Nursery and Growout Methods for Aquacultured Shellfish

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Introduction

Shellfish aquaculture has been developing steadily over the last decade. The number of growers of hard clams or Northern Quahogs (Mercenaria mercenaria) and the Eastern Oyster (Crassostrea virginica) has increased because of market demand, diminished wild stocks, pollution and habitat loss. Despite the growth of aquaculture businesses, these operations are facing limitations, particularly because of the high costs of shoreside land. Still, these limitations have catalyzed innovation by those in the industry, both manufacturers and culturists. This publication is an introduction to some current techniques for growing hard clams and oysters. While it should be of use to growers who are not aware of recent developments, it should also be of value to prospective growers who are considering the potential of shellfish aquaculture.

The focus here is on the nursery and growout phases. The nursery phase covers shellfish seed, whether from a hatchery or from wild harvests. Once obtained, the seed can be nurseried in land-based systems or in the field. Growout covers the placement of these shellfish seed in the field where they grow to maturity.

Hard clams and oysters are both spawned in hatcheries and growers have different options:

-- Oyster larvae (free-swimming) can be purchased from hatcheries and set on shell at the grower's site through a process called remote setting. (See "Producing Oyster Seed by Remote Setting" from Maryland.) Oyster seed, that is oysters that have metamorphosed or "set" from the free-swimming stage, can also be purchased singly (cultchless) for growout through various methods.

-- Hard clam seed is purchased from hatcheries. Early nursery seed ranges from .3 to .5 millimeters (mm) shell length; at these sizes, seed is fragile and susceptible to injury from improper handling or to mortality from environmental fluctuations of salinity, oxygen or temperature. At greater than .5 mm, the seed can be placed in a land-based or field-based nursery for growth to a larger size with more confidence of success.

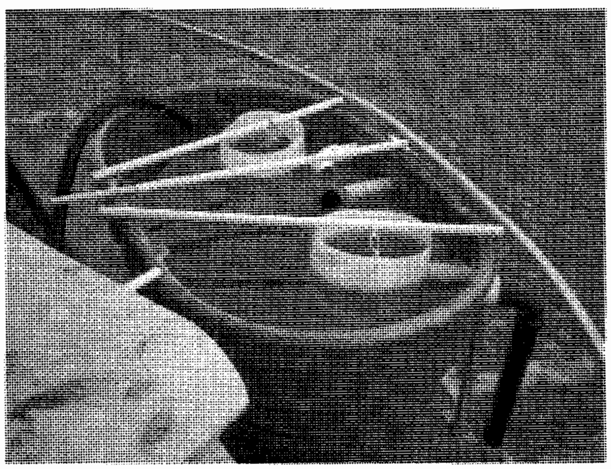
While shellfish can be nurseried in land based or field based systems, there are numbers of considerations that are not covered here. Prospective culturists must take into account, for instance, maintenance costs such as water, power and feed as well as regulatory and permitting issues. Such issues are covered in other publications that are listed at the back of this publication.

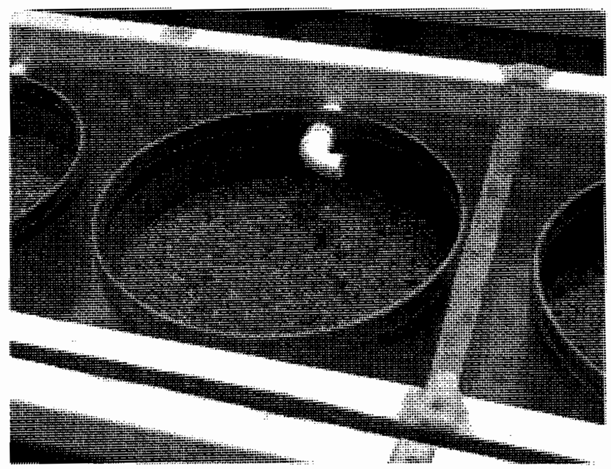
Land Based Nurseries

Typically, two types of equipment are used in a land based nursery facility, the upweller and the raceway (see below). An upweller is a vertical flowthrough system that is used for smaller seed. A raceway is a long rectangular horizontal flowthrough container in which seed can be grown to a sufficient size for planting in the field. While hard clams and oysters can be grown for a time in upwellers, oysters must usually be moved into a field site for growout; clams can be nurseried to larger sizes in a raceway system before planting in the field.

Upweller systems

Upwellers consist of individual cylinders or boxes, commonly called "silos," in which the seed shellfish is placed; the silo is then set in a large trough or tank so that water can be pumped through. Most importantly, the bottom of the silo is covered by mesh material. The mesh can be a simple window screen or a high quality product, ranging from a few microns to a couple of millimeters. In choosing a mesh, a primary consideration is the organism's size, which will of course increase, thus requiring larger mesh size as the seed grows (see below). Mesh materials have included galvanized hardware cloth or plastic mesh from aquaculture suppliers. Silos themselves can be constructed of various materials. Five-gallon plastic buckets, PVC pipe, large plastic barrels (whole or half) or plastic home storage containers are commonly used. The shape is less important than the size of the screening.





Photos 1 and 2. Upwellers can be as simple as horse troughs and spackle buckets or may be substantial with fiberglass tanks and PVC silos.

The silo is connected to the trough by a length of horizontal pipe that goes through both near the top. Water is pumped from the estuary into the trough where it rises through the bottom mesh of the silo and exits through the length of pipe that joins the silo to the trough. This continuous flow carries plankton which the seed clams or oysters feed on. Routine maintenance of upwellers is essential, particularly clearing the mesh of shellfish feces, pseudo-feces, and silt that growing shellfish and bay water add to the system; if not kept clean, water will not circulate through the silo, thus preventing food from reaching the shellfish seed and reducing growth. A hose and spray nozzle are generally sufficient for cleaning; they can also help reduce some biofouling if the seed is very small. As the organisms grow, seed on upwellers should be transferred to silos that have larger screening.

The larger the mesh size, the more water and plankton that can reach the seed, which then leads to faster growth. Culturists should be careful not to force water too quickly through the silos: excessive velocities may cause the seed to bounce on the screen mesh which could inhibit growth. At the same time, high water flow in an upweller will also reduce the organism's ability to filter phytoplankton, which reduces growth efficiency and thus increases costs because of a longer growth time.

To give an example of flows, the Virginia Institute of Marine Science Wachapreague Lab in Virginia offers the following recommendations on water velocity as a function of clam size and number of clams in an upweller.

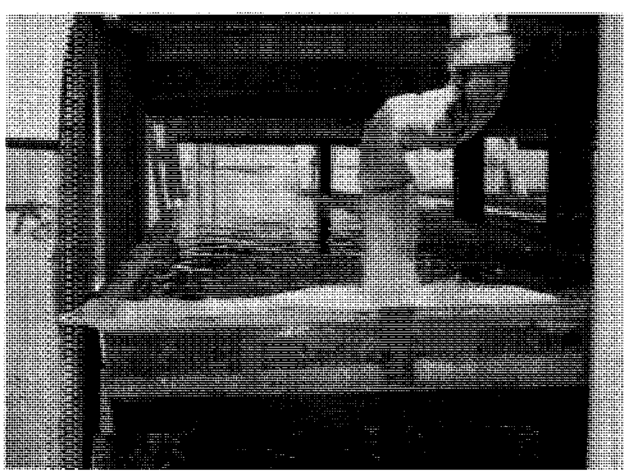
SIZE	#/ML	FLOW
1 -2 mm clams	800 clams/ ml	50 gal/min/L
3 -4 mm clams	70/ml	20 gal/min/L
8 mm clams	7/ml	4 gal/min/L

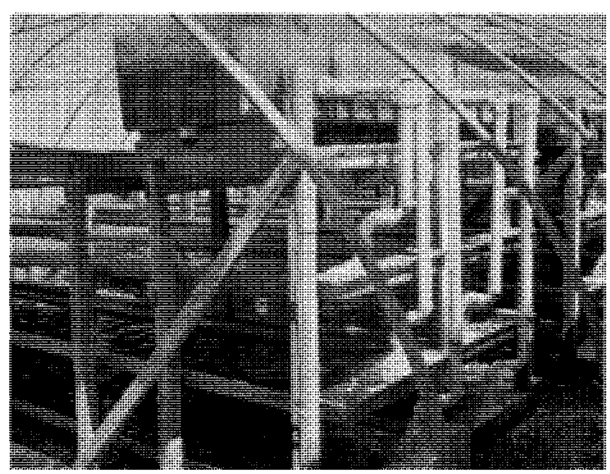
With these recommendations, assume a pump flow of 400 gallons/min to the upweller. The system can produce 8 liters of 1 - 2 mm clams or about 6.4 million seed, or 20 liters of 3 - 4 mm clams or about 1.4 million seed.

Actual growth rates will vary, depending on a number of factors. They may be biological such as differences in genetic competence, or environmental differences such as changes in temperature, salinity, time of year, system management, and seed parentage. Often the reason will elude the grower.

Raceways

Once hard clam seed has reached the larger size (around 3mm) they may be taken from the upweller silos and placed in raceways. A raceway in its most basic form is a couple sheets of plywood connected end to end with 2" x 4" sides. Water is pumped onto one end; it flows over the seed and drops off the other end. Most raceways are now made of fiberglass and are often 20 to 30 feet in length. It is now common to see stacked raceways. Stacking makes better use of limited waterfront ground space. Regular maintenance and sieving of fast growing seed is essential. Taking out the larger seed from a raceway allows the smaller seed to access more food and they will grow more uniformly.





Photos 3 and 4. Stacking fiberglass raceways with an overhead sluice box for delivering water can maximize water front space.

Once the seed has reached a larger size, it can be then moved into a growout phase. Clam seed of 10 to 15 mm would typically be bottom planted and oysters of 15 to 20mm could be placed in plastic mesh bags, with larger ones planted on bottom grounds, though not directly on sediments where they can sink and be smothered.

Field Based Nurseries

Seed can also be raised in a field nursery, making use of equipment that can be used for years. However, states and local jurisdictions differ widely in their regulations and potential culturists must ensure they can obtain proper permits and meet other requirements for growing shellfish in the field.

Presently two general methods are used for raising clam or oyster seed in the field: plastic mesh bags and floating upweller systems.

Plastic Mesh Bags

Bags can be purchased or constructed from rolls of plastic or nylon mesh screening. The bags are an extruded polyethylene material, about 18" x 36", open at one end for adding seed, cleaning and harvesting. Depending on the bag and its manufactured specifications, the ends can be sealed with split PVC pipe or they can be folded up into a box shape where one end may be sealed permanently with hog rings and the other closed with wire or plastic ties. The mesh size of these bags depends on the size of the shellfish they are to retain. Larger seed should be kept in increasingly larger mesh bags.

Photo 5. Commercially available plastic mesh bags for field nursery of clams and oysters.

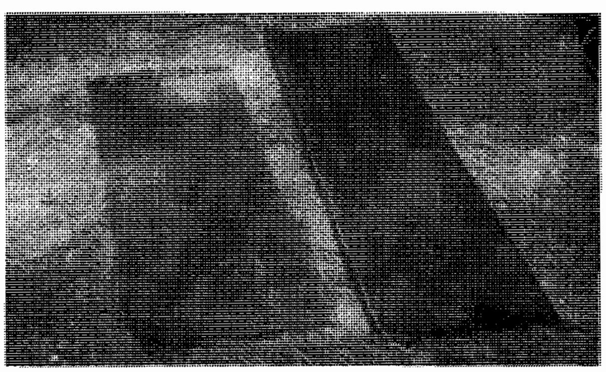


Photo 6. Some field nursery operators purchase plastic mesh in rolls, cut them in various length from 3 to 8 feet, fold them length-wise and sew one side and the an end of the mesh to make a custom sized bag. Once the seed is added the open end can be sealed with a piece of split PVC pipe.

Clam seed in these bags for a nursery phase grow well when placed on the bay bottom but oysters do better on racks (see "Field Nursery for Hard Clam Seed" reference). Oyster seed coming from the upwellers at 2 to 4 mm in size can be grown in a late nursery phase in plastic mesh bags that are raised off the bottom on racks made from a variety of materials such as concrete reinforcing bar (rebar) or fiberglass bar racks. Starting with 2 mm mesh, the oysters can continue to grow in bags to market size. As oysters grow, they must be divided resulting with smaller numbers of oysters in each bag. Seed that ranges from 2 to 4 mm might be stocked at 4,000 to 5,000 per bag though the largest size for final growout might only have 250 per bag. In some places where water flow is high, the oysters on racks have grown in length so fast, that they have extremely thin shells, which will break upon shucking. These shellfish should be taken out of the bags and planted on the substrate so that the growth of oyster meat will slow down and the shell will accrue more thickness. An alternative would be to move the bags and racks higher in the intertidal zone, which would improve shell quality while reducing the predator threat of placing them on the bottom.

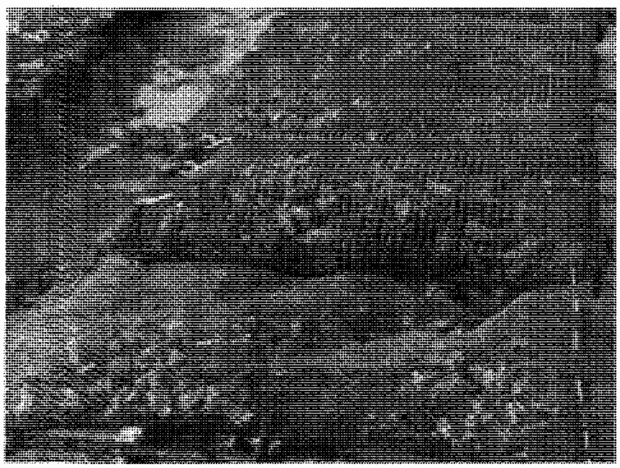
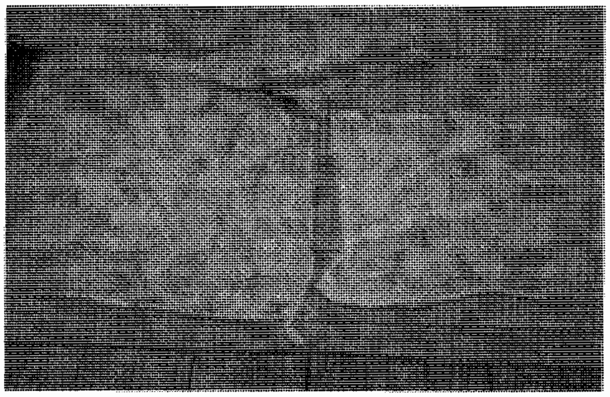
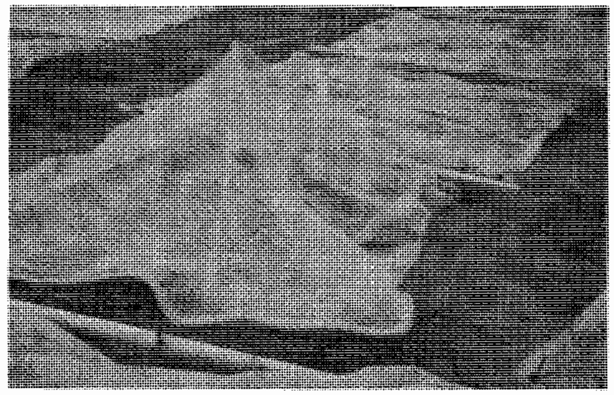


Photo 7. Bag and racks are common methods for growing oysters. These oysters are under cultivation in France.

Photo 8. Good water quality and flow make Well Fleet Harbor in Massachusetts a good site for cultivating oysters.

Clam growers in Florida have been able to use soft mesh bags sewn from polyester or nylon mesh material. Four-feet square, the bags are staked to the bottom; as the seed grows, it can be placed in larger soft mesh bags for growth to market size. Larger mesh bags are sometimes placed over the smaller mesh nursery bags to reduce predation by crabs that can reach or tear through the soft mesh and crush seed. Growers who consider using such bags should experiment first since some bottom types are better suited than others. While hard-packed sand bottoms are a sign of good water flow, sand may not fill the bags well enough to allow the seed to dig in. Consequently, growth rates may be poorer and the clams may be more subject to predation. Areas where bottom sediments might filter into the bags through substrate suspension and settling may provide better siltation in the bags. Only local testing will serve to answer this question.

Photos 9 and 10. Soft bags are used in Florida for growing hard clams

Some clam culturists in Virginia use sand trays - open top plastic boxes with 3 to 4 inches of sand - to grow 4 to 6 mm clam seed. After adding the seed, the trays can be covered with 1/8 to 1/4" plastic mesh to help prevent against predation from crabs, fish or other invertebrates.

The intent with all methods of growing shellfish is to allow the greatest volume of water possible to be given or directed to the shellfish to allow for the largest amount of feed to reach them. This hopefully will result in optimum growth.

Floating Upweller Systems ("FLUPSY'S")

A newer method of field nursery for small hard clam or oyster seed is upwellers deployed directly in the water. These upwellers can be powered in three ways: tidally, electrically and by compressed air. In each, the same concept of the silo with screening on the bottom on which the seed sits is utilized. The method of moving the water changes.

The tidal powered upweller uses the force of tides to move the water through the silos and the seed. Attached to a mooring with a line and bridle, this upweller has a funnel or scoop under the water's surface to direct the water into the box which contains the silos. After passing up through the seed the water exits each silo and passes out of the upweller unit. As with all upwellers, these silos must be cleaned periodically so a gas powered water pump must be brought by boat to clean them.

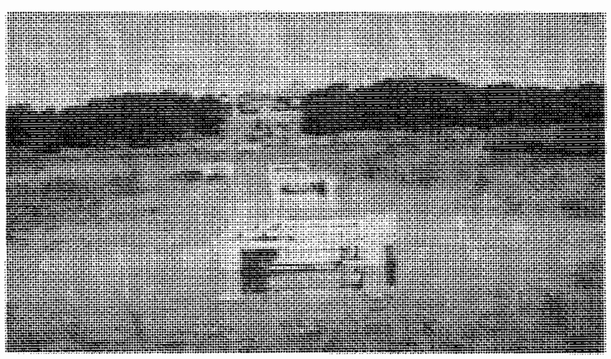
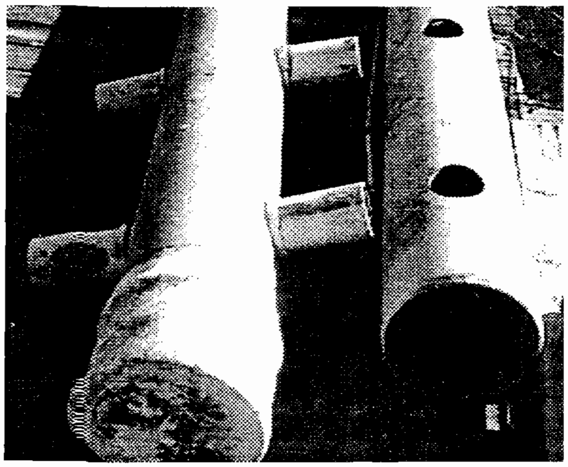
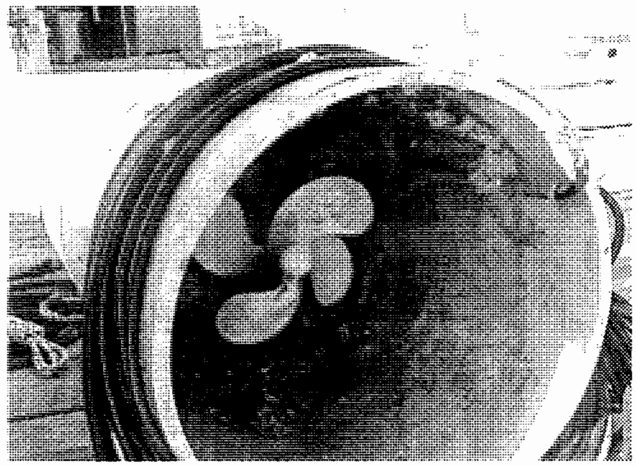


Photo 13. Tidal powered upwellers can make good use of steady currents in areas of low user conflicts.

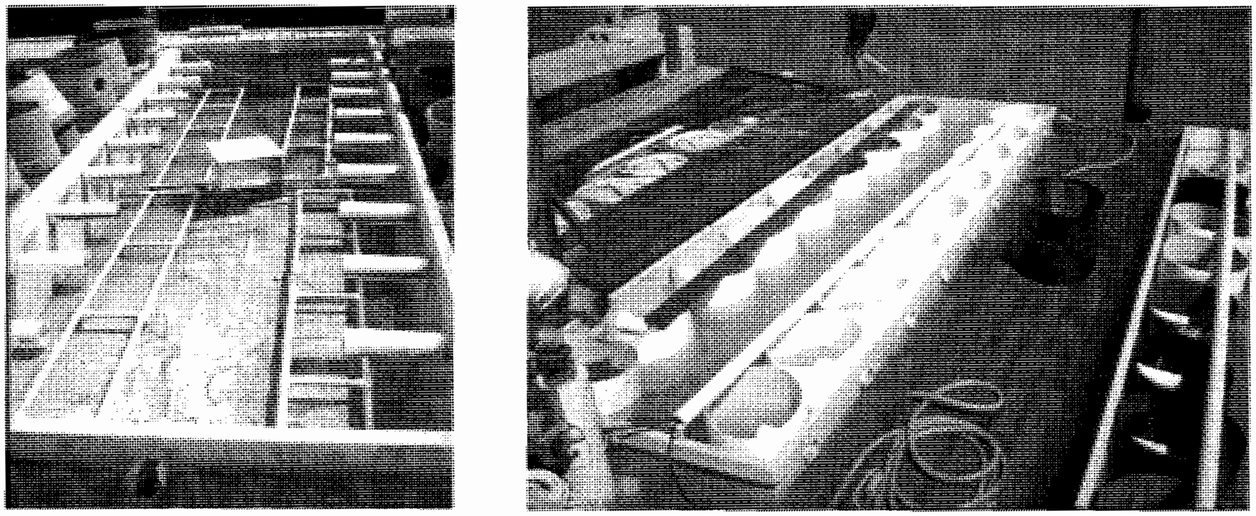
The electrically powered upweller is a unit that can be used in a boat slip or incorporated into a floating dock. Presently two configurations exist. The axial flow upweller uses a large central PVC pipe (8" or so) or plywood sluice box into which smaller PVC pipes are glued. One end of the pipe or sluice box is capped. Silos may be made square to economize on space in this array. The silos are attached onto the smaller pipes that extend horizontally from the center pipe or sluice box. The entire unit can be placed inside a floating dock or a protected boat slip. A horizontally mounted propeller inside the large pipe or sluice box at the open end draws the water from the silos. Water circulators (in the colder climates they are called "ice eaters") move the water.





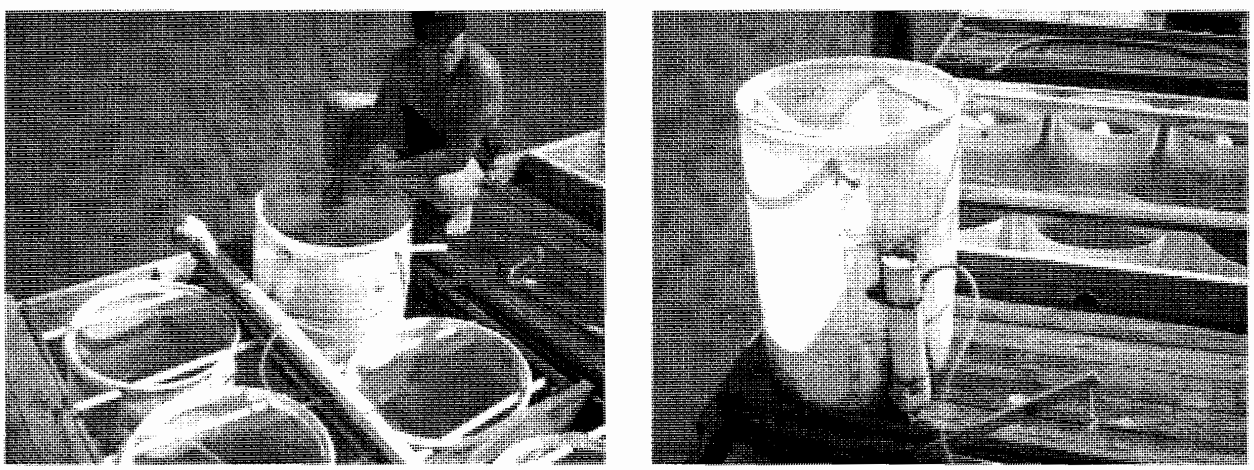
Photos 14 and 15. Axial flow upwellers can be stand-alone or incorporated into floating clocks.

The other unit is a large floating box (20'L x 6'W x 2'D) which has 4" pipe couplings glued into holes on the sides. Into the couplings are placed 12 to 16" pieces of 4"pipe. Silos made from cut 55 gallon plastic barrels are fitted onto these pipes. Each box has a power source of a small horsepower motor (3/4 to 1 hp) that drives water through a shaft and propeller into the box. The water is pumped into the box until it sinks to the level of the couplings. The water leaves the box through the silos and side pipes. Three methods presently are used to pump the water in. One is a pumping array of a direct drive motor and shaft encased in PVC pipe attached to the end of the box. Another places the direct drive motor and propeller in the center of the box, and the third is the use of an "ice eater" mounted through a large hole in the center of the box. When cleaning is necessary, a polarity switch can reverse the propeller which will pump the water out of the box allowing it to rise up in the boat slip, so that one can step into the box, and perform normal maintenance. Foam floatation is added to the bottom of the box. This can be used to raise the box by itself when the power is turned off or in conjunction with the reversing polarity switch. Once the cleaning is completed, the power is turned on correctly and the box fills. It then sinks to the appropriate depth and continues to supply water and feed to the seed.



Photos 16 and 17. Floating powered upwellers fit in a boat slip and can be very efficient at rearing shell fish seed.

The airlift method involves a large plastic barrel with a U shaped PVC tube going through the side of the barrel. On the outside ascending part is an airstone connected by plastic tubing to an air blower. Once the air blower is turned on, the air bubbles rise up through the airstone drawing the water with them. This removes water from the part of the "U" inside of the barrel. The removal of the water forces new water to enter from the mesh bottom of the barrel passing by the seed. Each barrel has to be attached to a frame to keep it upright.



Photos 11 and 12. Simple airlifts can be used to move water through in-water nursery silos.

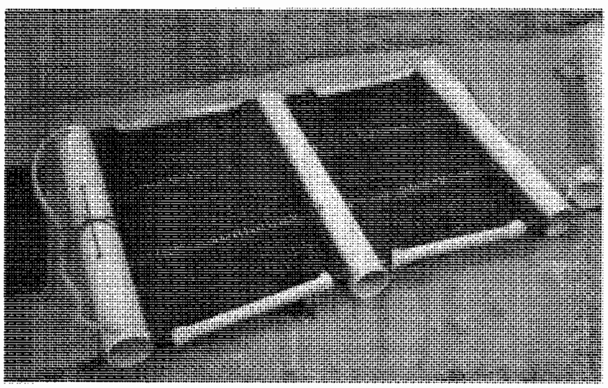
The nursery phase ends when the clam seed reaches a field plantable size of 10 - 15 mm. Sometimes in the fall, growers will have clam seed that is not large enough for field planting. They may be only 4 - 8mm. The nursery may continue with this seed being planted in the bottom at higher densities than normal field planting under smaller mesh (1/6"). They remain there through the winter until late spring when they have grown to a larger size which would be appropriate for field planting. They would then be thinned and replanted in normal densities for final growout.

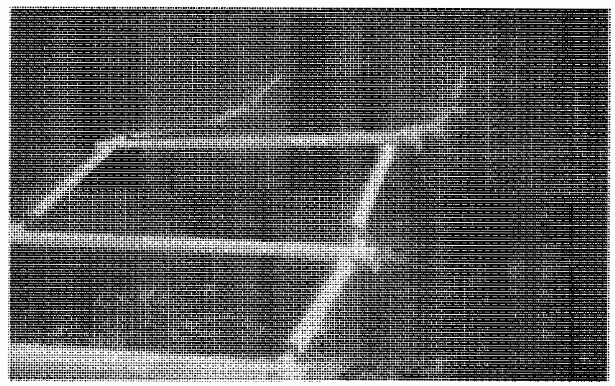
Field Growout

Oysters:

Single cultured oysters are usually grown to full market size in the commercially available plastic mesh bags on racks raised off the bottom. In the final stage, they are stocked at about 250 per bag. If oysters are laid down on the bottom they can become victims of various predators depending on the coastal waters in which they are growing.

There are two deviations from the usual rack system. In the early 90's in Florida, growers connected bags on a belt system. Made from PVC pipe and polypropylene rope, bags were lifted off the bottom by the 4" PVC pipe and held into this soft ladder configuration with split pipe run over the bag ends bent around the rope. Using specially designed boats with open centers, the belts could be raised off the bay bottom, run over a work rack on the boat, where maintenance could be performed and lowered back down as the boat moved forward. This system is no longer in use for oysters in Florida, but a similar system has been used for the field nursery for hard clam seed there.

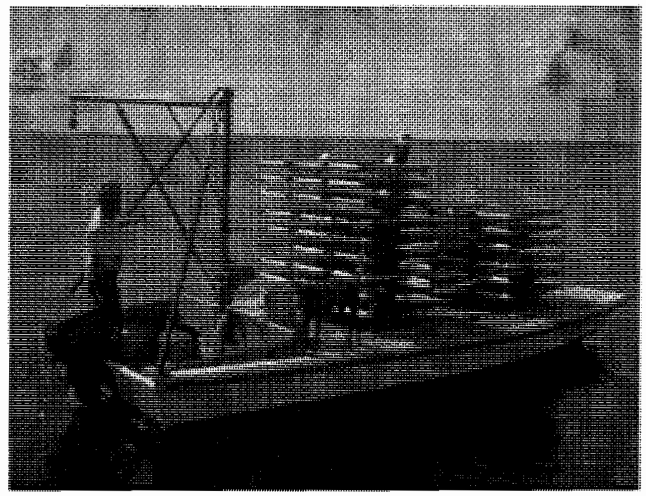




Photos 18 and 19. Oyster belt systems were used in Florida.

The second rack system simply makes better use of the water column. As with one level racks, bags are attached to racks with several levels. They are raised up on legs which keep the bottom bags out of the sediment. This also requires an adaptation of one's vessel to allow for the installation of a davit and winch for lifting these racks aboard.

Depending on the location, fouling can severely reduce growth rates. Macro-algae, tunicates, barnacles, oyster overset or other fouling organisms must be removed in a timely fashion to allow for good water flow to the crop. This can be done with simple brushing, scraping, fresh water or hyper-saline dips, or air drying. Growers should also be quite aware of winter icing conditions and the problem of regulated use of the water column in some jurisdictions.

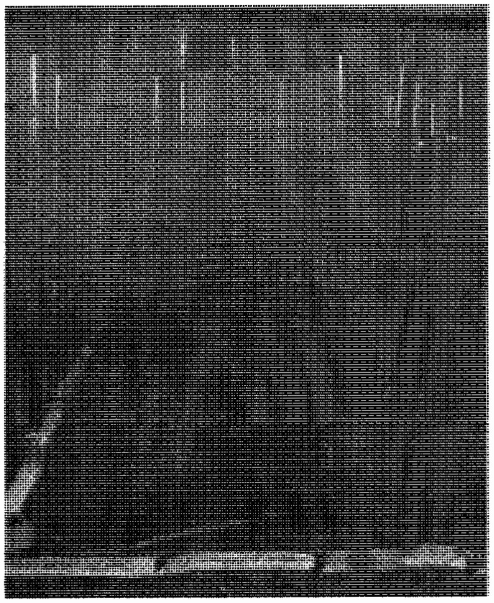


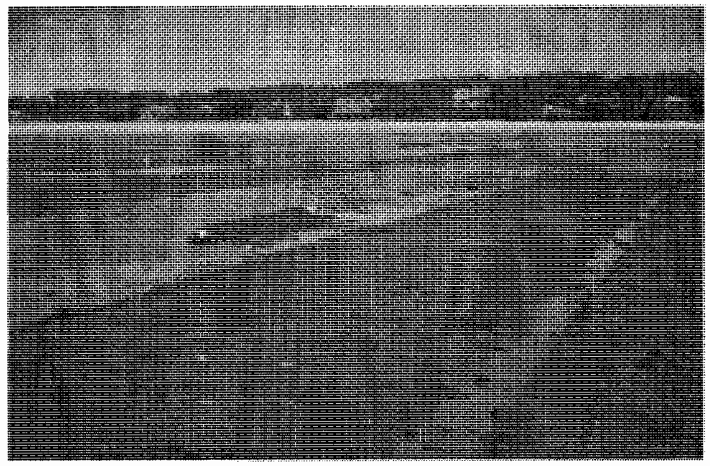
Photos 20 and 21. Oysters grown in racks of various configurations make good use of the water column. Boats may have to be specially rigged to handle them.

Hard Clams:

Once hard clams reach 20 mm in shell length, they appear to grow better if they are surrounded by substrate. Some early experiments with plastic mesh bags containing just clam seed and no substrate resulted in stubby clams that grew much slower than their cohorts that were bottom planted.

The most common method for the final growout of hard clams is to plant them in small beds at densities from 50 to 100 per square foot covering them with 1/4 to 1/2" plastic mesh. These are commonly called predator control screens or nets. The size of these beds varies in length, but the width is usually 14' since that is the width that the rolls of netting come in. This mesh was originally designed to keep birds off fruit trees and brambles, but it works just fine to keep out crabs, whelks, skates and rays. Growers in various states prefer different lengths on their beds. In Massachusetts, these plots can be up to 150' long, in New Jersey they are typically 20' long since those growers use one length of rebar on the side of these predator control screens, and in Virginia the beds are usually about 50'. Growers use various methods to hold down the sides and ends of these screens. This seal around the edge of each screen is extremely important since this forms a barrier for the various predators will get past the weakest part of the array. Culturists will use rebar, lead line, dug in lumber, or tubular stone bags on the perimeter when setting out the screens. Combinations of these materials are common. Torn screens must be repaired or replaced immediately so that predators will not gain access to the plot and feast on the shellfish contained within.





Photos 22 and 23. The size of bottom plantings for hard clams varies from state to state. North Carolina and Virginia (l.) plant about 50' while MA (r.) beds may be up to 150'.

Lest one thinks that the growers just plant these seed, go away for a couple years, and come back to harvest 100% of what they planted, it should be known that plot management and screen cleaning is a very large part of the culture process. Various macroalgae can bloom in an area, cover the screens thus suffocating the growing clams, and cause mass mortalities. In the more northern areas, ice damage can be significant.

Some growers will actually remove the predator control screens in the fall after the threat of crab predation is over for the year and reduce losses of screens due to ice. They are, of course, replaced in the spring before the crabs come back from hibernation. Mortality in this growout phase can fluctuate, but most growers will say that actual survival is about 55 to 65% during those 2 to 3 years. Anything more than that is unexpected but gratefully appreciated.

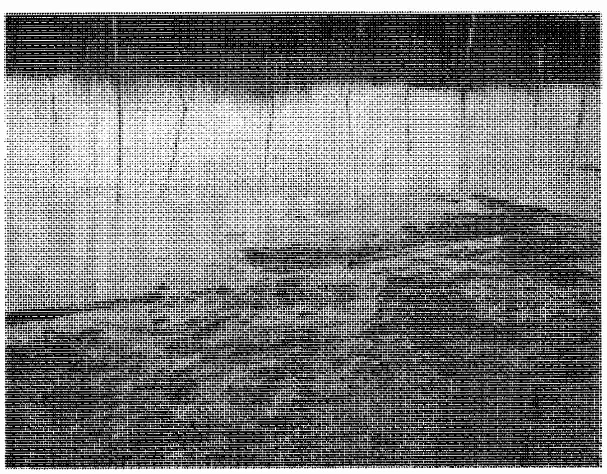


Photo 24. Biofouling has to be removed as well as macroalgae or the clam crop may suffocate and die.

In Florida where clam culture has grown significantly, the thin gauge plastic mesh predator control screens will not withstand the onslaughts of the large crabs, inshore fish, and other predators so another method has been popular there. Polyester mesh bags, previously mentioned in the nursery section, are the most common method for growing seed to market size. These bags which are about 4 feet square are staked down on each corner allowing natural accumulation of sediment to fill into the bag. Once the clams have grown to market size, the entire bag is lifted up and the sediment shaken from it. The harvested clams are then taken to be counted, bagged and sold.

Recordkeeping

Recordkeeping is a critical element of the aquaculture business and growers must be able to assess how the seed from various suppliers perform, or how their own spawns grow. New computer programs are very useful in tracking, and all growers should make the effort to record their activities and the environmental changes which could affect their profit. Like land farmers, successful shellfish culturists must maintain detailed records that will serve as guides to predict and review fluctuations on the farmed shellfish beds. Accurate record keeping goes beyond writing down observations and data. Culturists must analyze this information periodically and modify their operation appropriately to increase their profitability. Improved management practices translate into increased production and lower operating costs. (See "Recordkeeping for the Shellfish Culturist" and the CLAMFARM software from New Jersey.)

Closing Considerations

A shellfish grower should never be bound by the tools or inventions of others. Many growers have experimented with various methods of doing a field nursery and should be encouraged to try different methods. Each site is different and what may work on one place, may not work in another. New growers should first use proven gear and methods to grow shellfish, and after they have had some success, experiment on their own. Failures early on can easily discourage growers. This may cause them to drop out of aquaculture with a negative impression that they could pass onto others who might have had success following proven methods. Perseverance is important and critical to success in shellfish culture. Boldness and experimentation can create new and better methods of producing better shellfish grown to market size in a faster time. Necessity may well be the mother of invention.

Local Information

Those interested in more detailed information about shellfish aquaculture are directed to the local Marine Extension Agents which are located in each state. A list of those contacts is on the Northeastern Regional Aquaculture Center's Website which is located at: http://www.umassd.edu/specialprograms/nrac/

At the local area, prospective aquaculturists may find information from their county extension office that should be listed in the Government Blue Pages of the phone book.

Publications of Interest

Northeastern Regional Aquaculture Center

These NRAC publications should be available free of charge from your local Marine Extension Agent.

Is Aquatic Farming for You?, Buttner, Joe, Gef Flimlin, 1991, Northeastern Regional Aquaculture Center, Factsheet 101-1991.

Aquaculture Systems for the Northeast, Buttner, Joe, Gef Flimlin, Don Webster, 1992, Northeastern Regional Aquaculture Center, Factsheet 120 -1992.

Aquaculture Species for the Northeast, Buttner, Joe, Gef Flimlin, Don Webster, 1992, Northeastern Regional Aquaculture Center, Factsheet 130-1992.

Major Predators of Cultured Shellfish, Flimlin, Gef, Brian F. Beal, 1993. Northeastern Regional Aquaculture Center, Bulletin 180-1993.

Rhode Island

The Northern Quahog: Biology of Mercenaria mercenaria. Rice, M.A. (1992). Rhode Island Sea Grant Publication No. RIU-B-92-001, University of Rhode Island, Narragansett. 60 pp. ISBN-0-938412-33-7.

New Jersey

Available from Rutgers Cooperative Extension of Ocean County, 1623 Whitesville Rd. Toms River, NJ 08755, 732-349-1152. Single copies are free:

Recordkeeping For the Shellfish Culturist, Flimlin, Gef, 1998, NJ Sea Grant Marine Advisory Service Bulletin 13, NJSG-98-390, Rutgers Cooperative Extension Fact Sheet Number FS-916.

Principles of Animal Husbandry for Shellfish Culturists, Flimlin, Gef, Jeff Davidson, 1998, NJ Sea Grant Marine Advisory Service Bulletin 12, NJSG-98-386, Rutgers Cooperative Extension Fact Sheet Number FS-915.

Use of Oxygen Readings to Avoid Gas Bubble Disease in Clam Hatcheries, Kraeuter, John N. Gef Flimlin, 1998, NJ Sea Grant Marine Advisory Service Bulletin 11, NJSG- 98-378, Rutgers Cooperative Extension Fact Sheet Number, FS906.

Field Nursery for Hard Clam Seed, Flimlin, Gef, John N. Kraeuter, 1997, NJ Sea Grant Marine Advisory Service Bulletin #10, NJSG-97-361, Rutgers Cooperative Extension Fact Sheet Number. FS885.

Sources of Aquacultured Clams in New Jersey, Flimlin, Gef, 1994, Rutgers Cooperative Extension, New Jersey Agricultural Experiment Station, Fact Sheet Number FS-785, New Jersey Sea Grant Fact Sheet Number NJSG-94-299.

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