provide a voluntary set of standards and procedures for improving production while helping to preserve the environment. They are a key in the factor that has come to be known as “sustainability” – a desirable state that ensures the long-term efficacy of the business.

These BMPs combine legislative and regulatory mandates, as well as suggested and accepted practices that can help the aquaculture producer become a good neighbor within his area of operation. Through them, the MACC hopes to provide support for the growth of the aquaculture industry in Maryland, as well as its continued economic success.

SECTION III. SHELLFISH CULTURE

Subcommittee Membership:
Steve Gordon, Industry, Chair
Ben Parks, TFL
Gina Hunt, Maryland Department of Natural Resources
Erin Butler, Maryland Department of Health and Mental Hygiene
Jon Farrington, Industry
Rich Bohn, Maryland Department of Natural Resources
Don Meritt, University of Maryland Center for Environmental Science
Mitch Tarnowski, Maryland Department of Natural Resources
Luke Breza, Industry
Thomas Taylor, Jr., Industry
Lori Orme, Industry
Ernie Nichols, Industry

Shellfish have long been a major part of Maryland's seafood production. While the state had some of the earliest leasing laws, created from an interest in aquaculture and increasing production of the Eastern oyster, socio-political problems have kept the shellfish aquaculture industry from growing significantly. With the drastic decline in the oyster resource due to diseases, and the growth of the hard clam industry in the region, there exists a need to encourage shellfish growers to add to the population of these important shellfish. Growers, and the shellfish they produce, can play a large part in the restoration of the Chesapeake and coastal bays while providing quality seafood to an expanding market.

This section addresses the following areas:

I. Site Selection
II. Operations and Management
III. Permitting
IV. Human Health Issues
V. Biological Management

I. Site Selection and Access

A. Riparian Rights

Selecting a location to cultivate shellfish in Maryland requires many considerations, including legal restrictions and the rights of adjacent landowners. Maryland is one of many states that follow English common law often referred to as a Riparian Right. In *DNR v. Adams*, the Court of Special Appeals defined a riparian property owner as a person who owns property bordering on a body of water. *Code of Maryland Regulation 08.04.01.20* further defines this as a person possessing riparian rights, specifically including the right to gain access to tidal water.

Riparian rights given to a property owner are legal principals that derive from legal cases rather than statute. Applicable cases are discussed under Legal Restrictions to Access. In summary form, a riparian right is the right of the landowner to access the navigable water, but with no right superior to any other water user unless provided by statute.

Ownership of state waters is intertwined with rights of waterfront land owners. By virtue of the state's succession to the rights of the title of the Lord Proprietor who received the land by grant from the Crown of England, navigable waters and the land beneath these waters are owned by the State. The concept of the "Public Trust Doctrine" is that these navigable waters are preserved for the benefit of the public. In essence, these areas are owned in common by all the state's citizens.

In *Caine v. Cantrell*, the Court of Appeals reiterated that the State owned the area between mean high water and mean low water for public benefit. Therefore, individual private property only extends to the mean high water line. However, the right of a riparian owner to access the water past this line is a right of being the owner of that adjacent property.

B. Legal Restrictions to Access

Following is a list of rights provided to landowners that will need to be evaluated when selecting a site:

1. Access to water: A shellfish growing area may not restrict a riparian owner’s right to access the water. *Causey v. Gray* states that a riparian proprietor, whose land is bounded by a navigable river, regardless whether his or her title extends beyond the dry land, has the right of access. In a similar manner, Environment Article 16-201, Annotated Code of Maryland provides that a person who is the owner of land bounding on navigable water is entitled to make improvements into the water in front of the land to preserve that person's access to the navigable water or protect the shore of that person against erosion.

2. Improvement to property: A shellfish growing area may not restrict a riparian owner’s right to improve his or her private property. In *DNR v. Adams* the Court of Special Appeals lays out the rights of the riparian owner including: “the right of access to the navigable waters; the right to build piers, wharves, docks, and the other improvements to the line of navigation; the right to reclaim land; and the right to accretions to his lands. These rights do not depend upon ownership of the soil under water but upon lateral contact with the water. It is a universal rule that for riparian rights to attach to a tract of land, the water must form a boundary of the tract.”

3. Narrow entrance: Statute does extend riparian rights to the use in any creek, cove, or inlet that is less than 300 feet or less in width at mean low water for the purpose of preserving or depositing oysters or other shellfish. This right of a riparian proprietor, provided by *Natural Resources Article, 4-11A-06, Annotated Code of Maryland*, extends only to the middle of the creek, cove, or inlet. This statute also extends the right to grow and harvest shellfish to the owner of any pier or structure in the water column and as approved by the Army Corps of Engineers with certain restrictions.

4. Aquatic vegetation: A shellfish grower may not impair submerged aquatic vegetation. This provision is part of the lease contract between the State and the shellfish grower. See: Section II. Operations and Management, subsection F, Habitat Protection, for Shellfish Culture Best Management Practices to comply with this restriction.

5. Waterfowl hunting: The shellfish grower may not fish (i.e. work a shellfish growing area) while a duck blind is in use. *Natural Resources Article, 4-512, Annotated Code of Maryland* states that “during the open season for migratory waterfowl, a person may not fish by any means within 500 yards of any stationary blind or blind site which is occupied and is being used for hunting migratory waterfowl.”

C. Bottom Leases

As stated, the State owns the waters of the State and the land beneath it. However, the State may grant rights to this land as part of a lease. Tidelands without commercially significant quantities of naturally existing shellfish (i.e. unproductive tidelands) can be leased from the State for oyster cultivation. Productive tidelands with natural beds cannot be purchased or leased and remain part of the public fishery.

If your shellfish growing area involves use of State owned bottom, you must apply for a lease. Statute and Regulation specify criteria for a lease area. Natural Resources Article 4-11A-05 Annotated Code of Maryland states that a lease may not be granted for any of the following submerged areas of the State:

1. areas beneath a creek, cove, bay, or inlet less than 300 feet wide at its mouth at mean low tide
2. any natural oyster or natural clam bar as defined
3. any area within 150 feet of any natural oyster or natural clam bar in any county
4. any area within 600 feet of any natural oyster or clam bar in the Chesapeake Bay
5. any clam bed as defined by the charts of the Oyster Survey of 1906 to 1912 and its amendments

The lease area for production of clams or oysters must be on unproductive tideland. Unproductive is defined by harvesting rates listed in the *Code of Maryland Regulation 08.02.08.11*. MD BMP Manual Page 19 rev July 2007

D. Water Column (Off Bottom) Leases

Statutes related to natural clam and oyster bars and their productivity do not apply to a lease of the water column. However, other statutes regarding riparian rights to access the water, navigation, and the hunting blind restriction still apply and should be considered in selecting a site.

Section III, Permitting, subsection C, Off-Bottom Shellfish Aquaculture covers the permits needed for water column leasing and off-bottom aquaculture. Part of the permitting process for off-bottom aquaculture is a Tidal Wetlands License. Approval is required from the Board of Public Works for this license. In selecting your site, it is important to note that the Board of Public Works will consider the public interest in respect to your license application. In particular *Code of Maryland Regulation 23.02.04.01* specifies that the Board will consider:

- (a) The preservation of tidal wetlands;
- (b) The conservation of natural values and living resources;
- (c) Fishing and crabbing;
- (d) Navigational needs;
- (e) Water access and related recreation; and
- (f) Maritime commerce.

E. Water Quality Considerations

A person interested in raising shellfish intended for human consumption must verify the classification of growing waters under the National Shellfish Sanitation Program. It is valuable to research this aspect of your site prior to applying for any permits by contacting the Maryland Department of the Environment, Shellfish Program. Additional management considerations and recommended best management practices are covered under Section IV, Human Health Issues, of this document.

F. Best Management Practices - Being a Good Neighbor

1. An open discussion with neighbors early in the planning stage can minimize conflict later. Try to amend your plan to accommodate comments you receive.
2. According to *Natural Resources Article, 4-11A-10, Annotated Code of Maryland* you must clearly mark the corner boundaries of your bottom lease and navigation hazards. However, markers should be made as visually unobtrusive as possible and the minimum number of markers should be used to protect a neighbor's view.
3. Recognize that other users have access to the water column above a bottom lease site. Be polite to visitors and look at these visits and a way to educate the public about aquaculture. Inform locals of site markers and their significance.
4. Placement of floating gear must be within the permitted boundaries and the leaseholder should be sensitive to navigation issues.
5. Recognizing that water column aquaculture enterprises affect traditional uses of the water, contact the local County Watermen's Association regarding site selection. The Maryland Watermen's Association can direct you to the leader of local county organizations. Understanding boat traffic and commercial use of an area will help minimize protests to your application.
6. Check local city and county ordinances. It is your responsibility to obtain necessary city and county permits. Zoning variances, critical area activity applications, and building permits may be required. Permits may also be required for commercial activities, especially in residential areas.
7. Keep noise to a minimum. *Code of Maryland Regulation 08.18.03.03* requires maximum noise level of any vessel operating on the waters of the State not to exceed 90 decibels.
8. Maintain the gear and appearance of your growing area. See Section II, Operations and Management, for best management practices related to maintenance of shellfish gear.

II. Operations and Management

A. Site Marking and Access Control

The great variety of recreational and commercial opportunities on Maryland waters, along with the proliferation of residential development on waterfront property, may lead to user conflicts with aquaculture operations. Seascape impacts, obstacles to navigation, boating safety, waterfowl hunting, and access to the water column over the shellfish beds are all issues that may raise objections to shellfish farms.

While boundary markers for the shellfish grounds are important for boater safety and protecting the beds, a high density can raise complaints about interference with views and access to the area. State regulations already in place that delineate growing areas, ensure access for others, and reduce conflicts with watermen, along with the judicious application of best management practices, can address the concerns of property owners and the maritime community.

Issues

- Delineating and protecting beds
- Seascape Impacts
- Navigation and boater safety
- Public access
  - Water column access (boating, fishing, crabbing)
  - Waterfowl hunting blinds

Best Management Practices

1. Clearly mark corner boundaries and navigation hazards.
2. Markers should be as visually unobtrusive as is prudent. A minimum number of markers should be used to protect the seascape.
3. Unnecessary, damaged, or heavily fouled markers should be removed and disposed of in a timely manner.
4. Recognize other users have access to the water column above the site. Be polite to visitors and look at these visits as a way to educate the public about aquaculture. Inform locals of site markers and their significance.
5. Use of fencing, water-column netting, close-set stakes or other means that extend from the bottom to the water surface and restrict movement through site is strongly discouraged.
6. Be aware of the 500 yard restriction on any fishing activity around duck blinds when occupied for hunting migratory waterfowl. If site access is necessary during this period, work out a schedule with hunting neighbors.
7. Placement of floating gear must be within the permitted boundaries and should be sensitive to navigation issues.
8. It is recommended to not exceed an 18 inch elevation limit on structures placed on site bottom to minimize interference with watercraft.

B. Vessel and Equipment Use

Boats and engine-powered equipment are an integral part of aquaculture operations. However, care must be taken so that use of vessels and equipment, as well as accidental spills of toxic substances, does not damage the environment. Fuels, lubricants, and other chemicals used in routine operations should be properly stored and handled to minimize risk of spillage. Boat and equipment noise is another issue, particularly in residential and recreational areas, as well as areas occupied by noise-sensitive wildlife.

Issues

Mechanical damage to marine life and habitat
Pollution
Noise

Best Management Practices

1. Avoid damaging marine life and sensitive habitat such as seagrass meadows or salt marshes when operating vessels and equipment.
2. Take precautions to prevent release of contaminants from vessels and equipment into the marine environment.
3. Vessels must be in compliance with Code of Maryland Regulation 08.18.03.03 concerning noise. When operating equipment, be aware of the noise generated and try to reduce its impact on neighbors.
4. Keep vessels and equipment clean and well maintained.

C. Predator Control

Predators are the major cause of shellfish mortality in field-culture operations. Maryland waters contain an abundance of mollusk-eating species. To control loss, growers use nets, mesh bags, cages, or other means to exclude predators. This gear must be routinely inspected for displacement, damage, or burial and cleaned of bio-fouling. Because ice can dislodge or damage nets and other gear, they are sometimes removed in winter when predation is low.

There are environmental, navigation, and aesthetic issues regarding protective gear. Dislodged gear can be transported and serve as an entanglement to wildlife and boat propellers. Derelict gear washed up on shore is unsightly and often malodorous. Lost, abandoned, and improperly disposed of netting also creates a negative image of the industry and builds opposition to it.

It is the grower's responsibility to be sure gear is securely anchored, old netting is properly disposed of, and to completely remove gear and associated materials when operations end. Beyond caring for their own site, growers should retrieve others' derelict gear. Virginia growers have a Clam Net Hotline with a year-round commitment to cleaning up stray nets. This is an idea Maryland growers should seriously consider. A strong group effort by the shellfish aquaculture community to police themselves as well as educating their fellow growers is crucial in dealing with this problem and fostering good will towards the industry.

Issues

Abandoned, lost, or improperly discarded nets and associated gear
Pollutants from culture gear
Loss of access to water column
Aesthetic impacts

Best Management Practices

1. Make periodic inspections and repair or replace damaged gear.
2. Assure gear is securely anchored.
3. Police site immediately following a storm event to ensure gear and materials are secure.
4. Remove all old or unnecessary gear and associated materials in a timely manner. Re-use, recycle, or properly dispose of all materials.
5. Fencing, water column nets, and closely set stakes are not considered to be best management practices. If absolutely necessary, additional permits are required.
6. In addition to your own, keep an eye on your neighbors' sites and equipment for vandalism and theft.
7. Prepare for winter conditions.
8. Secure or remove gear and be sure it is in good condition
9. Regularly monitor site
10. Conduct a spring cleanup with other growers
11. Do not use exposed lead to secure gear. Dispose of lead responsibly.
12. Use only durable, long-life materials. Materials that readily deteriorate (e.g. unprotected Styrofoam) are unacceptable.
13. Follow good neighbor practices with regards to noise. Restrict activities to daylight hours.
14. Where possible, try to be consistent in color scheme and design (e.g. uniform flotation, structures, rafts, etc.) to present a neat, orderly appearance.
15. Identify gear with tags.
16. Be on the lookout for abandoned gear from others. Always gather this and dispose of properly. Notify the owner of the problem, if possible.
17. Industry and the bay or river keepers might wish to establish an aquaculture gear hotline, similar to Virginia's Clam Net Hotline, for the public to report derelict gear. Industry should make a commitment to provide cleanup of any gear reported through this system.
18. All culture materials including cover nets, bags, markers, etc. should be clean and free of pollutants, including petroleum-based products such as creosote, oils, greases, or other contaminants.

D. Biological Fouling Organisms

Marine organisms that accumulate on submerged aquaculture gear are known collectively as biofouling. Among MD many others, these include tunicates (sea-squirts), mussels, and tube-building worms, as well as macroalgae (seaweeds). Although biofouling usually relates to attached organisms, the definition can be broadened to include drift macroalgae and the sloughed-off leaves of seagrasses that may be trapped by aquaculture structures.

Biofouling can become a problem when it clogs the mesh of grow-out nets, bags, and cages, cutting off water circulation to the shellfish. This can inhibit growth and ultimately kill the shellfish unless measures are taken to control the biofouling. Using a hand brush can usually remove most biofouling, especially macroalgae, on the surface of the structure. High-pressure spraying with water is especially effective for mud and sand tubes, especially if they accumulate inside the container. For more stubborn biofouling, the gear may have to be swapped out and dried in an upland location before cleaning, or perhaps even discarded. Chemical treatment of biofouling in not acceptable except for high-concentration brine dips.

There are environmental and aesthetic issues associated with biofouling control, especially concerning the destination of removed macroalgae. The macroalgae may accumulate downstream from the site, smothering organisms or leading to a buildup of organic detritus, or it may wash up on the shoreline, creating visual and odor problems. These concerns are conditions dependent and may not be an issue on a specific site.

Issues

- Water flow
- Macroalgal growth
- Odors and noise

Best Management Practices

1. Inspect gear and routinely to maintain adequate water flow to shellfish.
2. When practical, cleaning should be confined to the aquaculture site. Otherwise, old, heavily fouled gear should be removed and taken to upland sites for cleaning or disposal.
3. Sweeping with brush can remove most biofouling.
4. Do not allow removed material to accumulate on downstream sites where it may cause local environmental degradation.
5. Take care that removed macroalgae does not pose a nuisance. If so, transport to a more acceptable overboard or upland disposal site.
6. If using internal combustion engine, be aware of noise issues.
7. When drying gear be mindful of adjacent upland owners. Clean heavily fouled gear prior to dry storage.
8. Make sure that all upland cleaning activity is conducted at an approved site. Public access boat ramps and parking lots are not approved sites.
9. Do not use anti-fouling paints on shellfish culture gear.

E. Trash Management

Aside from primary gear such as nets, mesh bags, and stakes, aquaculture operations and workers generate other refuse, including used cable ties, old lines, broken baskets, leaking buckets, cans, bottles, plastic bags, cigarette wrappers, etc. It is essential that trash be managed responsibly, both for the environment and the success of the industry. The sight of garbage floating on the water or washed up on shore creates a negative image in the public′s mind, turning people against aquaculture.

Issues

- Effects of discarded or abandoned ancillary materials (cable ties, bottles, lines, baskets, etc) on the environment.

Best Management Practices

1. Remove trash from your grounds, even if not from your operation, and dispose of in an appropriate upland location.
2. Be conservative in using materials; re-use and recycle when possible. This also makes economic sense.
3. Educate members of the industry and their staff on the importance of waste management.

F. Habitat Protection

Among the important marine habitats are seagrass beds, or rooted vascular submerged aquatic vegetation (SAV), which supports a diverse community of animals. Seagrass often occurs in environments that are conducive to shellfish aquaculture, which potentially can affect each other.

Aquaculture activities, such as placing nets or other gear directly on the grasses, boat and foot traffic within beds, and some harvesting practices, can damage plants. The presence of SAV also makes the task of growing shellfish more difficult as nets are lifted off the bottom by the plants, allowing predators access to the shellfish. Sediment and detritus accretion can foul gear and suffocate animals; dissolved oxygen fluctuation and organic sediment common in seagrass beds can inhibit shellfish growth; and the structure of the plants (roots, rhizomes, and shoots) can make it difficult to harvest the shellfish.

On the other hand, the proximity of cultured shellfish to SAV can be beneficial to seagrass. Bivalves filter the water, improving water clarity, which is a limiting factor for SAV growth since plants need light. Shellfish transfer nutrients from the water column to the sediment, fertilizing the grasses. Seagrass seeds and reproductive shoots get trapped in netting, allowing plants to colonize previously unvegetated areas.

Avoid existing seagrass beds when planning an aquaculture operation. If the site is in shallow water, check with DNR for SAV maps but, more importantly, inspect the site during warm weather when the plants are actively growing to determine location and density. Destruction of seagrass through aquaculture is not acceptable and is prohibited in the bottom lease agreement.

Issues

- Damage to important habitat, especially submerged aquatic vegetation, from gear, traffic, and harvesting associated with aquaculture operations.

Best Management Practices

1. Conduct a site visit to a prospective growing area to ensure that it does not contain significant amounts of submerged aquatic vegetation.
2. Avoid planting shellfish or placing gear in existing seagrass beds.
3. If SAV invades areas of existing aquaculture, growers should avoid unnecessary damage to grasses.
4. Minimize damage to seagrass when operating vessels in SAV beds by running vessels at the lowest possible speed with the prop raised to avoid bottom contact.

III. Permitting

There are three major types of shellfish culture in Maryland: the culture of shellfish or seed in land-based facilities, grow-out on submerged (leased) bottoms, and off-bottom grow-out in containers suspended in the water column. State aquaculture permits are not required for grow-out on leased bottom, but harvesting or leasing laws can vary from county to county. Land-based systems will require an aquaculture permit, and may need to address water appropriation or discharge issues. Off-bottom grow-out requires a state aquaculture permit as well as approval from a joint state/federal program for navigable waters (with final approval from the Maryland Board of Public Works).

A Shellfish Import Permit is required for imports across state lines that are destined for placement in the waters of the state. Harvesting and selling seafood, particularly for human consumption, may require Water Quality Certification and harvesting permits discussed in the section on Human Health Issues.

A. Shellfish Bottom Leasing

There are three ways to obtain control of Shellfish Bottom Leases in Maryland. The typical method for obtaining a lease involves checking charts for Natural Oyster Bottom or designated Clam Bottom, then examining areas outside of these for suitable locations. A number of factors determine what might be a suitable location, and it is the responsibility of the applicant to make these decisions, see section I, Site Selection and Access. Applications returned with the appropriate non-refundable fees are followed by a hydrographic and biological survey of the site (see the *Shellfish Leasing flow chart*). Lease applications are then posted for public comment for four consecutive weeks in that county. Discovering commercial quantities of clams or oysters on the site, as well as evidence of recent harvests there, may result in the denial of a lease application.

Another avenue may be to locate abandoned leases in an area, and apply in the same way as for a new lease. Often areas that have been leased in the past are more easily prepared or used for shellfish culture. There are a number of abandoned leases, but about half of the tidewater Chesapeake Bay counties are “closed” to new leasing, particularly in the upper Bay area. These closures were requested by the affected counties and are legislated. Previous leases are honored, but new leases are prohibited.

A third approach would be to transfer an existing parcel from a current leaseholder. Transfers require only a $5 fee. In all cases the recipient of the lease must also meet the standards required of an applicant or leaseholder, such as full-time residency in Maryland and prompt payment of fees or rents.

Maps of existing leases, charted natural resources and cancelled leases may be obtained from the Hydrographic Operations office at the DNR Matapeake Work Station. This office receives applications and performs the hydrographic survey. It should be noted that a number of statutes affect the size, area controlled, and harvest methods used on leases; these laws are located in the *Natural Resources Article, ''4-11A-01 through 15*.

B. Land-based Shellfish Aquaculture

Shellfish aquaculture facilities on land (without water column or bottom rights) will require a state aquaculture permit. Aquaculture permits are issued by the Department of Natural Resources (as required by *'4-11A-02 (2)(b)*) to protect wild stocks of fish, identify fish as products of aquaculture operations rather than natural resources, and serve as a primary entrance to other required permits.

Applications for an aquaculture permit are available directly from the permit coordinator in the DNR Fisheries Service or on-line at the Department=s website. Applications for an aquaculture permit should include site plans and descriptions, maps to the facility, a solid waste management plan for disposing of processing wastes or mortalities, and (if employing others) a certificate of compliance with state workman=s compensation laws.

The species to be raised and its origin must be detailed. Permit holders must keep production records quarterly, and report yearly production to the Department.

For land-based aquaculture, water appropriation and use permits may be required, as well as discharge and/or NPDES permits, pond construction or mining permits (depending on the extent of proposed activities). Appropriate county zoning and use permits must also be obtained. It is the responsibility of the applicant to obtain appropriate county permits. Zoning variances, critical area activity applications, and building permits may be required. Permits may also be required for conducting commercial activities, especially in residential areas.

On land as well as in state waters, water quality criterion for the harvest of shellfish for human consumption must be met. Contact the Department of Health and Mental Hygiene’s Office of Food Protection and Consumer Health Services to inquire if such standards apply to shellfish grown or held in land-based systems.

C. Off-bottom Shellfish Aquaculture

Shellfish culture (not on leased bottom) in public waters involves areas perceived to be utilized by multiple stakeholders, including recreational and commercial fishers, boaters and adjacent landowners. Permission to raise shellfish in navigable waters includes a state aquaculture permit and a Tidal Wetlands License, which is available from the Department of the Environment’s Water Management Administration (see the Off-Bottom Aquaculture flow chart). A permitted area may not exceed 5 acres per individual. Two persons may jointly obtain a permit for up to 10 acres. A single permit may include more than one location.

Activities may not interfere with ongoing oyster bottom leases or fisheries at the same location, and aquaculture is not permissible over charted natural resources or protected State oyster sanctuaries or reserves. In some designated Oyster Recovery Areas, typically in upper reaches of major tributaries, only oysters free of specified oyster diseases may be stocked.

Following an application for an aquaculture permit, an application for a Tidal Wetlands License (required in navigable waters, and for the alteration of any flood plain, tidal or nontidal wetland in Maryland) is normally the next step in receiving approval to conduct aquaculture in State waters. The Tidal Wetlands License is a joint Federal/State application, submitted to the MDE Water Management Administration, Regulatory Services Coordination Office. This joint permit application receives a tracking number and is distributed by the Water Management Administration to the appropriate agencies.

The U.S. Army Corps of Engineers (ACE) will coordinate efforts with other Federal agencies, such as the Environmental Protection Agency, Fish and Wildlife Service, and National Marine Fisheries Service. The MDE Tidal Wetlands Division will coordinate with other State agencies, including the Chesapeake Bay Critical Areas Commission, the MDNR Environmental Review Unit, Natural Resource Police and Boating and Hydrographic Operations Unit, the Maryland Historical Trust and the MDHMH. MDE will also contact the local Planning and Zoning offices. Upon receipt of the Tidal Wetlands License application, all agencies involved will initiate procedures for issuing any other necessary permits. These permits may include a water use permit, waste water discharge permit and Section 401 Water Quality Certification.

The Tidal Wetlands License application review involves issues of conflicting uses of the waterway, as related to activities in navigable waters and land-based operations. Many of the impacts of aquaculture are reviewed, and may include conflicts with established recreational and commercial boating or fisheries, water quality impacts, the protection of submerged aquatic vegetation, boating safety issues, and the like. These considerations are important with the understanding that any water column aquaculture enterprise will impact public rights and traditional uses of the waters, at least to some degree.

A major consideration is that the use of an area for aquaculture does not unreasonably impair navigation. For example, an aquaculture site may not be within a navigable channel marked or maintained by a State, local, or federal agency, or unreasonably interfere with the exercise of riparian rights by adjoining riparian landowners, including access to navigation channels from piers or other means of access.

For many projects at and above 500 square feet of surface area used, a lease of State real property is required. A lease is required because the structures would occupy State Tidal wetlands or waterways for commercial benefit. Following public review and processing of the application, the MDE Water Management Administration makes a recommendation to the Maryland Board of Public Works Wetlands Administration concerning issuance of a Tidal Wetlands License and the granting of a water column aquaculture lease by the Board. Upon approval by the Board, a prescribed one-time license fee is paid to the Board and a rate-per-acre fee is set. The annual fee is paid through the Department of Natural Resources to the State Treasurer for the term during which a pertinent water column lease is valid.

D. Shellfish Import Permit

To protect the shellfish resources of the state from introduced diseases and parasites, imports of shellfish which are destined for immersion in state waters require prior approval (*'4-743, Quarantine of shellfish*). Diseases of the most concern are developed by the Aquatic Health Management Committee under the Aquaculture Council in cooperation with the Department of Natural Resources, to ensure protection of both natural resources and other aquaculturists who may be affected by disease-causing agents.

An application for a Shellfish Import Permit, and listed diseases, may be found on the DNR website (www.dnr.state.md.us). A Certificate of Health (examining for specific diseases or parasites) may be required from the importer prior to approval. The application should be submitted 30 days before a planned shipment; contact the Permit Coordinator at the Department of Natural Resources in advance of any application to determine the animal health status that is required for a given species.

Best Management Practices

1. Contact the Aquaculture Coordinator prior to applying for permits for shellfish culture other than shellfish leases. Specific limitations to and permits required for different types of aquaculture operations are dependent on the proposed activities.
2. File reports required by permit agencies in a timely manner.
3. Contact the Department of Natural Resources for harvesting or planting restrictions on shellfish bottom leases in specific counties or restrictions on shellfish introductions based on disease status.

IV. Human Health Issues

Molluscan shellfish such as clams, oysters, scallops, and mussels, are filter-feeding organisms. They strain surrounding water through their gills which trap and transfer food particles to their digestive tract. If the water is contaminated with disease-causing bacteria, these bacteria are also trapped and consumed as food. Because shellfish pump large quantities of water through the gills each day, bacterial concentrations in shellfish from polluted waters can accumulate to dangerous levels.

Shellfish can be contaminated either in a growing area before harvest or during activities involved in harvesting, processing, or distribution. Since shellfish are routinely eaten raw or partially cooked, the risk is high that if shellfish contaminated by polluted waters or poor handling practices are consumed, human illness will result.
Therefore, to assure that molluscan shellfish are safe for human consumption, it is mandatory that shellfish be harvested from approved harvest waters and be harvested, handled, and processed in a sanitary manner.

The Maryland Department of the Environment (MDE) is responsible for conducting sanitary surveys of all shellfish growing waters. This includes monitoring and assessing shellfish waters and the adjacent shoreline to properly classify shellfish harvest waters. The Maryland Department of Health & Mental Hygiene (MDHMH) is responsible for the inspecting, licensing, and certifying shellfish dealers to control the processing and distribution of shellfish.
Management Consideration

1. Classification of the shellfish growing waters determines if shellfish aquaculture may be conducted at a specific location.
2. License and certification will be required to harvest shellfish for human consumption.

A. Site Selection of Traditional On-bottom and Surface Aquaculture

Select sites that have the least variability in water quality, meaning areas where water classification is consistent or remains unchanged. Classifying shellfish waters is an on-going process because water quality is dependent on many uncontrolled factors and the shellfish water classification for any given area is subject to change. An aquaculture business should be aware of and be able to adapt to the potential change in shellfish water classification.

Contact MDE to determine the classification of the proposed aquaculture site. Four classifications are possible:

1. Approved- direct harvest of product allowed
2. Conditionally Approved- direct harvesting allowed when the conditional area is in the open status
3. Restricted- no direct harvest allowed, relay required
4. Prohibited- growing or harvesting of shellfish not allowed

A site may be turn out to be unclassified because the MDE has not made appropriate investigation through sampling and shoreline survey to determine its classification. If the site is unclassified it will take between 18 months and 3 years to gather suitable data to determine the classification.

It is best to find a site that is classified as approved where direct harvesting is permitted at anytime. Restricted sites require relay, where shellfish are harvested and moved to an approved area for natural cleansing. There are water temperature and seasonal restraints in using relay. See *Procedures for Relay* … for relay requirements. It is the responsibility of the aquaculturist to locate a suitable relay site and get written permission for its use.

B. Site Selection of Off-bottom, Near-Shore Aquaculture

Off-bottom aquaculture of shellfish in floats is often conducted in areas that have traditionally had no known shellfish population or harvest. Because shellfish sanitary surveys for classification are conducted in areas that have a known shellfish harvest the near-shore sites are often unclassified.

Established sampling stations for natural oyster bottom and lease bottom shellfish do not capture the water quality on the surface; therefore the sampling data may not be applied to a near-shore off-bottom aquaculture site. In order to classify an area MDE must conduct an appropriate investigation of the site through a thorough assessment of the site to include sufficient water sample results to determine water quality and a shoreline survey. The process can take 10 to 18 months before preliminary classification can be determined. The other licenses issued by MDE, BPW and ACE as outlined in section III, Permitting, of this document will not be issued until the classification is determined. Growers should have an approved relay site available since shellfish water at off-bottom, near-shore aquaculture sites is typically classified as restricted.

C. Land-based Aquaculture

1. Local zoning laws may apply.
2. Tanks, pumps, and lines must be constructed of food-grade materials.
3. Water classification requirements are dependent on the type of operation.
4. Wet storage, which is the storage of shellfish after harvest in tanks for purging or salting, requires a DHMH license.

D. Harvest and sale

Molluscan shellfish are susceptible to contamination during harvest, storage, and transportation. Temperature abuse of harvested shellfish allows bacteria to grow in the shellfish which may cause illness and shorten shelf life. To assure that post-harvest shellfish sanitation is maintained, license / certification is required from the MD Department of Health and Mental Hygiene. To gain this license / certification, an aquaculturist must have:

1. Received the required permits from DNR, MDE, BPW, and ACE to operate the aquaculture site;
2. An approved relay area if site is classified as restricted;
3. Taken Hazard Analysis Critical Control Point (HACCP) training;
4. A written operational plan; and
5. A HACCP plan

It is best to contact DHMH, complete HACCP training, and develop plans before shellfish are of harvest size.

V. Biological Management

Successful shellfish culture depends upon having access to sufficient supplies of high quality water. The parameters that are required depend largely upon the species being cultured and the use of those species. Species destined for human consumption will also be expected to be cultured in water that meets standards developed by government agencies designed to protect human health. Location of an aquaculture operation at a site with poor water quality is usually problematic and should be avoided.

A. Water Quality for Shellfish Growth and Health:

Site selection should result in locations that provide the water quality parameters necessary for good growth and survival of the species being grown. Issues include:

1. Salinity: The amount of salt in the water can be highly variable both seasonally and from year to year. Care should be taken to insure that those variations are not so severe as to cause problems with either growth or survival of the shellfish.
2. Temperature: Water temperatures also vary seasonally and geographically within Maryland. As with salinity, care should be taken to insure that those variations are not so severe as to cause problems.
3. Dissolved Oxygen: Many water sources experience fluctuations in dissolved oxygen with severe cases resulting in hypoxia or anoxia. Either of these events are capable of causing problems during culture either in growth or survival.
4. Suspended Sediments: Heavy sediment loads can cause problems with culture. While usually not as severe as A, B, and C above, extremely heavy sediment loads should be avoided.
5. Algal Blooms: Many shellfish are filter feeders and as such depend upon algae for growth. The presence of sufficient quantities of high quality phytoplankton will largely determine the growth rate and impact the survival of the crop. Where possible, care should be taken to locate shellfish operations where advantageous algal blooms are typical
6. Harmful Algal Blooms: Harmful algal blooms (HAB's) are common in Maryland and around the world. Their occurrence is increasing and both periodicity and severity. Not all HAB's are harmful to shellfish growing operations but many are. HAB's can cause growth to stop or cause mortality. There may also be

human health risks associated with HAB's. Location of a shellfish growing operation in locations where regular HAB's occur could result in unmarketable product for at least part of the year.

7. Disease: Shellfish are prone to several diseases and some of these can cause huge mortalities in the crop. Potential growers should become familiar with those diseases likely to effect their crop and the water quality conditions necessary for them to proliferate. It may be possible to locate all or part of an operation away from some water quality parameters to minimize effects of disease.
8. Polluted Waters: There are many types of pollutants possible in any water source. In general, it is recommended that shellfish growing operations be located away from waters that contain toxic pollutants. While impossible to list all potential pollutants in this document, some of the more commonly encountered are:
   - runoff from industrial or urban areas
   - point source discharge from industrial or sewage treatment plants, marinas (which may contain high concentrations of anti-fouling chemicals) and
   - areas subject to episodes where heavily polluted bottom sediment may be stirred up and re-suspended

In summary, BMPs for shellfish culture should incorporate all of these issues. It should be understood that often more than one of these water quality concerns will be an issue at a site. The presence of a single water quality issue may not be a make or break decision but many of them are. Often the presence of several of these issues, while even on a minor basis, may jointly become severe and render the shellfish culture operation ineffective.

B. Restoration Shellfish Aquaculture

A recent emphasis in Maryland has been the production of shellfish for use in restoration programs. While most of the above concerns apply to this specific type of aquaculture there may be instances where some of them are not applicable. For instance, water quality associated with human health issues need not be applicable to shellfish used to restore sites that are not designated for human consumption. Also, production of some stages of the shellfish life cycle may be able to be cultured even in the face of some water quality issues if they will be re-located to other sites sometime during their life cycle. BMP=s for restoration aquaculture may be very different than those recommended for shellfish destined for harvest and subsequent human consumption.

In summary, it is best to locate any aquaculture operation away from water quality problems. The benefits to not only the species under culture but also to the amount of regulatory issues that need to be dealt with in order for the crop to be sold for human consumption.

C. Genetics

Shellfish growers may benefit from recent advances in the field of genetics. Hatchery production of oysters, clams and other shellfish species are generally produced through the use of wild broodstock or from broodstock that have been produced in other hatchery operations. Recently, researchers have successfully produced broodstock that may result in superior performance for farming. Much of this effort has been targeted on the development of oyster stocks that survive to market size in the face of disease and yield (the product of survival and growth). For example, several stocks have been developed by the Mid-Atlantic Shellfish Genetics and Breeding Consortium that have been used to produce market sized oysters in areas impacted by disease. This work is ongoing and some success is evident in the growth of oyster culture especially in Virginia. Further success is anticipated with additional improvements in traits, such as shell growth, meat quality, or shelf life. Selection, particularly by commercial hatcheries themselves, has also begun on hard clams and it is likely that future research could include other economically important species as the need is identified.

Another aspect of genetics is ploidy manipulation. It is possible through hatchery manipulation of the fertilization process or using tetraploids to produce shellfish that are triploids (three sets of chromosomes, like many domesticated plant species). Triploids have been a valuable tool in many shellfish grow-out operations around the world and increasingly in aquaculture in the Bay. Since triploids do not expend much energy producing gametes they may exhibit increased growth. The extent of this growth advantage can only be determined by deploying them in specific grow-out systems and recording their performance over non-triploid animals. Another benefit of triploid animals is that they do not spawn and therefore they do not undergo a dramatic loss of meat quality during the spawning season like their diploid counterparts. This can result in a superior quality product to market during periods of the year when diploid animals are difficult to sell. Finally, a third advantage of triploids, because they are sterile, is that they can be farmed in close proximity to natural populations of shellfish with no effect on the population genetics in wild animals. That is, they can not interbreed with natural populations (or themselves) making it possible to juxtapose farming and restoration.

Despite the use of domesticated stock for farming, hatchery operators should still consider proper fertilization techniques that insure the maximum genetic diversity among the larvae produced. Failure to use reasonable number of parents for larval batches could result in partial or total larval failure. Even in batches of larvae that successfully complete the larval period and result in seed stocks, limiting the number of broodstock can result in genetic bottlenecks that could begin to express themselves in poor performance of the stocks over time.

For restoration aquaculture, genetic considerations may be quite different than for farming. Typically, every effort should be made to insure that the “effective population number” of parents is as high as possible. For one, restoration animals are planted in the environment with the expectation that they will survive, grow, and contribute to the natural recruitment of the species in the region. There have been concerns raised over the potential for creating genetic bottlenecks in the wild populations that could ultimately have deleterious effects on the naturally occurring stocks. Conversely it has also been proposed to use selected stocks (which by design have some degree of bottlenecking) to infuse desirable characteristics into stocks suffering from disease. Neither of these concerns has been adequately proven and it remains to be seen whether shellfish growers will need to be concerned with special genetic practices for restoration in the future. However, there are some simple steps that can help to moderate any ill effects from hatchery planting of oysters for restoration.

Most restoration projects are fairly large in scale involving millions of animals. Additionally, most sites receive seed oysters more than once and in multiple years. One approach to minimizing potentially harmful effects of limited parental contribution is to plant seed oysters from spawns produced from as many parents as possible, to plant sites with seed oysters from multiple spawns, and to plant sites with multiple year classes. Unless broodstock are collected from the population that is being restored ‘ a practice surely to result in population bottlenecks ‘ using multiple spawns over multiple years will increase the number of parents that contribute to the genetic diversity of the population on the restored bar.