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Preface

This document is intended to respond to a growing demand for information on intensive, off-bottom aquaculture of the eastern oyster, *Crassostrea virginica*, in Virginia and neighboring coastal states. Over the past few years the number of individuals involved in intensive oyster aquaculture in Virginia has increased dramatically, and we now estimate that over 2000 separate off-bottom oyster culture operations are underway within the coastal waters of Virginia. Individuals involved in this activity include non-commercial *gardeners*, traditional watermen and members of the well-established hard clam aquaculture industry. In addition to growing oysters for personal consumption and marketing, an increasing number of individuals are participating in the activity to supply oysters for environmental restoration projects.

This publication represents an attempt to fulfill the need for an introduction to culturing oysters. The approach described here reflects a strategy which we have been developing and refining over the past 10 years. It is neither complete nor exclusive. It is directed towards the culture of *C. virginica* in areas where the common oyster diseases Dermo and MSX (caused by the pathogens *Perkinsus marinus* and *Haplosporidium nelsoni*, respectively) are endemic and it includes information for both commercial aquaculturists and non-commercial gardeners. This publication is revised from a 1997 edition and contains new information about the status of selective breeding programs, regulations in Virginia related to oyster aquaculture and non-indigenous oyster species. We have also attempted in this revision to provide a listing of more reference materials for individuals interested in further reading. As in the past, our experiences are drawn largely from work in Virginia, but the general strategy should be applicable in many locations from southern New Jersey south along the U.S. Atlantic coast.

It is never quite the right time for a publication of this type. Refinements in techniques and new lessons learned from failures are ongoing. Nevertheless, we offer this in the hope that it will provide an outline of the major components of culturing oysters in the region.

Historical Perspective

It is now clear that a prominent feature of the Chesapeake Bay, and other estuaries along the U.S. Atlantic coast, were large, structurally complex oyster reefs.[1,2] These reef environments not only provided critical habitat for the survival and growth of oysters,[3-5] but it is becoming increasingly clear that they were important habitat for other commercial and non-commercial species.[6-9] Additionally, the oysters and other suspension feeders on these reefs likely affected water quality, phytoplankton abundance and food web structure within the Bay and similar estuaries.[10-12] Critical features of these reefs included 3-dimensional relief above the seabed, interstitial space within the fabric of the reef surface and multiple year classes (>10) of oysters.

The demise of Virginia's oyster fishery has been over 100 years in the making. The initiation of this decline had as much to do with the development of the steam canning process in the 1870's as it did with pollution and disease. This process made possible the wholesale over exploitation which ultimately led to reduction of populations below those capable of coping with natural threats or sustaining a fishery. The virtual elimination of natural oyster reef habitat and alteration of population structure to include only a few year classes fundamentally changed the nature of the resource.

During the past few decades oyster populations in Virginia have been particularly hard hit by the sustained presence of two parasite-induced diseases (MSX [caused by *Haplosporidium nelsoni*] and Dermo [caused by *Perkinsus marinus*]). These protozoan parasites have been found at record high levels in recent years; Dermo has now spread to all public oyster beds in Virginia and accounts for 70 to 90% mortality in most.[13] Clearly the presence of these diseases present major challenges to current efforts to restore wild populations of oysters and develop oyster aquaculture.

Diseases

Contrary to popular accounts these diseases are not caused by viruses, but rather by single-celled protozoa. The causative agent of MSX is *Haplosporidium nelsoni*; Dermo results from infections by *Perkinsus marinus*. Neither parasite is harmful to humans and no threat is posed by consuming shellfish infected with either parasite. *P. marinus* is endemic to the area and Dermo disease has likely afflicted oyster populations for a long time,[14] but the origin of *H. nelsoni* is less certain.

Both parasites thrive in salinities above 15‰ and exhibit lowered virulence at lower salinities. Below about 10‰ *H. nelsoni* is eliminated from its host, while *P. marinus* persists at lower salinities but does not reach pathogenic intensities. Transporting of oysters infected with *P. marinus* from low salinity to higher salinity (above 15‰) will generally result in rapid disease progression.[15-17]

New infections of both *H. nelsoni* and *P. marinus* generally occur during warmer months with the peak period for new Dermo infections generally occurring in August and early September in Virginia.[14] MSX infections can arise from May through September, yet the life cycle of *H. nelsoni* and the mode of infection remain unknown. Although observed levels of the parasites in oyster tissues are reduced in the wintertime, infections are not eliminated by current "normal" wintertime temperatures.[14] The pathology of MSX infections can be confined to local outbreaks resulting in fast acting and high mortality events. Dermo infections tend to be more chronic and result in high cumulative mortality, the levels of which can rival that of MSX.

Disease Resistance and Selective Breeding Programs

There is an abiding hope by many that a disease resistant oyster will someday be available for both aquaculture and restoration of wild stocks. Research related to this goal has generally followed three lines: (1) the search for natural strains of the native oyster which exhibit some disease tolerance; (2) selective breeding programs; and (3) investigations with non-indigenous oyster species. The first has been the focus of several researchers who have identified variations in disease susceptibility in natural populations.[18,19] The widely used practice of using large, old (and presumably, therefore, disease resistant) field-collected animals as brood stock by some hatcheries is representative of this strategy. Problems with this approach include the unverified nature of disease exposure among the brood stock and the uncertainty of resistance to both of the major diseases.

Selective breeding programs begin with natural variation among wild populations and select for desired traits. For the eastern oyster, development of dual resistance to both *Perkinsus marinus* (Dermo) and *Haplosporidium nelsoni* (MSX) has been the priority. The most successful of these efforts was initiated at Rutgers University over 35 years ago. Selected lines of oysters were developed with a high degree of resistance to MSX.[20] These stocks initially proved to be highly susceptible to Dermo and slow growing,[21] but subsequent selection efforts have made significant improvements in both of these areas. The current oyster breeding program, known as CROSBreed (Cooperative Regional Oyster Selective Breeding program), is a multi-state cooperative effort to further develop and test these oyster lines. Currently, under the direction of the Aquaculture Genetics and Breeding Technology Center (ABC) at VIMS, this program has developed a hardy strain of oyster which exhibits good growth rates and reduced susceptibility to both MSX and Dermo in low to moderate salinities (approximately 10-25‰). However, the performance of this strain of oysters in higher salinity has not yet been established. CROSBreed oysters have been distributed to commercial hatcheries, and seed from these lines may be purchased from these hatcheries. As discussed below in the section on Purchasing Seed and Materials, it is not advisable to publish a fixed list of seed suppliers which sell this or any other strain–it would likely be out of date by the time the ink was dry. Rather, we provide in the Appendix a list of contacts within VIMS and other organizations which should between them be knowledgeable about seed availability in any given year.

It is important to note that selective breeding is an ongoing process and that even as one generation of CROSBreed oysters has been distributed to hatcheries, another generation is being developed and tested. We fully expect that no one strain of oyster will meet all needs and that some day, as Dr. Standish Allen, Director of the ABC notes, "you will be able to purchase your oyster seed from a catalog, selecting the seed most appropriate for your environment and farming practice." Selective breeding programs are, however, unlikely to develop the "perfect oyster" and diseases likely will remain a significant issue, requiring a comprehensive management approach as described below.

One final avenue for acquiring a disease resistant oyster that has received attention in recent years is the use of non-indigenous or exotic oyster species. Existing data suggest that at least two other oyster species, the Pacific oyster (*Crassostrea gigas*) and the Suminoe oyster *(Crassostrea ariakensis*) are less susceptible to Dermo and MSX than our native oyster. It is beyond the scope of this publication to discuss all of the ecological and legal issues surrounding the importation and use of a non-indigenous species. We note, however, that ***it is illegal to introduce a non-indigenous species into Virginia coastal waters without approval of the Commissioner of Fisheries*** and similar requirements apply in other coastal states. Given the uncertain state of our current knowledge of the ecological and economic consequences of introducing an exotic oyster species, we think it unlikely that such an action will be approved in the near term. New technologies, currently under development in the VIMS ABC, may facilitate the production of reproductively sterile exotic oyster species and speed approval of their use in aquaculture. Presently, however, the native oyster is the only game in town. Fortunately, by following the few simple steps in the strategy outlined below it is generally possible to culture the native oyster to market size, even in disease endemic waters.

Overview of the Strategy

Growing native oysters in the presence of these diseases requires an integrated strategy which emphasizes (1) brood stock selection, (2) management around disease and (3) rapid growth to harvest size. All too often attempts to culture oysters have focused on just one of these components to the exclusion of others; for instance, the development of a "super" disease resistant oyster or a particular containment system for holding oysters off the bottom.

<u>Brood stock selection</u> - The foregoing section discussed the importance of brood stock selection programs and described one such program (CROSBreed). We stress again that, while disease tolerant oyster lines have been developed, it is unlikely that a fully disease resistant oyster will ever be realized. A more realistic scenario is that continuing small improvements in the disease tolerance of oyster stocks will enhance the success of integrated approaches to oyster culture.

The most important point for the oyster culturists with respect to brood stock selection is to ensure that seed is purchased from a hatchery which has used the *best available* brood stocks, by which we mean oysters with a proven record of good growth and survival in disease endemic areas. As the evaluation of wild stocks from different regions and breeding programs progress, we expect that the best available stocks will change and, as noted above, may become site specific.

<u>Managing around disease</u> - The second component of our strategy for culturing oysters is to manage around the diseases. One approach is to grow oysters in low salinity sites. Below 10‰ *Haplosporidium nelsoni* does not persist and, while *Perkinsus marinus* can survive at these salinities, it does not cause mortality. Raising oysters throughout the entire growing cycle in low salinity can be an effective means of avoiding disease, but it results in a very watery tasting oyster which is generally regarded as less desirable. Moreover, oysters grown at some low salinity sites are at risk of mortality from freshets.

A temporal approach to managing around diseases, particularly Dermo, can be effective. June through early September is the period within Virginia during which new infections of *P. marinus* generally occur and existing infections intensify.[14] By avoiding exposure to the pathogen during the early stage of seed production, it is possible to limit oysters to a single disease exposure period (summer) during the culture cycle. As noted above, this level of exposure to *P. marinus* is generally not sufficient to cause mortality in hardy oyster stocks. Seed producers may dramatically reduce the risk of *P. marinus* exposure by spawning oysters in late June to early August (so that the seed do not go into overboard nurseries until the major disease threat has passed).

Box 1

Fall Seed

1st Fall →	1st Winter →	1st Spring →	1st Summer →	2nd Fall →	2nd Winter →	2nd Spring →	2nd Summer
good growth	poor growth	good growth	poor growth	good growth	poor growth	good growth	poor growth
			disease exposure				**disease exposure**
				Harvest →		→ *Harvest*	

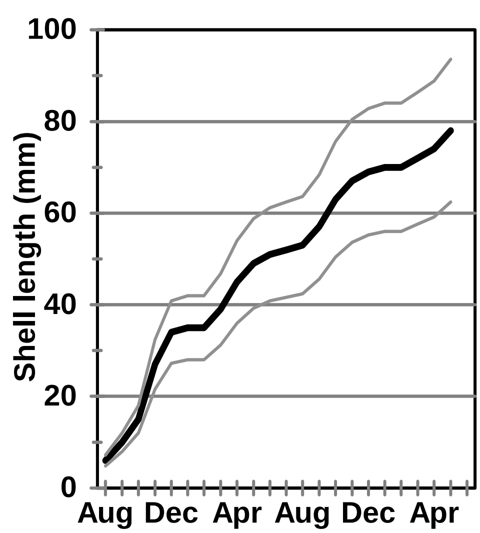
<u>*Spring Seed*</u>

1st Spring →	1st Summer →	1st Fall →	1st Winter →	2nd Spring →	2nd Summer
good growth	poor growth	good growth	poor growth	good growth	poor growth
	disease exposure				**disease exposure**
				Harvest →	

Over the past 10 years we have advocated a strategy whereby oyster culturists purchase *fall seed*. That is, oyster seed spawned in July or even early August and moved to nursery facilities when the threat of disease exposure is reduced. This strategy maximizes the number of growing seasons prior to reaching two disease exposure seasons (see Box 1). We define growing seasons as the fall (September - November) and spring (March - May) periods during which oysters in Virginia generally experience the greatest growth and disease exposure seasons as June through August. Each of these periods are, however, approximations and variations are observed both spatially and temporally.

The use of *fall seed* is predicated on achieving very rapid growth during the first fall season (see Box 2). In our experience, failure to achieve this results in small oysters (less than 35 mm) entering the winter months and a much reduced likelihood that oysters will reach harvestable size prior to succumbing to disease. Among the many examples of successful oyster culture in Virginia over the past 10 years, have been several cases of alternative approaches to the fall seed strategy. *Spring seed*, spawned as early as

Box 2. Idealized growth curve for cultured oysters using *fall seed*. Middle line represents average growth at a good growing site; upper and lower lines represent excellent and poor sites, respectively, within the expected range.



March, has successfully been used by numerous growers. While this approach provides for fewer growing seasons prior to two disease exposure seasons (see Box 1), it does avert the risks posed entering the winter with small oysters. We have generally observed this strategy to work at sites where very high growth rates are achieved, such as the high salinity environments of the Atlantic side of the Eastern Shore, permitting growth to harvest size in 14 months or less. Further, some individuals have had success growing oysters which were spawned during May or June and placed in the field during July. Successful use of these *summer seed* would appear to require a culture site with only modest disease exposure risk. For the oyster culturist it is most important to **ensure that the seed you purchase is disease free** at the time of the purchase and that they were produced from the best available brood stocks.

A final aspect of temporal disease management is to harvest oysters before they enter their second summer when *P. marinus* infections are likely to intensify and the oysters succumb to Dermo. It is better to eat a 2½ inch oyster in April than to wait a few months for it to grow larger and lose it to disease.

Grow them fast! - The third component of the strategy is rapid growth to harvest size. This has generally been achieved in off-bottom culture, in which oysters are suspended above the bottom in bags or floats. The principal behind this approach is that both the quantity and quality of the food available to the oyster is improved when suspended in the water column. Unfortunately, there are no strict guidelines with respect to the best position in the water column to place the oysters. Often raising the oysters as little as 6 inches above the bottom is sufficient to reduce the amount of suspended sediments which they must filter and improve their growth rates, but performance is very site specific and depends on the bottom type, water depth and food availability. Placement of oysters in racks or bags in the intertidal can have advantages which include access to oysters, fouling control and predator protection; however, extended exposure reduces the feeding time available for oysters and reduces growth rates. If intertidal culture sites are used, oysters should be placed in the low intertidal to reduce exposure to extremes of heat and cold.

Box 3 Highlights of the strategy:

- Purchase disease-free seed produced from the best available brood stock
- Select a good growing site
- Protect oysters from predators with appropriate meshes
- Keep meshes clean and unobstructed
- Harvest oysters as soon as they are large enough

The quantity and quality of food available to oysters can vary considerably between locations and is a function both of the hydrodynamics at a site and the abundance of phytoplankton in the water. At present the best approach for an oyster grower with access to more than one site is to experiment with different areas to determine the site which affords the best growth. Others confined to a single location may have to evaluate different seed stocks and handling strategies in order to maximize oyster growth and survival.

Oyster growth rates are also dependent upon salinity. Below 10‰ oyster growth rates are generally reduced compared to higher salinities; some stocks show intermediate growth rates at salinities between 10 - 20‰ and highest growth rates at high salinities, but that may be a function of heritage. As noted above, we expect that oyster seed bred for selected salinity regimes may be available in the near future.

Containment Systems

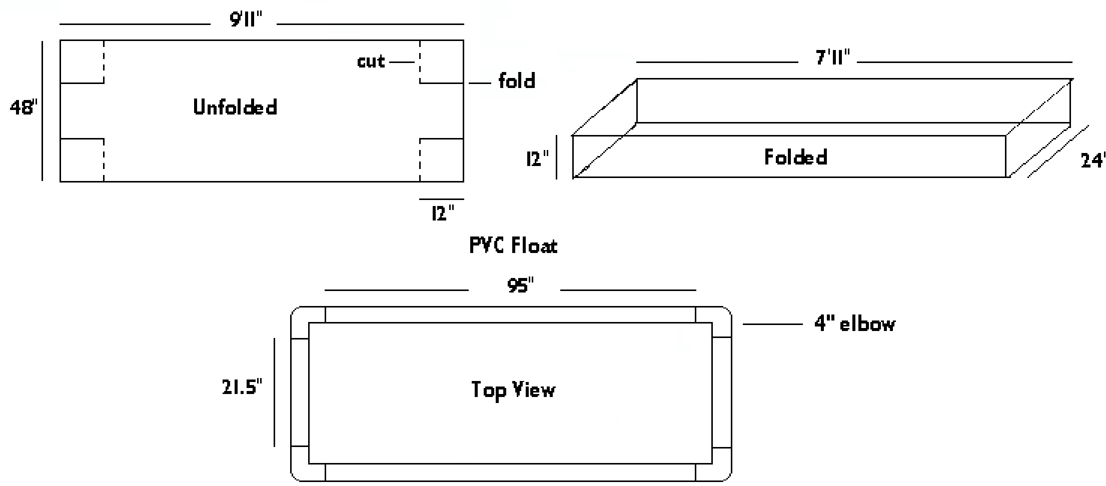
A wide range of options are available for maintaining oysters off the bottom, each combining advantages and disadvantages. Published methods include the use of fixed racks, floats and suspended bags—e.g. the flexible belt[22] and the chub ladder system.[23] No single method will work for everyone and no single method guarantees success. Each grower must consider characteristics of the growing site and his or her handling capabilities. We describe a particular containment system below, but do not mean to imply that it is the most desirable for everyone. Recently a number of different modifications of this system has become commercially available.

The important features of any system for maintaining oysters in off-bottom culture are (1) adequate predator protection, (2) minimal flow obstruction, (3) ease of maintenance and handling, and (4) low cost. Additionally, it may be necessary, depending upon location, to consider the impediments of navigation or aesthetics associated with the structures.

<u>Taylor Float</u>

The Taylor float, so called because much of the design and original testing was done by Jake Taylor, is constructed of 4 inch diameter PVC pipe and galvanized wire (Box 4). The float is approximately 2 ft x 8 ft x 1 ft deep and is of sufficient size to grow 1,500 to 2,000 oysters to market size. Lightweight, schedule 20 PVC drain pipe works as well as the more expensive schedule 40 pipe. Sizes of the pipe and the number of fittings are shown in Box 4. The mesh cage of the float is generally constructed of 1 inch square, double-dipped, 16 gauge galvanized hardware cloth, cut and folded as shown in the figure. The plastic-coated form of this wire generally sells for about 20% more than the un-coated, but that is more than offset by an extended life, especially in high salinity sites. The wire cage is then attached to the PVC float using 14.25" cable ties.

Box 4. Schematic of Taylor float construction and approximate materials cost.



Materials for 1 Taylor float: Approximate Cost

- ❑ 10' x 4' double-dipped 16 gauge vinyl coated wire, 1" x 1" squares 15.90
- ❑ (2) 10' lengths of 4" schedule 20 gauge PVC pipe. 6.70
- ❑ (4) 4" schedule 20 gauge PVC 90° elbows 5.00
- ❑ (20) 14 ¼" black plastic cable ties 2.70
- ❑ 1"x 3"x 8' wood strip for lid 1.85
- ❑ 3' x 8' filter cloth for lid 1.00
- ❑ Gray PVC glue & PVC cleaner 1.00
- ❑ 24" #8 crab pot line 0.60
- ❑ ½" stainless steel hog rings 0.50
- ❑ Miscellaneous 2.00

Total $37.25

Some tips for making floats

G The wire is generally purchased in 100 ft rolls which may actually vary in length by several inches. Roll out your wire first and measure the total length before cutting. That way if the roll is a little short, you can spread those missing inches among the cuts and still get 10 floats per roll.

G Clean and glue the pipe joints well. Water in your pipes can sink the float!

It is important to attach zinc bars as sacrificial anodes to this mesh to reduce corrosion and extend the life of the float. Oyster seed which are too small to be retained within the 1 inch mesh may be placed inside mesh bags (described below) which are then placed within the float. As the sizes of the oysters increase, the mesh size of the bags should also be increased and the densities of oysters reduced. Also, a ½ inch mesh liner made of thin plastic (sold as bird netting to protect fruit trees) may be placed within the float and attached with cable ties. This liner is inexpensive, adding only approximately $1.00 to the cost of a float.

We have investigated several lid options for this float including ¼ inch thick plywood lids, wire mesh, shade cloth and no lids. Performance of different lid options varies with location and opinions about the best type of lid vary between culturists. Lids have been found to be useful in restricting the growth of macroalgae in the floats and reducing predation by otters and seagulls. However, barnacle and oyster settlement may be greater under lids and seagulls roosting (with the associated problem of elevated fecal coliform bacteria levels) may be greater on floats with lids. Individual culturists will need to experiment with the use of lids at their site to determine their value.

Several modifications to this basic design have been used by growers in Virginia. One involves using plastic mesh in the place of galvanized. Plastic has the advantage of not corroding, but is more expensive, provides less rigidity and offers more surface area for fouling. The PVC pipe may, of course, be cut to any size to fit the needs of individual culturists and some non-commercial oyster gardeners have chosen to work with half-sized Taylor floats, which are constructed by reducing the longest segments of pipe (shown in Box 4) from 95 inches to 47.5 inches.

Advantages of this containment system include low materials cost and sturdy design. The open mesh of the wire float provides limited surface area for fouling and permits good water flow. Disadvantages include the cumbersome size and need for a hoist to retrieve the floats when they are full of oysters. Further, in some locations the use of these floats may be restricted by navigational or aesthetical concerns.

Again, we do not wish to imply by presenting designs for the Taylor float here that this is the preferred containment system for all growers. In fact, we expect that this system will be replaced in the near future by any number of improved designs. For the present, however, we receive a large number of requests for the design specifications and this manual is intended in part to meet those requests.

Constructing the mesh bags and liner:

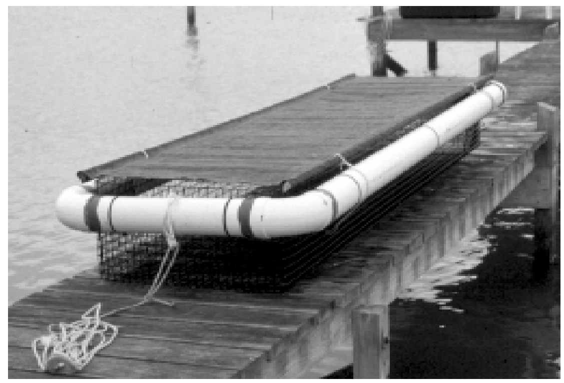
1/16" mesh bags- Fiberglass window screen can be purchased in 4 ft x 100 ft rolls. Cut 18-inch x 24-inch sections and sew two panels together with monofilament line, double stitching along three sides. After placing oysters in the bag, seal by stapling 2 ¾ inch x 18 inch wood strips together on the open side; adding 2 additional wood strips along the bottom of the bag provides additional strength to the bag.

1/8" mesh bags- Plastic mesh may be ordered from several aquaculture supply vendors in flat and tubular forms. The latter are much better for constructing bags. The standard dimensions of a roll of 1/8 inch tubular mesh are 36 inches x 200 ft. Each roll makes about 100 24-inch x 18-inch bags. One end of the bag should be closed with ½" stainless steel hog rings, and the other end with cable ties.

3/8" mesh bags- These bags can be purchased individually from aquaculture supply companies or rolls of tubular mesh can be purchased. Each bag measures 40 inches x 20 inches. The one open end can be closed with cable ties.

½" liner- Liners are constructed from very thin mesh which is sold as bird netting to protect fruit trees It generally comes in 3000 ft x 14 ft rolls, but may be purchased in small quantities from some vendors. Cut 9 ft x 3 ft sections and secure it to the inside of the float using cable ties. The liner should extend 6 inches up the sides of the float and be secured at the top with cable ties.

Box 5. Side view of Taylor float.



Purchasing Seed and Materials

The question most commonly posed to us is, "Where do I get seed?" Given our foregoing discussion of the importance of using good quality, disease-free seed, this is obviously a critically important question. Unfortunately, it is impractical to respond to that question here. Oyster seed are sold by a number of commercial hatcheries along the U.S. Atlantic and Gulf coasts, but their availability and quality can vary annually. Any list which we might provide at the time of this writing would be quickly out of date and give the perception of endorsing some hatcheries and excluding others. Similarly, purchasing materials to construct floats or other containment systems can be done through a number of sources.

The Virginia Shellfish Growers Association, a trade group which represents many of the shellfish culturists in the Commonwealth, counts among its members most of the shellfish hatchery operators. You can contact them to get more information about seed supplies from their members. Further, the private, non-profit Chesapeake Bay Foundation is actively involved in working with oyster culturists in Virginia and Maryland, often coordinating seed purchases and holding float construction workshops. Finally, in Virginia there are a number of oyster gardening clubs which have been organized to facilitate information exchange, as well as seed and materials purchases. The appendix provides contacts or initial points of inquiry for contacting each of these groups.

Procedures

We recognize that there can be more than a single approach to culturing oysters in this region, but offer this basic sequence of steps as a starting point. The steps and the oyster densities are given for oyster culture using the Taylor float, because we are most familiar with this system, but the basic approach can be followed using other systems. Modifications based upon using smaller seed are outlined below in Box 6. We recommend that beginning culturists and gardeners start with the larger seed.

1. Obtain required permit (see section on Regulations below).
2. Securely moor floats in the water.
3. Place 15 - 20 mm seed oysters in 3/8" mesh bags at a density not exceeding 2500 oysters/bag and place no more than 2 bags/Taylor float. [Numbers will vary in other floats]. The best time to initiate this step is in late September after the greatest threat of *P. marinus* infection has passed. **Remember to start with disease-free seed from good brood stock.**
4. After 2 - 6 weeks, depending upon growth rates, remove oysters from the bags and place into a float with ½" mesh lining. Densities within the float should not exceed 2000 animals. Alternatively, some growers prefer to keep oysters in d - 2 inch mesh bags throughout the culture cycle. If this is done, densities should be reduced to approximately 600 oysters/bag and 2 - 3 bags/float.
5. Over the next 6 - 18 months maintain the oysters and floats in good condition (see below) and **harvest oysters as soon as they are large enough to eat!** The oysters will grow at varying rates and leaving large oysters within the float will slow the growth of the remaining

ones. {*Note: This suggestion is made with Virginia growers in mind. Other states may have regulations regarding minimum harvest sizes for aquacultured oysters. In all cases growers should abide by Health Department regulations regarding the certification of their growing waters.*}

Box 6 provides a summary of the steps involved, including those for starting with small seed.

Box 6. Number and size of mesh bags and oysters used in a Taylor float.

2500 2-3 mm oysters/ 1/16" mesh bags; 2 bags/float for approximately 2-4 weeks

2500 6-12 mm oysters/ 1/8" mesh bag; 2 bags/ float for approximately 2-4 weeks

2500 15-20 mm oysters/ 3/8" mesh bag; 1 bag/ float for approximately 2-4 weeks

1500 -2000 20-50 mm oysters/float with ½" mesh liner for approximately 5-8 mo.

1500 -2000 50-75 mm oysters/float without liner for approximately 3-8 mo.

Maintenance and Care

Maintaining an oyster garden is a little like caring for a vegetable garden. **It is a lot easier if you stay on top of a few relatively simple tasks!** Analogous to weeding a tomato patch, the bags and floats that are holding oysters must be cleaned periodically. The frequency with which this clean-ing must be done will vary between sites and between seasons and years at individual sites. Regular inspection of the floats and bags is re-quired to judge when cleaning is needed.*

The principal cause of fouling is marine organisms which settle from the plankton and attach to the floats, bags and oysters. Most of these organisms can be removed by washing with water (fresh or salt) and scrubbing with a stiff brush. High pressure washing is sometimes required to remove firmly attached organ-isms, but care must be taken when using high pressure washers not to damage small oysters.

In some locations the settlement of barnacles, mussels and even oysters onto the floats can be a particular problem, since these organisms are not easily washed off. If detected early enough, these animals can be cleaned off using a brine dip[24,25] (described below in the section about flatworms). It is especially important that a brine dip only be used with oysters greater than 5 mm, since smaller oysters will suffer mortality from the procedure.[25]

Predators and Other Associated Organisms

Predators ranging from flatworms to river otters may be found associated with off-bottom cultured oysters, but not all

*If oysters are retained in bags throughout the grow-out period, we recommend that you flip the bags every 2-3 weeks to remove excess sediment and re-distribute the oysters.

animals pose a threat to the oysters. Distinguishing between those organisms which eat or otherwise harm oysters and those which do not is important. A complete accounting of the organisms associated with cultured oysters is beyond the scope of this document, but a few common examples are given below.

Flatworms - The oyster leech or oyster flatworm, *Stylocus ellipticus* (formerly *Eustylochus ellipticus)* can be a very significant predator on small oysters. In Virginia *S. ellipticus* generally invades oysters in late spring or early summer, though occasionally late summer infestations will occur. This animal is usually no larger than 25 mm, flat and thin with irregular margins and it lacks the "centipede looking" appendages seen on the common clam worm. It can be green, yellowish brown, or salmon in color with a whitish branching intestine that can be seen through the skin. Flatworms prey on barnacles and small oysters and can be devastating to a crop of cultured oysters if left untreated.

The preferred treatment for flatworm infestation is a brine dip. The bags with oysters should be left out of water for about one hour before the dipping to make sure all oysters are closed. A brine solution is made by dissolving 25 pounds of salt in 10 gallons of estuarine water in a plastic trash can. Each bag is dipped into the brine solution for five minutes with agitation. The bags are then left out of water another hour before being placed back in the float.

Another treatment is to raise the bags above the low water mark so they are exposed to the sun at low tide. This method should kill the flatworms but not the oysters, but is subject to variation in success depending upon weather conditions.

Clam worm - This polychaete worm (*Nereis succinea*) is usually the most common worm associated with cultured oysters in the region. It is generally 1 - 3 cm in length, segmented and has numerous small appendages running the length of the body on each side. Usually light pink to reddish brown in color, this worm is easily spotted crawling across the shells of oysters. Fortunately, this animal does not pose a threat to oysters and the oyster culturist need not be concerned with them.

Crabs - There are a variety of crabs which may be associated with oyster cultivation and most should be viewed as predators. The blue crab (*Callinectes sapidus*) is a voracious predator on oysters and care should be take to exclude them from the bags and floats. Several species of mud crabs (*Panopeous* and related genera) also feed on small oysters. During mid to late summer in this region several of these crabs, especially the blue crab, settle out of the plankton and into bottom habitats. At this time the small crabs may pass through meshes as small as ½ inch and grow rapidly to a size capable of consuming oysters. It is important, therefore, to regularly inspect floats and bags and remove any crabs.

In high salinity environments in the area hermit crabs (genus *Pagurus*) are common. Though some of these crabs can grow to a size capable of eating small oysters, they generally do not pose a threat to cultured oysters and can in fact be put to beneficial use. Small hermit crabs, those found in shells 1 - 2 cm in length, can be added to the inside of 3/8 inch mesh bags to help control the fouling. They will graze on small animals and plants which settle onto the bag and obstruct water flow. **Do not add hermit crabs to bags with smaller seed as they may consume small oysters.**

Grass shrimp- Often the most common organisms associated with oyster floats are small grass shrimp (*Paleomonetes pugio* and *P. vulgaris*). These animals do not pose a threat to the oysters and may be ignored.

Snails - In high salinity areas oyster drills (*Urosalpinx cinerea* and *Eupleura caudata*) are major predators on oysters. Fortunately, they are seldom found in off-bottom floats or trays and the few which do manage to invade a float are easily removed by hand. The common periwinkle (*Littorina littorea*), which is usually observed on the stems of salt marsh cord grass, feeds on small fouling organisms. Adding a dozen or so periwinkles to the inside of the bags containing oysters will reduce the fouling and help keep meshes cleaner.

Epifauna - Organisms that are found attached to hard substrates (including oysters, mesh bags and floats) are known as epifauna. Many are benign and only impact the aesthetic appeal of the oysters. Others may compete with the oysters for food resources and may cause a reduction in water flow (and hence food) through the containment/culture system.

Barnacles are hard-shelled crustaceans. They generally attach in large numbers and can compete with oysters for space and food. They can be eliminated by aerial exposure if identified early enough, but large individuals must be physically removed with a scraper. Care must be taken when handling floats or oysters covered with barnacles as they are abrasive.

Sea Squirts (Sea Grapes) are commonly found in higher saline waters. They resemble grapes with siphons. They can be eliminated by either scraping-off or aerial exposure for 1-2 hrs (depending on the air temperature).

Hydroids are 'algae-like' colonial animals. They can be found in large numbers particularly on the surface of the mesh bags or the float. They can result in reduced flow into the culture structure and can be removed by washing with freshwater allied with scrubbing with a brush. Aerial exposure will also result in them being dried out and subsequent brushing will remove them.

Other bivalve species in the form of mussels and ark shells may settle on or in the culture systems. They pose no real threat unless they are extremely abundant. Vigilance is the key to determining their numbers and whether action is necessary. Mussels can be removed only by picking them from among the oysters and it's easier to remove them when they are small.

Mammals - The principal mammalian threats to cultured oysters are river otters, raccoons and humans. The first two are generally excluded with securely fastened lids, fending off the latter often requires greater vigilance.

We are currently preparing a fuller description of organisms associated with cultured oysters, including a pictorial guide, as part of a more detailed handbook on oyster cultivation which should be published in 2000.[25] This book will also incorporate more details of predator and fouling control mechanisms.

Harvesting

Following the procedures outlined above some oysters should be ready for harvest within approximately 12 months (fall of the second year). Oysters should be harvested as soon as they are large enough to consume or be marketed. For the gardener this is largely a matter of personal preference since regulations limiting harvest size for wild stocks do not pertain to cultured oysters in Virginia (but again growers in other states should check local regulations). Rapidly grown oysters tend to have thin shells with a high meat content. We recommend harvesting cultured oysters at relatively small sizes 2¾ - 3 inches in shell length. This reduces crowding in the floats and allows the remaining oysters to grow faster. Of course, for oyster culturists market demands will place size limits on practical harvest size for oysters.

Health Concerns

Oysters filter large volumes of water and thus have the capacity to concentrate both toxins and human pathogens. Tidal waters in Virginia are classified *open*, *seasonally restricted* or *closed* to shellfish harvest by the Virginia Department of Health. It is important to know the designation of your growing waters and to take care in consuming shellfish (especially raw) from waters of unknown designation. Contact the local office of the Shellfish Sanitation Program within the Virginia Department of Health for more information about status of water quality in your growing area.

It is possible to *relay* oysters from contaminated waters to clean waters prior to harvest and consumption. However, a number of specific restrictions apply. Water temperature at the time of the relaying must exceed 50^{o}F (10^{o}C) and a minimum of 15 days in the clean water is required. Regulations guiding relaying of shellfish were originally directed towards relocations of wild stocks and the entire procedure required oversight by a marine patrol officer of the Virginia Marine Resources Commission. At the time of this writing the Virginia Marine Resources Commission (VMRC) and the VA Shellfish Sanitation Program are reviewing their required procedures for relaying shellfish from contaminated to clean waters in an attempt to develop procedures more amenable to aquaculturists. Interested growers in Virginia should contact their regional office of the Shellfish Sanitation Program.

Regulations

Most states have regulations on the placement of structures in the water for aquaculture and on the importation of seed from other states. Restrictions have been placed on the importation of hatchery-reared oyster seed into Virginia and Maryland. In Virginia, Marine Resource Commission regulation #450-01-0102 requires that the hatchery-reared oyster seed (shell height less than 25 mm) be accompanied by certification from a shellfish pathologist that the seed are disease free. All importation of oyster seed into Maryland from northern hatcheries is forbidden due to concerns over juvenile oyster mortality syndrome. Because these regulations are subject to change and new ones may be promulgated, it is wise to check with the VMRC or appropriate agency in states other than Virginia before making plans to import oyster seed.

As noted above, cultured oysters are exempted from fisheries management size restrictions; however, regulation 4VAC 20-720-90 requires that "any person harvesting or attempting to harvest oysters...on the seaside of the Eastern Shore" must first obtain a harvest permit from the Virginia Marine Resources Commission. The requirement for this permit includes aquaculture operations.

The VMRC has recently developed a general permit (#3) which authorizes the use of riparian waters for the noncommercial culture of shellfish. This permit is intended to facilitate the development of noncommercial oyster gardening and is much less cumbersome than previous permitting requirements. However, certain restrictions apply concerning the size and location of the structures and impacts to navigation and submerged aquatic vegetation. Interested individuals should contact the VMRC to receive a copy of the permit application.

Economic Considerations

It is not our goal in this brochure to provide a detailed economic analysis of oyster cultivation. However, there are a few important economic considerations which we would like to briefly highlight. We begin with a very cursory, "back of the envelop" estimate of the cost of production. Using the ranges of cost values in Box 7, we compute that the cost of production currently ranges between 6.5 and 11¢ per oyster and that does not include such expenses as maintenance and operation of a vessel, leases, licenses, marketing costs and a variety of other legitimate expenses. In a forthcoming book,[26] slated for publication in the spring 2000, we will discuss these estimates in more detail. Additional discussion of the economics of culturing oysters in the mid-Atlantic region are provided in publications by Allen & colleagues[27] and Lacey & Thacker.[28]

Box 7. Rough estimates of production costs for oysters cultured using the methods described here.

	Cost/Oyster
Seed	0.5¢ - 2¢
Materials	3¢ - 4¢
Labor	3¢ - 5¢

In this publication we wish to make three points about the economics of culturing oysters using the methods which we have described.

1 - It is not cheap! With a production cost which is probably around 10¢ an oyster, it costs more to produce an oyster by this means than the wholesale price for wild-harvested oysters from the Atlantic and Gulf coasts. Though the price for wild-harvested oysters has varied greatly for the past several years, for product delivered to Virginia it has generally been in the neighborhood of 8-9¢ an oyster. For the noncommercial oyster gardener this cost of production is usually not an issue. (After all, those of us with backyard vegetable gardens seldom are concerned that it is more expensive than buying our tomatoes from the grocery store.) For the commercial oyster culturists, however, this production cost is a critical issue, making it is necessary to market the oysters as a high quality product at a premium price. At the present time, this appears to be working well in Virginia where oyster culturists are generally selling oysters between 20 to 45¢ apiece.

2 - There is more marginal gain to be made from marketing than from cutting production costs. This follows directly from the foregoing discussion and our estimates of production costs. Although it is common now to hear commercial oyster culturists in Virginia proclaim “we’ve got to cut our costs so that we can get our production up,” we believe that this misses two critical points. First, if our production cost estimates, which include labor at $8-10/hr, are reasonable, then the solution to the labor-intensiveness of the approach is to hire more labor. The profit margin would seem to support this contention. The second point is that, while improvements to the cost of production are surely possible (perhaps they could be reduced by a nickel per oyster), far greater range for improving profit margins exist in the sales price. After all, current variation in sales price is at least 25¢ an oyster.

3 - Seed oysters are cheaper than other production costs. This is an important point for both commercial and noncommercial oyster culturists. Since it costs more in materials and labor to grow an oyster to harvestable size than the price of seed, ***it is a waste of money to retain oysters too small to reach harvestable size.*** In other words, buy more seed oysters than you need and be liberal in throwing away slow growers during the cultivation cycle. We often hear growers say of their runts "it doesn't cost me anything to keep them." Not true! In addition to labor and materials costs associated with holding them, they compete for food with your other oysters and slow the growth of all oysters in the system. Unfortunately, it is not possible to provide a single set of guidelines as to what constitutes an oyster which is too small to retain. That will vary to some degree between different culture sites and each grower must learn from experience. Generally, we find that oysters smaller than the lower curve in Box 3 have limited chance of reaching harvest size before succumbing to disease.

Much still remains to be done in improving the economics of oyster cultivation and the marketing of cultured eastern oysters. At the present time we cannot be absolutely certain of the economic viability of the approach described here. However, we believe that the fundamentals of the approach are sound and that it is either economically profitable or on the verge of being so. Continued improvements in culture practices and marketing techniques should improve the current economic outlook for the practice.

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Appendix I

List of contacts for further information on oyster aquaculture in Virginia and Maryland.

Permits

Virginia Marine Resources Commission (VMRC):

Habitat Management Division, Mr. Robert Neikirk (757) 247-2252, **rneikirk@mrc.state.va.us**

Conservation and Replenishment, Dr. James Wesson (757) 247-2121, **jwesson@mrc.state.va.us**

Maryland Department of Natural Resources:

Shellfish Division, Steve Minkkinen (410) 260- 8326

Water Quality

Virginia Department of Health – Division of Shellfish Sanitation (804) 786-7937

Maryland Department of the Environment, (800) 633-6101

Extension Support

Virginia Institute of Marine Science (VIMS) - Sea Grant Advisory Services

Mr. Michael Oesterling, (804) 684-7165, **mike@vims.edu**

Mr. Tom Gallivan (also VIMS ABC Program), (757) 787-5575, **gallivan@vims.edu**

University of Maryland, Sea Grant Extension Program

Dr. Don Merritt (also Center for Envir. Studies), (410) 221-847 **meritt@hpl.umces.edu**

Don Webster, (410) 827-8056, **dw16@umail.umd.edu**

Jackie Takacs, (410) 326-7356, **takacs@cbl.umces.edu**

NGOs

Chesapeake Bay Foundation

In Virginia: Rob Brumbaugh, (757)-622-1964, **rbrumbaough@savethebay.cbf.org**

In Maryland: Bill Goldsborough, **bgoldsborough@savethebay.cbf.org**

Stew Harris, (410) 268-8816, **sharris@savethebay.cbf.org**

Maryland Oyster Recovery Partnership, (410) 269-5570

Virginia Shellfish Growers Association c\o VIMS Marine Advisory Service, (804) 684-7173

Oyster Gardening Organizations

Tidewater Oyster Gardeners Associations, Jackie Partin, (804) 694-4407, **jpartin@crosslink.net**

Northern Neck Oyster Gardeners, Don Beard, (804) 438-6563, **donbeard@rivnet.net**

Southside Virginia Oyster Gardeners Association, Cliff Love, (757) 481-6449

Assateague Coastal Trust, Ron Pilling, (410) 629-1538