I. INTRODUCTION

Clam culture in the United States began with the first successful rearing of larval hard clams, *Mercenaria mercenaria*, by W.F. Wells between 1920 and 1926. Culture methods for larval and juvenile clams were eventually standardized by Victor Loosanoff and his colleagues in the 1950s and early 1960s (Loosanoff and Davis, 1963a, 1963b). A number of commercial hatcheries began toward the latter part of this period. Clam culture in North America, however, was not commercially successful until economical and efficient nursery systems and field growout techniques were developed. Only over the last decade have nursery system and field growout technologies sufficiently evolved to make the controlled culture of the hard clam commercially attractive (Manzi and Castagna, 1989).

The reported landings of hard clams in the United States have decreased steadily from the turn of the century although production over the last decade has been relatively stable (Table 1). The proportion of these landings either directly or indirectly due to culture has been increasing. The data in Table 1 reveal that hard clam culture production has increased from about 140 thousand bushels in 1981 to about one-half million bushels in 1989. This represents an increase in total culture production of about 300 percent in less than a decade. Over this same period, the percent of total hard clam production due to culture has increased from about 6 percent in 1981 to over 43 percent in 1989. Although much of this increase has occurred in the South Atlantic states (Virginia, North Carolina, South Carolina, Georgia, Florida), it may reflect only apparent statistical increases (i.e., state reporting requirements are changing, finally allowing the segregation of cultured and wildstock landings). Total landings have decreased as well, providing an artificial proportional increase in the contribution of cultured product to overall production. The clam culture production statistics are also probably inflated by the inclusion of clams produced by partial culture activity - i.e., seed production, transplanting, replantings and other semiculture performed as part of natural clam harvesting practices.

Historically, with the exception of North Carolina and Virginia, the South Atlantic states have not been major hard clam producers. Recently however, with the advent of mechanical harvesting methods and the increased value of the species, all of the states but Georgia have developed substantial fisheries. Availability of leaseable growout areas and the environmental suitability of the region in general for culture have also stimulated considerable interest in commercial hard clam culture.

Virginia

In Virginia, the hard clam has been recognized as an important commodity since the writings of Captain John Smith. The lower portion of Chesapeake Bay including the lower James and York

<table>
<thead>
<tr>
<th>Year</th>
<th>Wildstock Landings</th>
<th>Clam Culture Production</th>
<th>Percent of Landings From Culture</th>
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<tr>
<td>1981</td>
<td>2,265</td>
<td>140</td>
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<tr>
<td>1982</td>
<td>1,607</td>
<td>221</td>
<td>13.8</td>
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<td>1983</td>
<td>1,773</td>
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<td>1984</td>
<td>1,844</td>
<td>211</td>
<td>11.4</td>
</tr>
<tr>
<td>1985</td>
<td>2,087</td>
<td>199</td>
<td>9.5</td>
</tr>
<tr>
<td>1986</td>
<td>1,474</td>
<td>313</td>
<td>21.2</td>
</tr>
<tr>
<td>1987</td>
<td>1,427</td>
<td>437</td>
<td>30.6</td>
</tr>
<tr>
<td>1988</td>
<td>1,546</td>
<td>520</td>
<td>33.6</td>
</tr>
<tr>
<td>1989</td>
<td>1,160</td>
<td>500(^1)</td>
<td>43.1</td>
</tr>
</tbody>
</table>

*Data from NMFS (1989), Rhodes (1989) and Anonymous (1990)*

\(^1\)Estimate
Rivers with their bays and tributaries and the Eastern Shore are prominent harvesting locations for the wild fishery. Harvesting methods in Virginia vary widely and include treading by foot, clam rake, basket rake, hand tongs, and patent tongs. In recent years, the wild harvest of clams in Virginia has increased as the harvest of oysters has declined. In 1988, the wild harvest of hard clams was valued at almost $4.8 million, making it the sixth most valuable fishery in the state.

Virginia has a long history of both experimental and commercial culture of the hard clam. The first commercial hard clam hatchery in North America opened its doors in 1956 in the town of Atlantic on the Eastern Shore. While the hatchery/nursery portion of this facility met with some success, the field growout aspect was a failure, most likely due to predation. Scientists in Virginia have since developed growout systems that protect small-size clam seed from predators, greatly increasing the potential for successful culture ventures. Virginia now boasts one of the largest commercial clam culture operations on the eastern seaboard and approximately two dozen smaller ones.

North Carolina

Mechanical harvesting has played a significant role in the growth of North Carolina's hard clam fishery. From 1959 to 1979, the average annual ex-vessel value of hard clams was less than $1 million. By 1986 it had increased to about $7.5 million. Most of the harvest before 1976 was by hand (rakes and tongs). The development of more efficient hydraulic dredges and "kicking" mechanical methods paralleled the rapid increase in the relative prices for clams in the 1970s and 1980s. Hydraulic dredges use a water nozzle to dislodge clams from the sediment and a conveyor to bring them to the surface. Dredges operate in water three to about 12 feet deep. Kickers use a metal kicker plate welded to the boat's rudder. The plate deflects the prop wash from the rudder to the bottom where it washes an 8- to 12-foot wide path. A heavy chain net pulled behind the boat catches clams washed out of the bottom sediments. Kickers can harvest in waters three to nine feet deep.

Mechanical harvest allows fishermen to bag more clams and reach deeper beds than by hand, but the advent of mechanical harvesting stirred controversy within the North Carolina fishery. Hand rakers claimed mechanical harvesters were encroaching on their territory, wiping out their fishery. Resource managers felt that kicking damaged grass beds. A study of this problem found indirect evidence that clam kicking reduces subsequent scallop harvests, Hsiao, et al. (1986). In 1987, kicking and dredging were outlawed from grass beds and live oyster rock. Now regulations allow for a mechanical harvesting season for clams from designated public bottoms only during the winter season. Hand harvesting is allowed year round and since mechanical harvesting was curtailed, hand-harvest landings have accounted for almost double those by mechanical methods. There are about 350 kick boats in North Carolina, 25 hydraulic dredges and 12,000 to 15,000 individually licensed hand harvesters. In 1969, only one regulation applied to hard clams, prohibiting their harvest from polluted areas. Since then, regulations have been enacted limiting the number of clams harvested per day, imposing size limits (1-inch thick), requiring culling of undersized clams, limiting mechanical harvest to certain areas and seasons, and prohibiting taking of clams at night.

In North Carolina, commercial hard clam culture has had a small but consistent presence. The state has had at least two commercial hatcheries operating in recent years and three or four commercial nurseries. Recently, a large Massachusetts-based hard clam culture company built a substantial land-based nursery in the state for overwintering seed.

South Carolina

Clams in South Carolina have undoubtedly been harvested both recreationally and commercially since colonial times. Until recently, however, commercial clam harvests have been rather modest. Almost all the clams harvested were consumed locally and the small fishery was centered in the Georgetown area. In 1973, mechanical harvesting (escalator harvesters) was introduced in the Santee Delta and landings increased rapidly over the next few years. The industry became a million-dollar fishery in 1982 and surpassed the value of oyster landings in 1983. At present, landings average over 40,000 bushels per year valued at $1.2 million or about 3 percent of the nation's total average landings and value. The state's landings are derived about equally from mechanical harvesters and hand harvests (primarily rakes and tongs but Self Contained Underwater Breathing Apparatus [SCUBA] has been gaining popularity).
Research on hard clam culture in South Carolina began in the mid-1970’s and the state has maintained a strong research effort. State-sponsored research has helped develop technology for upflow nursery systems, recirculating downflow systems for set and postset and intertidal growout technology. Now, the state is involved in a multi-institutional project to produce improved broodstocks for hard clam culture in the South Atlantic. Three small-scale commercial hard clam operations are on-going in the state.

Georgia

Before 1981, annual harvesting of hard clams in Georgia was sporadic and at low production levels. At the turn of the century, a small-clam fishery developed with peak landings of 43,000 pounds of meat in 1908. Clamming continued until 1932 but at low levels of production (1,000 to 2,000 pounds of meat annually). The fishery declined by 1933, presumably because of the economic depression. From 1933 to 1981, clams were reported harvested in only five years. Beginning in 1978, the Georgia Sea Grant Marine Extension Service and the Department of Natural Resources began encouraging fishermen to attempt clamming. In 1981, a company relocated to Camden County, Georgia and began clamming full time. Landings in 1981, primarily due to this company, were 5,855 pounds of meat. Fishermen then realized that there was money in clamming and approximately 60,000 pounds of clam meat were landed in 1988. Georgia fishermen harvest clams in three ways: clam or potato rakes, by hand or tonging. Clamming on the intertidal flats is performed by raking, while rakes and hands are used the small creeks. These two methods account for the majority of harvested clams. Tonging in larger creeks account for only a small percentage of harvested clams.

Molluscan culture research in Georgia showed considerable promise and several small-scale operations were started in the mid-1980s with seed purchased from out-of-state hatcheries. In 1985, however, the Department of Natural Resources found an oyster disease *Haplosporidium nelsoni*, popularly known as MSX, in an oyster population in Mud Creek, Camden County. In 1986, MSX was found in South Latham Creek, Glynn County. As a result of the discovery of MSX in coastal Georgia, the Department of Natural Resources banned the importation of any mollusk clams in Georgia ceased even though there is no connection between MSX and clam production. In 1990, one small-scale commercial clam hatchery was established.

Florida

Commercial harvesting of clams in Florida dates back to 1900 and averaged only about one million clams per year before to 1980. In the mid-1980s, annual landings increased to between 20 and 50 million clams with a commercial value exceeding $5 million some years. This increase was due to a large natural set of clams occurring on the east coast of Florida in the Indian River Lagoon. Recent declines in landings from that natural set have prompted many Florida clammers to investigate the potential of clam culture as an alternative to fishing natural stocks. The emergence of this new culture industry has brought with it the need for public access to the technology, equipment, seed and leases to be able to culture clams in the state of Florida.

Private marine research laboratories and several state agencies have supported most of the technical support and information transfer to potential clam farmers. One private research institution has operated a commercial-scale hatchery and nursery and sold most of the seed planted in the state, about 25 million seed clams per year. There were about seven hatcheries and 70 clam farms in operation in Florida in the late 1980s. It is predicted that harvests from clam farms in 1989 and 1990 may surpass wild harvest landings. With a growout time of 18-24 months and improved state leasing practices, the future of clam culture in Florida appears favorable.
II. LEARNING ABOUT HARD CLAM CULTURE

Information Sources

This guide can help you decide which method of clam culture might be best for your location and will help you develop numbers for your economic feasibility study. This manual does not, however, provide biological information on how to grow clams. Rather, it's a guide to making economic comparisons among clam culture methods and helping the investor/culturist determine the economic potential of clam culturing.

Most sections of this guide include a description of the production methods but not an in-depth discussion of what you will encounter when you begin clam farming. To help you learn about the "how-to" of clam farming and marketing, there are many sources of information. You should start by contacting one of your state's Sea Grant marine advisory agents, the Cooperative Extension Service, a marine research university or laboratory or a state agency (a listing of these follows). These organizations can give you literature, names of clam farmers and marketing businesses you can visit, as well as initial observations and recommendations.

Clam culturing is unique so the best advice is to begin on a small scale or possibly apprentice with someone already in the business. This way you learn about the complexity of the marine environment so your mistakes will not be as costly as if you were to begin on a large scale without a good feel for marine life and clam culturing. Larger start-up firms will benefit by hiring experienced personnel. The following contacts should all help you.

Sea Grant Marine Advisory Agents

Virginia:
Virginia Sea Grant College Program
Dept. of Marine Advisory Services
Virginia Institute of Marine Science
College of William & Mary
Gloucester Point, VA 23062
(804) 642-7165

Virginia Graduate Marine Science
Sea Grant Consortium
170 Rugby Road
University of Virginia
Charlottesville, VA 22903
(804) 924-5965

North Carolina:
University of North Carolina
Sea Grant College Program
Marine Advisory Specialist
P.O. Box 896
Atlantic Beach, NC 28512
(919) 247-4007

South Carolina:
Sea Grant Marine Extension Program
P.O. Drawer 1100
Georgetown, SC 29442
(803) 546-4481

Georgia:
Sea Grant Marine Extension Service
University of Georgia
P.O. Box Z
Brunswick, GA 31523
(912) 264-7268

Georgia Sea Grant
Ecology Building
University of Georgia
Athens, GA 30602
(404) 542-7671
Florida:

Sea Grant Extension Agent
Brevard Service Complex
1515 Sarno Road, Building B
Melbourne, FL 32935-5209
(407) 242-6514

Florida Sea Grant College Program
Building 803
University of Florida
Gainesville, FL 32611
(904) 392-3870

Marine Research Laboratories

Virginia:

Eastern Shore Laboratory
Virginia Institute of Marine Science
College of William and Mary
Wachapreague, VA 23480
(804) 787-5816

North Carolina:

University of North Carolina
Institute of Marine Science
P.O. Drawer 809
Morehead City, NC 28557
(919) 726-6841

Duke University Marine Laboratory
Pipers Island
Beaufort, NC 28516
(919) 728-2111

Georgia:

Shellfish Research Laboratory
University of Georgia
P. O. Box 13687
Savannah, GA 31416
(912) 356-2348

South Carolina:

Marine Resources Research Institute
South Carolina Wildlife and Marine Resources
P. O. Box 12559
Charleston, SC 29412
(803) 795-6350

Waddell Mariculture Center
P. O. Box 809
Bluffton, SC 29910
(803) 837-3795

Florida:

Harbor Branch Oceanographic Institution
Coastal, Environmental, and Aquacultural Sciences
5600 Old Dixie Highway
Ft. Pierce, FL 34946
(407) 465-2400

Florida Marine Research Institute
Florida Department of Natural Resources
100 8th Avenue, South
St. Petersburg, FL 33701
(813) 896-8626

Other Organizations and Agencies

Virginia:

Virginia Marine Resources Commission
P. O. Box 756
Newport News, VA 23607-0756
(804) 247-2200 (leases and licenses)

Virginia Bureau of Shellfish Sanitation
109 Governor Street
Room 904
Richmond, VA 233219
(804) 786-7937 (sanitation and shipping)

Virginia Department of Agriculture and Consumer Affairs
Division of Marketing
P. O. Box 1163
Richmond, VA 23209
(804) 371-6094

North Carolina:

North Carolina Division of Marine Fisheries
P. O. Box 769
Morehead City, NC 28557
(919) 726-7021 or (800) 682-2632
(leases and licenses)
North Carolina Division of Coastal Management  
P. O. Box 769  
Morehead City, NC 28557  
(919) 726-7021 (CAMA permits)

North Carolina Division of Shellfish Sanitation  
P. O. Box 769  
Morehead City, NC 28557  
(919) 726-6827 (sanitation and shipping)

North Carolina Department of Agriculture  
P. O. Box 27647  
Raleigh, NC 27611  
(919) 733-7125 (permit assistance)

South Carolina:

South Carolina Department of Wildlife and Marine Resources  
Division of Marine Resources  
P. O. Box 12559  
Charleston, SC 29412  
(803) 795-6350

South Carolina Coastal Council  
4130 Faber Place, Suite 130  
Charleston, SC 29405  
(803) 744-5838

South Carolina Department of Health and Environmental Control  
Division of Water Quality and Shellfish Sanitation  
2600 Bull Street  
Columbia, SC 29201  
(803) 734-5232

Georgia:

Department of Natural Resources  
Coastal Resources Division  
1 Conservation Way  
Brunswick GA 31523-9990  
(912) 264-0542 (leases and licenses)

Department of Agriculture  
P. O. Box 631  
Jesup, GA 31542  
(912) 427-3507 (health inspector)

Environmental Protection Division  
Department of Natural Resources  
Coastal Resource Division  
1200 Glynn Avenue  
Brunswick, GA 31523-9990  
(912) 264-7284 (CAMA permits)

Florida:

State of Florida  
Department of Agriculture and Consumer Services  
Mayo Building, Room 422  
Tallahassee, FL 32399-0800

Florida Department of Natural Resources  
Division of State Lands  
Bureau of Submerged Land Management  
3900 Commonwealth Boulevard  
Room 203  
Tallahassee, FL 32399  
(904) 487-4436 (leases)

Magazines and Periodicals

Fish Farmer  
Quadrant Subscription Services  
Oakfield House, Perrymount Road  
Haywards Heath, Sussex RH 163 DH England  
bi-monthly - $50/yr.

Aquaculture Magazine  
by Achill River Corporation  
P. O. Box 2329  
Asheville, NC 28802  
bi-monthly-$15/yr.  
Annual Buyer's Guide

Practical Aquaculture and Lake Management  
P. O. Box 1294  
Garner, NC 27529  
(919) 772-8548  
monthly-$12/yr.
### Magazines and Periodicals (cont.)

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<tr>
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<th>Address</th>
<th>Contact Information</th>
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<tr>
<td>World Aquaculture Magazine</td>
<td>16 East Fraternity Lane, Louisiana State University, Baton Rouge, LA 70803</td>
<td>(504) 388-3137 quarterly - $30/yr.</td>
</tr>
<tr>
<td>Water Farming Journal</td>
<td>3400 Neyrey Drive, Metairie, LA 70002</td>
<td>(504) 482-9500 monthly - $18/yr.</td>
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<tr>
<td>Canadian Aquaculture</td>
<td>4611 William Head Road, Victoria, British Columbia V8X3W9, Canada</td>
<td>(604) 478-9209 bi-monthly - $18/yr.</td>
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### Associations

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<tr>
<td>Virginia Shellfish Grower's Association</td>
<td>421 Messick Road, Poquoson, VA 23662</td>
<td>(804) 868-6058</td>
</tr>
<tr>
<td>Shellfish Farmers Association</td>
<td>480 River Prado Road, Ft. Pierce, FL 34946</td>
<td>(407) 466-2013 newsletter</td>
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<tr>
<td>World Aquaculture Society</td>
<td>16 East Fraternity Lane, Louisiana State University, Baton Rouge, LA 70803</td>
<td>(504) 388-3137 quarterly journal, quarterly magazine, annual meeting, $45/yr.</td>
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### National Shellfisheries Association

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<tr>
<td>College of Marine Studies</td>
<td>University of Delaware, Lewes, DE 19958</td>
<td>(302) 645-4060 quarterly NSA newsletter</td>
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<tr>
<td>South Carolina Aquaculture Association</td>
<td>South Carolina Department of Agriculture, P. O. Box 11280, Columbia, SC 29211</td>
<td>(803) 734-2200 annual meeting</td>
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### Brochures and Booklets

**Virginia:**

- Manual for Growing the Hard Clam (Mercenaria) SRAMSOE No. 249
  - 110 pages - $3.00
- Virginia Institute of Marine Science Sea Grant Communications
  - Gloucester Point, VA 23062

**North Carolina:**

- University of North Carolina Sea Grant College Program
  - Raleigh, NC $5.00
- "Shellfish: North Carolina Aquaculture Regulations"
- Clam Conference Video Series (one-week loan)

**All available from:**

- UNC Sea Grant MAS
  - P. O. Box 3146
  - Atlantic Beach, NC 28512
Brochures and Booklets (cont.)

South Carolina:

Economic Analysis of Commercial Hard Clam Mariculture in South Carolina
South Carolina Aquaculture Fisheries and Wildlife Cooperative
Publication #9001
SC Sea Grant Consortium
287 Meeting Street
Charleston, SC 29401

An Interim Guide for Aquaculture Permitting in South Carolina
SC Sea Grant Consortium
287 Meeting Street
Charleston, SC 29401

Florida:

A Manual for Farming the Hard Shell Clam in Florida
by D. Vaughan, L. Creswell and M. Pardee
Florida Department of Agriculture and Consumer Services
Division of Marketing
Mayo Building
Tallahassee, FL 32399-0800

New York:

Small-scale Farming of the Hard Clam on Long Island, NY
Aquaculture Innovation Program
The NY State Urban Development Corporation
1515 Broadway
New York, NY 10036

Books


III. BEGINNING A NEW CULTURE SYSTEM

Options

The clam culture process is divided into three stages: hatchery, nursery, and growout. The hatchery produces small seed grown from eggs through larval stages. The nursery grows larger seed for field planting. Growout produces marketable size clams from seed.

The hatchery stage consists of tanks and equipment to (1) condition adult clams into ripeness and spawn or induce release of reproductive cells or gametes, (2) grow and produce cultured algae as a food source for developing clams, and (3) grow early clam stages or larvae into the young clams or "set." The hatchery stage techniques are fairly standard and appropriate for most areas but are fairly complex and expensive. Standard methodology of larval cultivation has been developed (Loosanoff and Davis, 1963a, 1963b) and standard basic methods have been described (Castagna and Kraeutler, 1981).

The nursery stage takes the young clams or "set" and protects, feeds and grows them until they are large enough to plant in final growout conditions. This can be done by using a land-based, field-based or combination system. The land-based system holds clams in tanks or containers and provides food by pumping natural waters or cultured algae. The field-based nursery places juveniles in protected containers planted within the natural protected areas. Field-based nursery systems eliminate the need for pumping, but labor and equipment costs can be different from land-based systems. Nursery system design will vary in response to technical capability, equipment availability, predator pressures, cost considerations, land availability, permitting and labor limitations. Each of these must be considered for each locality when evaluating site requirements and available resources.

The growout stage uses the larger seeds which are planted in field conditions until harvest. Using natural phytoplankton as food, seeds can be grown in trays, bags, nets or cages designed to protect the seeds from predators and allow substantial water flow to provide food. Variables for growout to harvest are site specific and affected by predators, fouling, and approved harvesting techniques.

Hatchery, nursery and growout systems may not all be needed at once in order to develop a profitable business. One or two of these may be the best initial strategy for your business plan with additions or full integration possible later. In general, most culturing can become successful through a growout operation begun by purchasing large-size seed and growing them out. Later the farmer can add a nursery after becoming proficient at seed handling or if availability of seed or its cost becomes a limiting factor.

Specific equipment and techniques used in the nursery and growout phases of clam culture common to each state along the South Atlantic coast are described in: Virginia (Kraeutler and Castagna, 1985); North Carolina (Kemp, 1991); South Carolina (Manzi and Whetstone, 1981); Georgia (Walker, 1984) and Florida (Vaughan, Creswell and Pardee, 1989). Regional variability requires equipment, techniques, and planting strategies used in nursery and growout stages to be specialized by site requirements, environmental and biological conditions and economic constraints. A summary of important guidelines is given below in general order of priority.

SITE SELECTION is the most important step in establishing a clam farm. Be thorough in your examination of a site and remember that biological, environmental, sociological and operational factors all interact. Trial plots and experiments with equipment are recommended before a large-scale operation is established.

ECONOMIC considerations include a range of operational variables affected by environmental and biological conditions. Culture methods, equipment, labor and financial assessments may vary because of site specificity. Adequate initial investment capital is needed to offset negative annual profits which may occur during the first four to five years of operation. Year-to-year cash needs will be an additional financial burden during the start-up years and you must clearly understand the timing and magnitude of all costs and earnings.

LEASING, PERMITTING AND REGULATION requirements should be researched and all permits, licenses and notifications be made to proper authorities before starting your operation. Remember that water classifications, leasing, and harvesting regulations may change frequently.
MARKET considerations should include local and national demand, seasonality and consistency of supply. Historical landings of wild harvest may not reflect culture-product market potential.

BIOLOGICAL background of the species under cultivation should be understood when evaluating techniques, seed sources, growth problems and conditions for enhancing clam growth.

PREDATION is a major cause of mortality in a clam operation. Sufficient exclusion techniques must be incorporated into farming methods to ensure profitable survival rates.

HARVESTING regulations of permitted equipment and techniques as well as shellfish sanitation surveys of harvestable waters should be researched for present and future status for a specific area.

FIELD NURSERY AND GROWOUT TECHNIQUES vary in design and efficiency for each site. Experiment with modifying various methods and improve procedures to best suit your location.

RECORD KEEPING is an important factor in effective evaluation and organization of any farm operation. Maintain accurate records to establish patterns and trends that can help you modify and improve in delinquent areas as needed.

SECURITY is a vital component of any clam farm venture. Be sure that you have effective methods to protect your crop from theft. It may be necessary to include 24-hour surveillance near or on the field growout site.

Site Selection

Site selection is the primary consideration for potential clam farmers. The criteria for evaluating an appropriate growout site include ecological, resource use, and operational factors and their interaction. These considerations will influence clam growth and survival as well as equipment and methods. This greatly affects capital and labor and, therefore, profit. A small test plot of clam seed may be the best way to evaluate a site.

Ecology

Ecology of the site greatly affects clam growth and survival. Important biological factors include the living organisms that contribute to the food, fouling, predation, disease and water classification. Food (algae or phytoplankton) is a major factor contributing to clam growth. This is controlled by both the quantity (species density) of food as well as the quality (species diversity) of food available. How fast clams grow can be analyzed from old shell-growth lines, living clam shell-growth lines and seed-planting experiments.

Fouling organisms can affect water and food flow through protective equipment and can inhibit growth and lower product value. Fouling can vary seasonally and greatly affect equipment and labor costs. Fouling organisms may compete for the same food organisms as the clams, thus greatly affecting clam growth rates.

Clam predators are one of the most important aspects to consider in site selection. Their type and abundance need to be accounted for in deciding what equipment and methods are used for protection.

Other microorganisms may also be important if they are abundant enough to be a pest or contribute to diseases, shell deformities or degradation of water quality.

Other environmental factors include weather, wave and bottom conditions, clam survival, equipment needs and operational constraints. These conditions include geographic and seasonal variation in salinity, temperature, water quality and flow, bottom sediment characteristics, tidal range and wind and wave action.

The optimal salinity range is between 25 and 35 parts per thousand (ppt). Salinities much above or below this range for more than short periods may result in slow growth or even death. Optimal temperature range is between 20-28°C (68-82°F) but this may vary depending on geographic location in the South Atlantic. Clams can survive in higher and lower temperatures but growth rates are affected.

Protection from wind and wave action must be considered in site selection. Exposed areas to prevailing winds can cause sediment movement and working-condition problems. Although clams can grow in most sediment types and at most depths, the latter two will affect the equipment, methods and working conditions.
Resource Use

The way resources are currently used will affect the leasing of a site if existing or adjacent fisheries production areas exist or are perceived. Adjacent landowners and public opinion can greatly affect getting a lease or expanding an operation. Alternate uses by fisherman and boaters as well as residential aesthetics and future development should be considered. Potential sources of pollution and conflicts with other users need to be considered as well.

Operations

Upland access and its contribution to field operations, boat launching, equipment storage, harvesting and security is a major component of how well a clam farm operates. Site construction constraints, ability to expand, permitting and availability of utilities need to be addressed for all upland facilities. Plans for handling security should also include upland and field sites, as well as access between them.
IV. PERMITTING REQUIREMENTS AND CONDITIONS FOR OBTAINING A SHELLFISH LEASE

Shellfish growers operate in an environment that comes under the jurisdiction of a variety of public agencies. In some South Atlantic states shellfish growers deal primarily with a single regulatory agency, usually a department of marine resources or department of natural resources. However, usually a grower will need a permit or license for an activity under the jurisdiction of another regulatory agency. The discussion below outlines the permitting requirements and conditions for obtaining a shellfish lease in the states considered in this manual. The reader is cautioned that the rules and regulations regarding shellfish leasing and permitting are subject to change. The section below, therefore, is intended to be a general overview. Potential hard clam investors should thoroughly examine all relative rules and regulations.

Conditions for Obtaining a Shellfish Lease

Any clam culture operation that includes a growout phase will need to obtain a shellfish lease. This lease is not unlike that on business property. A shellfish lease is a legal agreement between the lessee and the lessor detailing the authorized use and restrictions on specified property or asset. Each state along the South Atlantic coast has similar conditions that each lease applicant and application must meet. Table 2 provides a state-by-state summary of these conditions. Note that in Florida, the shellfish lease referred to in this document is called an aquaculture lease and in South Carolina it is called a mariculture permit. However, the term shellfish lease will be used for convenience.

Eligible Grounds

Each state delineates between shellfish bottoms reserved for public access and those available for private lease subject to the approval of the water quality and safety for shellfish growing purposes. Although the method by which public bottoms are delineated differs by state, the public areas not available for lease are well documented. Clam-growing bottoms eligible for a new lease include all those within the territorial waters of a state exclusive of those areas designated as public and those approved areas not already assigned under an existing lease agreement.

Residency

The lease applicant must be a resident of the state to which the application is being made except in Georgia. Applications made under the name of a business or corporation follow similar rules in that the business or corporation must be chartered in the state to which application is made. Corporations may also be subject to the additional requirement that at least a majority of its shareholders be state residents. In Georgia, preference is given to state residents but residency is not a precondition for obtaining a lease.

Acreage Limits

In all states except Georgia, there exists a maximum amount of acreage that any one individual or business may be assigned on any single application. The maximum acreage for each state is in Table 2. Note also that in some states there are limits on the amount of leased bottom any one individual may hold in aggregate. For example, Virginia allows an individual up to 3,000 acres leased in his or her name. The maximum acreage that will be considered for any one lease application is 250 acres. The 3,000-acre limit applies to waters not more than 15 feet deep. In waters exceeding 15 feet the limit is 5,000 acres. In Florida, leases in Franklin County are restricted to no more than one acre. In some states larger lease sizes may be awarded provided the lessee demonstrates the ability to manage a larger area.

Lease Duration

In all states except Georgia, leases are granted for a fixed time. In Georgia, lease assignments are largely negotiated between the lessee and the state. Thus, many of the terms and conditions, including the duration of the agreement, are products of that process. In all other states the lease period is fixed by law but is renewable subject to satisfaction of all terms and conditions of the expiring lease.
Table 2. Conditions that must be met to acquire a shellfish lease in five South Atlantic states.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Virginia</th>
<th>South Carolina</th>
<th>North Carolina</th>
<th>Georgia</th>
<th>Florida</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eligible grounds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>(a)</td>
<td>(a)</td>
<td>(a)</td>
<td>(a)</td>
<td>(a)</td>
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<tr>
<td>(a =) any approved state bottom</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>(=) not assigned</td>
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<tr>
<td>(=) or designated</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>(=) as public.</td>
<td></td>
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</tr>
<tr>
<td>Residency</td>
<td></td>
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<tr>
<td>(R) = required</td>
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<tr>
<td>(NR) = not required</td>
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<tr>
<td>Acreage limits</td>
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<tr>
<td>(NR) = no restrictions</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Years of lease</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>(R) = renewable</td>
<td></td>
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<tr>
<td>(N) = negotiable</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Application fee</td>
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<tr>
<td>$25</td>
<td>$25</td>
<td>$100</td>
<td>$50</td>
<td>$200</td>
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</tr>
<tr>
<td>Survey</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>(a) = required at application</td>
<td></td>
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<td></td>
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<tr>
<td>(b) = required upon approval</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Public notice</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(R) = public notice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(=) required</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Management plan</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(NR) = not required</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R) = required</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lease fee (acre/yr)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>(M) = market value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1.50</td>
<td>$5.00</td>
<td>$5.00</td>
<td>$M</td>
<td>$15</td>
<td></td>
</tr>
</tbody>
</table>
Application Process

In all states formal lease applications must be filed. Although the agency with which the application must be made differs by state, application contents and process are similar. The following discussion indicates the essential elements that must accompany the lease application state by state.

Application Fee

Each lease application must be accompanied by payment of a nonrefundable fee, ranging from $25 in Virginia and South Carolina to $200 in Florida (Table 2). In Virginia, however, a variable recording fee must also be paid, depending upon the nature and duration of the application process.

Survey

In addition to a written description of the proposed lease site, a formal site survey must be conducted. In some instances the survey must be included at the time of application. In other cases the survey need not be submitted until application approval. The survey fee may be separate from the permit fee in some states and could be substantial.

Public Notice

In all states public notification of a lease application must be given. In all states except Georgia, the public review process allows time for objections and comments. In Georgia, the public review process precedes a public bid for the lease. Thus, in Georgia, the lease may not necessarily be granted to the individual who initiated the application. In some states public objection may substantially delay approval or cause a lease application to be denied.

Management Plan

In all cases when the lease application is made, the applicant must give a written description of the proposed use of the submerged lands. In Florida, North Carolina and Georgia, however, a management plan must be submitted. Information that may be required is the crop to be produced, production methods, harvest methods, and a timetable for development of leased bottoms.

Lease Fee

Each state requires an annual lease fee. In all states except Georgia the lease fee is the same regardless of the area being leased. In Georgia the lease fee depends on the shellfish production potential of the leased bottom. Thus, bottoms of low productivity would be assigned a lower lease fee than those of relatively greater production potential.

Lease Restrictions

The previous sections described basic considerations and requirements for obtaining a shellfish lease. In addition to these, each state may restrict lease use. A summary of the various types of restrictions and how each state deals with them is in Table 3.

Right to Fish

In all states, traditional uses of the water column for navigation or fishing may not be excluded by the holder of a shellfish lease. In principle, the holder of a shellfish lease has exclusive rights to the product of his or her own efforts but the holder does not have the right to exclude other uses of the water surface as long as they do not infringe on the shellfish-growing activity.

Restricted Use

In all states, acquisition of a shellfish lease does not carry all the rights and privileges accorded to private property. A shellfish lease is granted under the condition that the bottoms be used for no other purpose than the production of shellfish. Applicants should also check on the transferability or sub-leasing of leases to third parties. This may be very important in obtaining funds from a financial institution.

Harvestable Size

In some states, shellfish growers must adhere to the same harvestable-size restrictions imposed on shellfish harvested from wild stocks. In Virginia, the same rule applies; however, no minimum size limits have been set. In South Carolina, on the other hand, culture operations are exempted from any size restrictions. In Florida, any in-state shipment of clams must meet a 1" minimum size. Under certain conditions, however, out-of-state shipments of cultured clams are exempt from size restrictions.
Table 3. Restrictions or special requirements for a shellfish lease in five South Atlantic states.

<table>
<thead>
<tr>
<th>Restrictions or Special Requirements</th>
<th>Virginia</th>
<th>South Carolina</th>
<th>North Carolina</th>
<th>Georgia</th>
<th>Florida</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right to fish</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>R = right to fish applies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restricted use</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>R = restriction applies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvest size limits</td>
<td>A</td>
<td>C</td>
<td>C</td>
<td>B</td>
<td>B,D</td>
</tr>
<tr>
<td>A = size limit applies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>but none currently set</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B = size limit applies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C = aquaculture exempted</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D = aquaculture exempted for out-of-state shipment only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condemnation</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>R = restriction applies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvest time</td>
<td>S,N</td>
<td>N</td>
<td>N</td>
<td>S,N</td>
<td>N</td>
</tr>
<tr>
<td>S = no Sunday harvest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N = no night harvest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvest gear</td>
<td>HD,MP</td>
<td>MP</td>
<td>MP</td>
<td>MP</td>
<td>MP</td>
</tr>
<tr>
<td>HD = hydraulic dredge prohibited</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP = mechanical harvest allowed with permit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water column</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>NR = no restriction subject to navigation special permit requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Condemnation

In all states, all shellfish grounds can be condemned by state health authorities because of bacterial or chemical contamination of shellfish-growing waters.

Harvest Times/Season

In all states, shellfish-culture operations are exempt from seasonal restrictions on harvest. However, in Virginia and Georgia, nighttime and Sunday harvest is prohibited. In North Carolina only nighttime harvest is prohibited while in Florida and South Carolina, nighttime harvest is allowed with a special-use permit.

Harvest Gear

In all states, all methods of hand harvesting are permitted with proper licenses or permits. However, each state differs in its treatment of mechanical harvesters. With some exceptions each state permits all means of mechanical harvesting with proper permits. In Virginia however, hydraulic dredges are expressly prohibited although other forms of mechanical harvest are not.

Water Column

In all states, a leaseholder may be allowed to use the water column for production purposes as long as such activity does not impede navigation. However, with the exception of Virginia, a special water-column permit must be obtained. Further, with the exception of North Carolina, water-column leases are subject to the same terms and conditions as a bottom lease. In North Carolina, water-column permits require an annual fee of $500 per acre, are renewable on a two-year basis, and carry a minimum production requirement of 100 bushels per acre. Note also that in North Carolina a water-column lease is required for any production system that extends into the water column including pens, bags, trays, and cages. Only artificial beds and bottom nets can be used in North Carolina without a special water-column permit. In Florida only areas not designated as aquatic preserves are eligible for a water-column lease.

Other Permitting Requirements

Acquisition of a shellfish lease is equivalent to a clam production permit. In most states, however, permits may also be required to buy and sell clams, transfer seed clams or ship clams. Also, for operations including a land-based hatchery or nursery system, special permits may be required to pump sea water through the system and discharge wastes. A regulations summary for selling and land-based operations is in Table 4.

Selling Clams

The type of licenses required for selling clams depends on whether the harvested clams are to be sold directly to a registered wholesaler or dealer or whether the clam culturist acts as his or her own wholesaler. In Virginia and North Carolina, no license other than that required to harvest is necessary if the clam culturist sells directly to a qualified buyer. Florida, Georgia, and South Carolina, however, require a license to land and sell any clams harvested in waters of these states in addition to the license required for harvesting gear. Any clam culturist planning to become a wholesaler or distributor must be licensed. Virginia, South Carolina and Georgia require only an application for a wholesalers license. In Florida and North Carolina, however, there are special provisions for wholesalers.

North Carolina requires a shell-stock shippers license for any clams shipped live in the shell. If shucked clams are to be shipped, a shucker-packer license is required. Any clam dealer required to have a shell-stock and a shucker-packer license must be inspected and certified by the North Carolina Shellfish Sanitation Division. In Florida, one of two licenses is required depending upon the clams' destination. A Wholesale County Dealer license permits the licensee to buy and sell clams only within the county registered on the license. A Wholesale State Dealer license permits the licensee to buy and sell clams anywhere within the state inclusive of the county in which the dealer is located. In all states, anyone shipping clams out of state is subject to federal interstate-shipping regulations and must obtain a special shippers license.

Special Provisions for Seed

There is considerable concern among the South Atlantic states for the integrity of natural wildlife and ecosystems. Consequently, most states have special provisions regarding the import of seed stock from out of state. In Virginia, all non-native species are prohibited. In North and South Caro-
Table 4. Dealer licensing and land-based permit requirements for shellfish leases in five South Atlantic states.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Virginia</th>
<th>South Carolina</th>
<th>North Carolina</th>
<th>Georgia</th>
<th>Florida</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sale to buyer only</td>
<td>NL</td>
<td>LS</td>
<td>NL</td>
<td>LS</td>
<td>LS</td>
</tr>
<tr>
<td>NL = no license</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>required other</td>
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<tr>
<td>than harvest</td>
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<tr>
<td>LS = landing and</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>selling permit required</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wholesaler</td>
<td>WL</td>
<td>WL</td>
<td>SS,SH</td>
<td>WL</td>
<td>WC,WS</td>
</tr>
<tr>
<td>WL = wholesaler license</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>required</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>SS = shell-stock shippers</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>license required</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>SH = shucker-packer</td>
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<td></td>
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<tr>
<td>license required</td>
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<tr>
<td>WC = wholesaler</td>
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<tr>
<td>county license required</td>
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<tr>
<td>WS = wholesaler state</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>license required</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Seed stock</td>
<td>NS</td>
<td>ES</td>
<td>ES</td>
<td>IS</td>
<td>NS,ES</td>
</tr>
<tr>
<td>NS = non-native species</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>prohibited</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>ES = exotic-species</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>permit required</td>
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</tr>
<tr>
<td>for non-native species</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>IS = all out-of-state</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>seed prohibited</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump/discharge permits</td>
<td>PRV</td>
<td>PR</td>
<td>PR</td>
<td>PR</td>
<td>PRV</td>
</tr>
<tr>
<td>PRV = permit required,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reviewed on</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>case-by-case basis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR = permit required</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

17
olina, an exotic-species permit may be obtained to import non-native species. All out-of-state seed is prohibited in Georgia. A special permit must be obtained to import non-native seed to Florida waters even though the species may be native to the region.

Pumping/Discharge Regulations

Any land-based hatchery or nursery system will require pumping of seawater and discharge of waste. North Carolina, South Carolina and Georgia require a permit to pump or discharge water. In Georgia, application for such a permit must be made to the Division of Natural Resources, while in North Carolina, permit applications are to the North Carolina Coastal Commission. At present, South Carolina is making its permitting rules consistent with those of the federal government. Once completed, culture operations with limited flow rates will be exempt from the discharge-permitting requirements. Virginia has similar rules to those of North Carolina and Georgia, except that the type of discharge permit required depends on the water volume to be used. In Florida, permitting for pumping and discharging water from culture facilities is reviewed case by case. There is considerable concern, however, over the effluent volume and content pumped through clam culturing systems in the state. Consequently, rules and regulations regarding pumping and discharge permitting are currently being examined.

Federal and Local Considerations

Besides specific state regulations, federal, regional or local regulations may affect the siting or operation of a clam culture business. For example, there are large areas in Georgia suitable for clam culture that are located on federal lands. Although it is possible to lease these areas, applications must be made to the Department of Interior and specific guidelines governing the use of the site must be followed. In other instances, the regulatory requirements of the U.S. Army Corps of Engineers, the Environmental Protection Agency, and other federal agencies may affect a hard clam culture business.

In addition to federal concerns, local government regulations or decisions may affect clam culture businesses. In all cases, a lease application must be subjected to a public notice within the county or municipality adjoining the lease site. At that time, the lease application must satisfy local regulations and is subject to objections from specific individuals that may be adversely affected. In most instances, local and federal regulations will be location or operation specific and cannot be addressed in this guide. Anyone interested in investing in hard clam culture must be aware that federal and local regulations may affect his or her business plans and the time investigating the potential impacts of these regulations would be well spent. A summary of permitting-agency addresses in each state is in Table 5.
<table>
<thead>
<tr>
<th>Lease Application</th>
<th>Licenses</th>
<th>Discharge Permits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Virginia</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virginia Marine Resources Commission</td>
<td>Virginia Marine Resources Commission</td>
<td>Virginia Water Control Board</td>
</tr>
<tr>
<td>P. O. Box 756</td>
<td>P. O. Box 756</td>
<td>2107 North Hamilton Street</td>
</tr>
<tr>
<td>Newport News, VA 23607</td>
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<td>North Carolina Division of Coastal Management</td>
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<tr>
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<tr>
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<td>2600 Blair Stone Road</td>
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<tr>
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V. CULTURE TECHNIQUES

Brood Stock Collection and Reproductive Conditioning

Brood stock for hatchery production of larvae should be collected from local sources. Clams are easier to condition if collected before their natural spawning period(s). For South Atlantic clam populations, spring is the major spawning period. Although it is possible to recondition clams after spawning, it takes 8 to 10 weeks. By collecting clams before natural spawning, only days to a few weeks of conditioning may be required. Listed in Table 6 below are reports on the reproductive cycle of hard clams in the South Atlantic states.

Table 6. Information sources on reproductive cycle of hard clams in five South Atlantic states.

<table>
<thead>
<tr>
<th>Area</th>
<th>Spawning Period</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virginia</td>
<td>Spring-Fall</td>
<td>Castagna &amp; Kreauter (1981)</td>
</tr>
<tr>
<td>North Carolina</td>
<td>Spring-Fall</td>
<td>Porter (1964)</td>
</tr>
<tr>
<td>South Carolina</td>
<td>Spring-Fall</td>
<td>Eversole et al. (1980);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manzi et al. (1985)</td>
</tr>
<tr>
<td>Georgia</td>
<td>Spring-Fall-Winter¹</td>
<td>Pline (1984);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heffernan et al. (1989)</td>
</tr>
<tr>
<td>Florida East Coast</td>
<td>Spring-Fall</td>
<td>Hesselman et al. (1989)</td>
</tr>
<tr>
<td>Florida West Coast</td>
<td>Spring-Fall-Winter¹</td>
<td>Dalton and Menzel (1983)</td>
</tr>
</tbody>
</table>

¹ Although winter spawning has been documented, it is dependent on environmental factors and may not occur every year. (See Heffernan et al. 1989).

These studies should be consulted for approximate spawning times in the specific geographic area of interest. However, spawning cycles may vary from year to year. That is, a warmer-than-normal winter may result in an earlier-than-normal spawning and a colder-than-normal winter may delay spawning.

After collection clams should be washed and scrubbed to remove other organisms from their shells. Clams are placed in holding tanks containing chilled sea water (18 to 24°C) with sufficient food for conditioning, both of which should be replaced daily.

Spawning

To initiate spawning, clams are placed in a spawning table containing sea water heated 28 to 30°C. Clams should remain in the table until at least half begin siphoning. The water temperature in the table is then lowered to 20 to 22°C by adding chilled sea water. At 30-minute intervals, the water temperature is alternated between 20 to 22°C and 28 to 30°C. If the clams are well-conditioned, spawning should begin after three or four cycles. If not, a male may be sacrificed, stripped of sperm and a sperm suspension added to the water. If this fails, chemical serotonin may be injected into the clam to induce spawning. Gibbons and Castagna (1984) contains information such as dosage rates for serotonin.

Larval Culture

After spawning, eggs are collected, counted and placed in larval growing tanks. Eggs are collected by draining the water from the spawning table through two sieves. The top sieve (180 to 400 micron) filters out the debris, mucus, feces and pseudofeces, while allowing the eggs to pass through. The bottom sieve (25 micron) retains the eggs, which are washed into a precalibrated container, stirred well, and a one ml sample obtained. The sample is transferred to a Sedwick-Rafter counting cell placed under a compound microscope and the number of eggs per ml determined by direct count. By multiplying the number of eggs per ml sample, times total number of ml per container, the
total number of eggs can be estimated. Eggs are placed in larval tanks containing 5 micron filtered sea water at 26 to 30 ppt salinity at 25 to 30° C. After two days, larval tanks are drained down through a 44-micron sieve. Trophophore larvae are counted and returned to a new growing tank at a density of 15 larvae per ml. Until setting, which occurs between 8 to 14 days, larvae should be collected, counted and placed into new tanks every two days. Castagna and Kraeuter (1981) provide an excellent detailed description of hatchery procedures.

Post-set Growout

Once larvae have set, there are three basic means of maintaining the post-set clams: traditional, downweller, and upweller methods as described in Manzi and Castagna (1989). The traditional method requires leaving the larvae and set animals in the larval tanks and adding large amounts of cultured algae daily. Larval tank water is changed daily. Post-set larvae may also be placed in raceways containing static water. After a week, filtered, ambient temperature sea water is added at very slow flow rates. Flow rates are gradually increased with growth of animals as reported in Castagna and Kraeuter (1981). Table culture requires large amounts of space and is very labor intensive in areas of heavy silt, as compared to the other methods.

Downweller units may be as simple as a cylinder with a mesh screen attached to the bottom suspended within a recirculating reservoir. Post-set clams are placed in the cylinder and sea water with cultured algae is pumped via airflow or direct flow from the reservoir by the recirculating pump into the top of the cylinder. Excess water is forced down through the clams and out the bottom mesh. Reservoir tanks should be changed daily, or supplemental feeding from a common reservoir can be used during working hours and continuous ambient-flow through can be used during nonworking hours. The ambient flow flushes out waste products and unused algae, but complete tank cleaning should be done weekly. In upweller units, water circulates up through the bottom mesh, through the clams and exits in an opening near the top of the cylinder. The cylinder is in a reservoir. Water is driven by airlifts within the cylinder, drawing water from within the cylinder and forcing it back into the reservoir. Manzi and Castagna (1989) provide details.

Algal Production for Feeding Clam Larvae and Juveniles

Hatchery production of single-celled algae species for consumption by bivalve larvae and juveniles has developed from two basic methods: the Glancy Method (Glancy, 1965; Castagna and Kreuter, 1981; Castagna and Manzi, 1989) and the Milford Method (Loosanoff and Davis, 1963a,b; Davis, 1969). The Glancy Method is the simplest way to grow algae, but the Milford Method is presently the preferred culture system among hatchery operators. The Glancy Method involves filtration by continuous centrifuging and filtering of raw sea water through bag filters, or wound-core filters. Filters are usually of 3, 5, 10, and 25 micron in size. Filtered water stands for 48 hours in slowly aerated tanks exposed to sunlight or artificial light. Tanks may be outdoors, but are generally in a greenhouse or solarium to prevent contamination by other algal species from salt spray. Fertilizers will produce heavy blooms generally dominated by a single species. A major problem with this method is its dependence upon natural phytoplankton blooms. Whatever is blooming in the river (a desirable or non-desirable species) is what you will be culturing.

The Milford Method is a much more labor-intensive and technical means of culturing algae (see Castagna and Manzi, 1989). This method generally starts with unialgal culture. Cultures are generally started in sterile sea water in small 250-ml flasks in which culture media such as Guillard’s F/2 nutrients have been added (Guillard, 1983). Sterilization of the sea water may be achieved by autoclaving or by the addition of hypochlorite (2 percent solution). Chlorine is then neutralized by sodium thiosulfate. Flask cultures then inoculate 18-liter carboys to inoculate Kalwall tubes (see Castagna and Manzi, 1989) or tanks of various sizes. Culture vessels are aerated to supply CO2 and mix the culture. They may be supplied with additional CO2 from gas cylinders at various intervals to help maintain an optimal pH for best algae growth. Cultures are placed under natural light, fluorescent, halide lamps or a wide spectrum light source. This method produces a constant high-quality food source that is not dependent upon environmental fluctuations as is the Glancy Method.
VI. CLAM NURSERY SYSTEMS

Commercial hard clam culture systems rely primarily on final-growth procedures that use the natural environment. The large majority of field growout techniques presently used by commercial culturists require clam-seed stock of considerable size. In the South Atlantic states, field growout techniques include intertidal pens and trays, subtidal trays, soft trays and bottom plants - all of which require an initial seed size of at least 7-10 mm. Because it is not economically feasible to raise seed to this size in hatcheries, some form of intermediate growout is necessary to produce planting-size seed. Nursery systems are the link between hatcheries and field growout operations, providing the intermediate growth necessary to bring hatchery seed to field-planting size. A comparison of critical factors that determine which type system is best is in Table 7. Three types of nurseries for hard clam seed have evolved; field trays, raceways and upflow nurseries (Manzi and Castagna, 1989).

Field Nurseries

Field nurseries were the first to evolve and took several forms including rafts, intertidal and subtidal cages, trays and bottom plants using aggregate and/or plastic mesh netting for predator protection. Subtidal and intertidal trays have emerged as primary methods of field-nursery culture. Plastic trays are lined with fine netting. Gravel and/or sand is a protective substrate. The trays are placed in protected natural areas in either the low intertidal zone or on shallow subtidal bottoms. Although initially used with very small seed (1 mm), the intensive maintenance required with smaller mesh netting to provide good water exchange generally precludes the use of field-nursery culture systems for seed smaller than 3-4 mm. Recent standard practice with field nursery systems consists of planting 3-4 mm seed at high densities (1,000-1,500 seed/ft²) in mesh covered plastic trays often containing a pea-gravel substrate.

Recently, bottom-bag systems and oyster-belt systems have been developed and used as field nurseries for hard clam seed (Vaughan et al., 1989). Bottom bags are basically soft cages of plastic mesh attached to the substrate by a lead line or other anchoring system (e.g. rebar). Flotation is attached to the bags to allow them to "tent," for sediment deposition. The oyster belt is a flexible belt system using a pair of parallel polypropylene lines, supporting mesh bags between the lines (Figure 2). The method has had good initial results and substantially less maintenance than other subtidal tray or cage systems (Vaughan et al., 1989).

Land-based Nurseries

Raceways have been the traditional land-based nurseries for bivalve culture. They are generally long shallow tanks or troughs, or tiers of shallow trays, constructed of epoxy or resin-coated wood, fiberglass, plastic or concrete. Raw seawater is pumped from an adjacent source, delivered to one end of the raceway and directed to flow horizontally along the raceway to drains at the opposite end. In shallow raceways, seed is spread over the bottom in a single layer with water just covering the sand. This provides good water mixing and efficient water use. In deeper raceways, racks or tiers of trays are used to take three-dimensional advantage of water depth. In deep raceways, baffles are also commonly used to provide mixing within the horizontal water flow.

The use of land-based upflow nurseries was revived in the United States in the early 1980s. Upflow nurseries use ambient seawater, pumped from an adjacent source, to produce a vertical water flow directed up through a seed mass, rather than a horizontal flow across the seed as in raceways. Three upflow nursery systems are in common use; one recirculating system and two flow-through nursery systems. The recirculating system was developed for the production of clam post set and is used primarily in hatcheries. Normally a battery of recirculating (upflow and downflow) units are in a single reservoir tank and airlift pumps recirculate algal-enriched water among the units and the reservoir (Figure 3). Setting clams are introduced to the recirculating units and the resultant sets continue to be reared in the system until they are large enough to go into flow-through nurseries (one mm).

The two flow-through upflow nurseries using unsupplemented ambient seawater are (1) the active flow system that forces water at high velocity up through a seed mass and (2) the passive flow system which "pulls" water at low velocity up through a layer of seed. More simply, active or forced flow systems use water under pressure for the velocity necessary to initiate a slow fluidization of the seed mass. This is necessary for small seed (less than 3 mm) that tend to pack tightly resulting in a situation
Table 7. Comparison of critical factors that determine the appropriate hard clam nursery culture systems.

<table>
<thead>
<tr>
<th>Critical Factors</th>
<th>System Type</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Raceways</td>
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<tr>
<td>Location</td>
<td>Land-based and adjacent to high quality seawater source</td>
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<tr>
<td>Recommended initial seed size</td>
<td>1 mm</td>
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<tr>
<td>Maximum production seed size</td>
<td>8-10 mm</td>
</tr>
<tr>
<td>Recommended rates</td>
<td>0.5-1.0 gal/ft², 2.0-4.0 liters/0.1m²</td>
</tr>
<tr>
<td>Recommended densities</td>
<td>70-600/inch², 10-100/cm²</td>
</tr>
<tr>
<td>Maintenance requirement</td>
<td>High</td>
</tr>
<tr>
<td>Initial capital costs</td>
<td>High</td>
</tr>
<tr>
<td>Replacement costs</td>
<td>Low</td>
</tr>
<tr>
<td>Energy requirement (utilities)</td>
<td>High</td>
</tr>
<tr>
<td>Survival rates</td>
<td>High</td>
</tr>
<tr>
<td>Permitting</td>
<td>Depending on size, may need NPDES permit and others for discharge and intakes</td>
</tr>
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</table>
that would channelize lower velocity water flows. The slow fluid motion of water through the seed in an active flow column insures that all seed are serviced by the incoming water. Forced upflows normally consist of closed-bottom, small-diameter, PVC cylinders with an intermediate, positioned plastic screen supporting the seed mass. Water enters the closed cylinder below the screen and is forced up through the seed mass to an overflow near the cylinder top (Figure 4). Passive upflows are normally large-diameter, open-ended PVC cylinders suspended in a reservoir. Each cylinder uses an appropriate-size mesh screen to form the bottom and support the seed mass. Water entering the reservoir can exit only through drains positioned in each cylinder's upper end, and is thus drawn up through the seed mass to the drains (Figure 5). If flow rates in a passive upflow are correct, wastes and silt are swept through the seed mass and settle as a loose layer at the seed-mass surface.

Field nurseries and land-based nurseries each have advantages and disadvantages. Field trays are simple, low-energy systems that have relatively low operational costs. They do, however, require significant maintenance and harvest labor. They also suffer from incomplete predator protection, limited inspection access, and susceptibility to environmental perturbations, vandalism and theft. In contrast, land-based nurseries provide maximum protection and predator control, easy access and low maintenance but require an appreciable energy input. Field nurseries generally have less expensive capital costs than land-based systems but replacement costs may be higher in certain instances. Finally, location may play a distinct role in the efficacy of a particular nursery system. Climate and permitting considerations may exclude either land-based or field-based nurseries from certain areas. As with all culture operations, site selection is the most important thing for successful nursery systems so the culturist must select the system appropriate for the location.
(a) Schematic of recirculating upflow/downflow nursery system.

(b) Recirculating upflow nursery for recent hard clam post set. 
Figure 3.
(a) Schematic of passive and forced (active) upflow nurseries for bivalve mollusc seed.

(b) Forced (active) upflow nursery for young clam seed.

Figure 4.
(a) Commercial-scale passive upflow nursery for hard clams.

(b) Floating upflow nursery for hard clam seed (modification of land-based passive nursery system).

Figure 5.
VII. GROWOUT METHODS

Field Growout

Growout techniques can vary greatly from land-based systems to simple field broadcasting of seed onto the bottom without protection. Although complex land-based systems may be economically feasible in the future, only a few field growout techniques will be summarized. Most growout methods use pens, trays or nets. Many variations of size, material and handling techniques are used and may all produce harvestable clams, but differ in structure, labor, material cost, and yield. The lease area required to grow clams to harvestable size varies greatly from site to site. In general, about a million clams can be grown on one acre. Rarely is 100 percent of a lease possible to plant. Considerations for working areas, anchoring, grass beds and unusable bottom substrates may necessitate larger lease areas to accommodate usable planting areas. About 100 clams per square foot can be used as an upper density for planting, but much less than this may be required at some site locations. Survival rates are highly specific to planting methods and experience and may vary greatly. About 50 percent survival is a good general rate for most growout methods with experienced field management personnel and practices. Critical factors that determine the selection of growout methods are in Table 8.

Pens

Pens (cages or corrals) are box-like structures which allow water flow from all sides but inhibit predator access with mesh (Figure 6). The pens are constructed with support frames and mesh. Supporting frames are usually made of rebar metal rods or PVC piping. Rigid mesh materials are used to support vertical and horizontal positions off the sediment and in the water column. These can be made of vinyl-coated wire or high-density polyethylene mesh. Connections to the support framing are made of nylon ties, hog rings, or monofilament line. A box-like structure is made that will accumulate natural substrate, prevent access from predators and leave enough room for clam growth without sediment reaching the top of the pen. Intertidal placement or construction allows for low-tide tending and alleviates many fouling organism problems. Most pens are large enough so large numbers of clams can be planted with little routine maintenance. Harvesting is by removal of a lid or partial disassembly of the top layer. Clams are hand or rake harvested and may be assisted by water hose removal of sediments or concentration of harvestable products in one area. Pens can be mechanically harvested by suction in some states. Pens have to be rigid enough to withstand currents and are usually limited to intertidal use because of fouling.

Trays

Trays have been used effectively for growout systems for a long time. Trays have proven reliable and productive in terms of clam growth and survival if they are monitored and maintained properly. Trays consist of material that protects clams from predation and incorporate a sediment substrate. The growing container also allows for clam retrieval at harvest.

Trays can be made of all sizes and materials. Most have plastic,
Table 8. Comparison of critical factors that determine appropriate hard clam growout systems.

<table>
<thead>
<tr>
<th>Critical Factors</th>
<th>Pens</th>
<th>Trays</th>
<th>Nets</th>
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<tr>
<td>Location</td>
<td>Intertidal</td>
<td>Intertidal,</td>
<td>Subtidal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Subtidal</td>
<td></td>
</tr>
<tr>
<td>Sediment</td>
<td>Soft bottoms</td>
<td>Hard bottoms</td>
<td>Hard bottoms</td>
</tr>
<tr>
<td></td>
<td>Mud</td>
<td>Sand</td>
<td>Sand</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Moderate</td>
<td>Moderate to high</td>
<td>Low</td>
</tr>
<tr>
<td>requirement</td>
<td></td>
<td>(soft or hard tray)</td>
<td></td>
</tr>
<tr>
<td>Capital costs</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Labor to harvest</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Effort to access and inspect</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Special permits</td>
<td>Most states</td>
<td>Some states</td>
<td>No states</td>
</tr>
<tr>
<td>(in addition to lease)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Recommended method by state

- Virginia: X
- North Carolina: X
- South Carolina: X
- Georgia: X
- Florida: X
fiberglass, or wooden sides and bottom with mesh covering (Figure 7). Wooden trays were the first used and can be made of boards and plywood. Although these materials are locally available and inexpensive, they are more cumbersome and susceptible to deterioration. With rigid or hard trays, a lifting device must be used to hoist them because these units are very heavy. Boring clams and wood rot are persistent problems in wooden trays. Trays may be fouled externally with barnacles, oysters, etc., that need to be scraped off.

The soft tray was designed as a hybrid of tray-and bottom-net culture. The soft tray is made of flexible mesh such as nylon and made into a flat box (Figure 8). It has the properties of tray culture in that it provides both top and bottom protection but uses existing or naturally accumulating sediments. When lifted or harvested, all sediments remain on the bottom with only the clams and mesh lifted.

The soft tray can be made of woven nylon mesh and formed into bags of four x four feet or four x eight feet, which will take one or two people to handle. A float may be attached in the center of the bag to facilitate siltation. After an adequate amount of sediment has been deposited in the bag, however, the float should be removed. If the soft tray remains tented for an extended period, the net is more susceptible to fouling.

Fouling can be controlled by removing the float and/or by flipping the tray so that the upper surface is now on the bottom, and the fouling organisms are suffocated in the sediment. The clams should be rearranged and spread evenly in the bag as much as possible. A regular schedule of checking for rips or tears in the mesh is suggested.

Nets

Nets are the least expensive of growout culture techniques, both in material cost and maintenance labor. There are
Growout tray made out of nylon netting (soft tray) in four-foot square size.

Figure 8.

different types of bottom-net methods commonly used, but a nylon mesh weave netting has been fairly effective in predator control. A less expensive plastic mesh netting may also be used in areas where predation pressures are lower (Figure 9a).

Nets consist of netting (six x four mm mesh) with a weighted line attached to the sides. The net is staked to the bottom with metal stakes fabricated from rebar. Netting is made in rolls of 8-12 feet widths and variable lengths. The weighted line is fastened to the net approximately six inches from the outer edges to provide a protective "skirt" that will be buried vertically in the sand when the stakes are in place. The weighted line is attached with stainless wire hog rings. The completed net is rolled onto a length of pipe to facilitate planting. Some farmers also attach a line down the center of the net with loops to aid in lifting the net when it begins to sink beneath the silt. Growout nets range in length from 25 to 50 feet, although smaller sizes are not uncommon (Figure 9b).

To plant the clams, the nets are unrolled and secured over the top of seed that is broadcast on the natural sediment. A weighted line and stakes secure the net in the substrate along the edges. Other variations include sandbags along the sides of the net or a rebar frame buried around the plot perimeter over which the net is stretched.

Maintenance consists of periodic checks to ensure that the net has not become buried from the accumulation of sand or silt. Some sand (1/4") covering the net is beneficial as it will decrease fouling. Clams may be easily suffocated beneath a sinking net if they are too small or weak to raise it on their own. In waters with a high silt loading, floats or poles can be placed beneath the nets to avoid excessive siltation. If heavy fouling or destruction occurs, nets should be removed, repaired and replaced.

Although the bottom-net system is easy to plant, predators may access the net from the sides and sedimentation may be a problem. Harvesting is also restricted to normal allowable bottom-harvesting techniques.

Harvesting Methods

An important consideration in designing a plan for clam culturing is how the clams will be harvested. For production systems in which the clams are grown in containers that can be lifted, specialized methods can offer the advantage of several thousand clams harvested in a single haul. Special lifting equipment may be required and each system dictates the amount of time and staff required.

In systems where the container is too large to lift (pens) or does not surround the bottom (nets), the harvest method required may be similar to that used for wild commercial fisheries. This would include hand harvesting, SCUBA, clam rake, clam tongs, dredge or other mechanical harvesting techniques. Mechanical harvesters such as the hydraulic dredge, escalator dredge and suction harvesters offer the greatest labor efficiency and speed. The speed and ease of harvesting can also affect which marketing plan you use. Because of resource regulations and environmental concerns, many states severely restrict the use of mechanical harvesters. Some may allow special permits for culture use. In this regard, the choice of growout methods should
(a) Growout net rolled out on land.

(b) Growout net in intertidal zone.
   Figure 9.
not be made without considering the allowable harvesting methods available to you now and in the future.