PART I. INTRODUCTION

BIOLOGY OF THE HARD CLAM

Hard clams of the genus *Mercenaria* are found from the Gulf of St. Lawrence to the Gulf of Mexico and have been introduced to other areas of the United States, notably the coasts of California and Washington, to Puerto Rico, and to Great Britain. There are two species, *Mercenaria mercenaria* and *M. campechiensis*. *M. mercenaria* is distributed primarily in the more northerly latitudes while *M. campechiensis* is the more southerly species. On the west coast of Florida and in Georgia, South Carolina and North Carolina, both species may be found and some hybridization between the two may occur. A subspecies *M. c. texana* is found in the western Gulf of Mexico. Most of this manual will be referring specifically to *Mercenaria mercenaria*, although some of the generalizations may apply to all hard clams.

The hard clam requires relatively high salinities and is rarely found where salinities average below 20 parts per thousand (ppt). Hard clams occupy intertidal as well as subtidal habitats, burrowing into the substrate to various depths (normally less than 20 cm or 8"). They are found in a variety of substrates including sand, mud, shell and mixtures of these. Clams are filter feeders, removing food particles, primarily small phytoplankters (single-celled algae), from the water. A large adult clam filters an average of 7-8 liters (=2 gallons) per hour.

![Figure 1](image-url)

*Figure 1.* Commercial clam categories and how they are measured.
Figure 2.
Larval stages of the hard clam
Hard clams usually reach sexual maturity at a size of about 35 mm (1 1/8") shell length (SL) (Fig. 1). The sexes are separate but are externally indistinguishable. Clams are protandric, maturing as males at an early age and changing sex in subsequent years to spawn as females. When stimulated by appropriate environmental conditions (normally high water temperatures) clams release gametes (sperm or eggs) to the surrounding waters. The presence of gametes in the water stimulates other clams in the immediate vicinity to begin spawning. Fertilization occurs in the water column. In South Carolina, clams usually spawn intermittently from May through October. Clams are capable of producing prodigious quantities of young. A female clam can release several million eggs in a single spawning, but only an extremely small percentage survive the larval period to become juvenile clams.

Fertilized eggs (zygotes) undergo rapid cell division and within twelve hours develop into free-swimming trochophore larvae. Within another 12 hours, bivalve shells have formed and the larvae are in the veliger, or straight-hinge stage. Veligers are often referred to as "D" larvae because their shape resembles a capital letter "D" (Fig. 2). Prior to the veliger stage, the larva is sustained on lipids stored in the egg and dissolved organic matter (DOM) which is absorbed from the surrounding water. The veliger feeds on small phytoplankton, bacteria and DOM. The ciliated velum, which gives the veliger its name, is used for both locomotion and feeding. The length of the larval period is largely dependent on temperature and food supply. After 7–21 days the veliger larva develops a foot and is called a pediveliger (Fig. 2). This brief stage is soon followed by complete loss of the swimming organ (velum) and development of siphons. This is referred to as settlement, and newly settled clams may be called “set” or “post-set”. Post-set clams assume the sedentary life-style of the adult. The term post-set is informal and usually refers to clams which have completed the larval stage but are still housed in a hatchery.

Juvenile clams, less than 35 mm (~1 1/8") SL, are called seed (Fig. 1). As seed grow to market size they are classified into commercial categories. These are arbitrary classifications which may vary from state to state and dealer to dealer. In most states the smallest legal size for wild-caught clams is a littleneck, usually defined as 1 inch (~25 mm) thick. This generally corresponds to a shell length of 45–50 mm (1 1/8–2"). Slightly larger clams (1 1/4" or 30 mm thick, 50–60 mm or 2–2 1/8" SL) are referred to as topnecks. Cherrystones are approximately 1 1/4–1 1/2 inches (32–38 mm) thick and 65–79 mm (2 1/8–3 1/4") long. Anything larger than that is a chowder. Littlenecks command the highest price of the commercial categories. In many states, maricultured clams may be sold at smaller sizes and some companies have created their own names for these size classes. In South Carolina, wild clams grow to littleneck size in 3–4 years, while maricultured clams may reach this size in about 2 years.
HARD CLAM FISHERY AND AQUACULTURE INDUSTRY

Fourteen species of clams are harvested commercially in the United States, but the bulk of the landings (98% in 1991) is comprised of four species: surf clams (Spisula solidissima), soft-shell clams (Mya arenaria), ocean quahogs (Arctica islandica) and hard clams (Mercenaria spp.). In 1991, hard clams represented less than 10% of the total clam harvest, but accounted for almost 50% of the value (NMFS 1992).

Hard clams are harvested commercially in most of the Atlantic states, but a large proportion of the harvest comes from the northeast, primarily Long Island Sound. Reported landings have decreased steadily since the turn of the century. Decreased harvests may be attributed to overfishing, habitat deterioration, and closing of shellfish grounds because of pollution. Whatever the causes, decreased landings have resulted in excess of demand over supply, creating conditions favorable for development of a clam culture industry.

The hard clam has several characteristics which make it an excellent aquaculture candidate (Table 1). Culture technology has been developed and private and/or public hard clam culture activities are ongoing in almost all coastal states except Alaska and Hawaii. Over the period 1980–1989, the production of hard clams from culture activities increased from 140,000 bushels to about 500,000 bushels (Adams et al. 1991). In 1989, culture activities accounted for more than 40% of the total hard clam landings in the United States (Adams et al. 1991).

<table>
<thead>
<tr>
<th>Economic</th>
<th>Biological</th>
</tr>
</thead>
<tbody>
<tr>
<td>High market demand</td>
<td>Tolerance to wide range of environmental conditions</td>
</tr>
<tr>
<td>High unit value</td>
<td>High fecundity (egg production)</td>
</tr>
<tr>
<td>Smallest size (littleneck) is also most valuable</td>
<td>External fertilization (ease of genetic manipulation)</td>
</tr>
<tr>
<td>Good shelf life</td>
<td>Spawnable year-round</td>
</tr>
<tr>
<td></td>
<td>Ease of larval culture</td>
</tr>
<tr>
<td></td>
<td>High survival under culture conditions</td>
</tr>
<tr>
<td></td>
<td>Few diseases</td>
</tr>
</tbody>
</table>
PART II. HARD CLAM AQUACULTURE

The culture of the hard clam can be divided into three stages: hatchery culture, nursery culture, and field grow-out. In the hatchery, broodstock clams are induced to spawn and the offspring are reared for 1–2 months to a size of about 1 mm SL. Beyond this size it becomes uneconomical to continue to rear the clams under controlled hatchery conditions. If seed clams were transferred to field culture at this point, survival would be extremely low. To overcome this problem, young clams are grown under semi-controlled conditions in a nursery for 3–6 months until they reach a size of 8–10 mm SL. Seed are then transferred to field culture. Grow-out to market size requires an additional 1.5–2.5 years in South Carolina.

A commercial clam venture may be totally integrated, including hatchery, nursery and grow-out. However, many ventures are limited to only one or two of the culture stages. There are commercial hatcheries and nurseries from which seed clams, anywhere from 300 μm up to planting size (>8 mm), may be purchased. Thus, a commercial enterprise could purchase its young clams, bypassing either the hatchery or both the hatchery and nursery stages.

In this section we will present an overview of all aspects of clam culture, with special reference to implementation in South Carolina. There are many different methodologies and technologies in use and under development for hard clam culture, particularly for the grow-out phase. It would be impossible to describe all of these in detail. We have concentrated on those systems which have actually been used in South Carolina and have attempted to describe basic concepts. Parts III and IV are detailed manuals for hatchery and nursery culture, based on an integrated culture system developed at the Marine Resources Research Institute in Charleston.

HATCHERY CULTURE

A hatchery allows for the controlled production of larval clams. There are five main processes in hatchery culture of the hard clam: (1) maintenance and conditioning of broodstock; (2) spawning; (3) larval culture; (4) post-set culture; and (5) food production (algae culture). These activities are supported by a water distribution and treatment system, air distribution system, freshwater washdown facilities, supplemental lighting for algae culture, and support test equipment and instrumentation. This section provides a brief overview of hatchery processes. Details of operation are provided in Part III.

Maintenance and conditioning of broodstock

Adult clams are brought into the hatchery several weeks prior to spawning for "conditioning". Conditioning is the process of inducing gametogenesis, or the
ripening of gonads, to bring the clams into spawning readiness. In South Carolina, clams become naturally ripe in the spring and remain intermittently ripe into the fall. To get them to ripen at any other time of year, one must simulate early spring conditions, i.e. cool temperature (≈18–20°C) and ample food. It generally takes 2–8 weeks for a clam to condition, but this varies depending on the time of year and the physiological condition of the clams. A clam which is already ripe can be maintained in this condition for a long period (up to 6 months) by keeping it in cool water (18–20°C) and providing an abundance of food. Partially ripe clams will become spawnable in 2–4 weeks under these same conditions. It is much more difficult to condition clams which have recently spawned. Therefore, for year-round operation, it may be advisable to collect naturally ripe clams in early spring and keep them in conditioning tanks in order to maintain a population of readily spawnable individuals. Naturally ripe clams may also be procured in the fall, although the portion of the wild population which is ripe at this time is lower than in the spring.

**Spawning**

When clams spawn they release eggs or sperm into the water column where fertilization takes place. Spawning is induced by alternately heating and cooling the clams in a water bath. Sperm or eggs from a sacrificed clam may also be used to stimulate spawning. If controlled breeding is desired, the clams are spawned in individual beakers, thus allowing control of fertilization. If it is only desired to produce larvae, and the parentage or breeding scheme is unimportant, it is easier to “mass spawn” the clams in a common container. Sperm from spawning males will stimulate other clams to spawn also and the eggs will be fertilized in the common spawning container.

**Larviculture**

Zygotes (fertilized eggs) are maintained in clean, filtered seawater at relatively high densities (30 or more per milliliter of culture water) for 24 hours or until the veliger stage is reached. At that point the larvae are thinned to 5–10/ml and provided with food (algae). The veliger stage lasts from 7 to 21 days, the length depending largely on temperature and food quality. Over this time period the larvae grow from an initial size of ≈100 µm to a size of 180–250 µm and are gradually thinned to a final density of 1/ml. During this period, larvae are kept in static cultures, the water is changed frequently (daily if possible), and food is added daily. Some hatcheries aerate larval cultures but this is not usually necessary. Water for larval culture must be filtered (1–10 µm) to remove silt and native plankton. Depending on quality of the seawater, it may also need to be treated with charcoal to remove dissolved organics and sterilized (usually with ultraviolet light) to kill bacteria.

Suitable larval culture containers may be made of fiberglass or plastic, usually no more than a meter deep (≈3 ft). Container
size is dictated by desired larval production. Plastic buckets (20 L = 5 gal) can be used to grow small quantities of larvae (= 20,000). Large hatcheries have fiberglass tanks which may hold several thousand liters of water and millions of larvae. Containers may be flat-bottomed or conical-shaped. Conical bottoms facilitate draining and cleaning. Tanks may have valved drains at the bottom or may be drained with siphon hoses. When the water is drained from the containers, the larvae are captured on a fine-mesh nylon or polyester screen.

Towards the end of the larval period, usually at a size of 200–250 μm, the larvae begin the metamorphosis to the juvenile form. The first indication of this metamorphosis is the appearance of a foot. This stage is called “pediveliger” because the larva has both a velum and a foot. The pediveliger stage is fairly short and within a few days the velum disappears entirely and siphons are formed. This metamorphosis is known as “setting” and the young clams are referred to as “set” or “post-set”.

**Post-set culture**

Pediveligers are often removed from the larval culture system and maintained in a separate post-set culture system until metamorphosis is completed. This improves survival because pediveligers, although still capable of swimming, spend most of the time crawling on the bottom of the tanks where waste products and dead larvae are concentrated. Post-set may be cultured in a variety of systems. Many hatcheries utilize shallow trays provided with a gentle flow of seawater, augmented with cultured algae. These trays may be stacked in tiers to save floor space. At MRRI, we maintain post-set in a recirculating culture system employing downwellers and/or upwellers. This system is easier to clean than a tray system, allows better control of water quality and feeding rations, and supports a large quantity of clams in a small space.

Downwellers (also known as “silos”) are open-ended cylinders, usually constructed of plastic pipe, suspended in a reservoir. The bottom of the cylinder is covered with a fine mesh which supports the clams. Before they can be moved to silos, the clams should be large enough to stay on a 150 μm mesh. Smaller mesh will clog too readily, obstructing the flow of water. Water (and food) is circulated through the silos with airlifts (Fig. 3). In a downweller, the airlift is positioned outside of the cylinder and moves water from the reservoir into the silo. Downwellers are used for early post-set which might be sucked up the airlift. When the post-set reach a size of about 0.5 mm SL, the silos may be converted to upwellers by moving the airlift to the inside of the cylinder. Water is then pumped out of the silo, drawing water up through the clams. The silos are suspended in a reservoir (a container accommodating one or more silos). The reservoir volume should provide at least 0.5 ml water for each clam. Food is added to the reservoir either in batches or by continuous delivery. All the water in the reservoir is changed regularly,
Figure 3.
Recirculating downwelling and upwelling units

daily if possible but at least three times a week.

Post-set clams are usually maintained in a hatchery until they have reached a minimum size of 1 mm or can be retained on a 710 μm mesh. At that point, the clams may be transferred to a nursery culture system.

Food production

Broodstock, larvae and post-set are fed phytoplankton which is produced in the hatchery. There are three basic methods of algal production: the “Wells-Glancy” method, the “brown water method” (Ogle 1982), and the “Milford” method. The Wells-Glancy method is described in Castagna and Kraeuter (1981) and Castagna and Manzi (1989). This method and the brown water method are relatively low-tech and inexpensive, but are not as reliable as the Milford method for producing consistently high quality food. They are most often employed in seasonally operated, low-budget hatcheries or as a supplement to the Milford method.

The Wells-Glancy and brown water methods both rely on native phytoplankton available in the seawater supply. The water is filtered (5–15 μm) to remove zooplankters and used immediately as culture water for larvae (the brown water method) or allowed to bloom for 24–48 hours before being used. Fertilizer may be added to encourage a denser bloom. Tanks used for this method are usually fairly shallow to allow light penetration. They should be aerated gently. This type of culture is usually performed in a greenhouse or solarium although artificial lighting may also be used.
The Milford method of algal culture is a sequential process in which single species of phytoplankters are grown in batch cultures. Phytoplankters for culture can be obtained by isolating native species, but more commonly are purchased from a laboratory specializing in isolation and production of phytoplankton clones, or from another hatchery (see Appendix D). Most hatcheries grow two or more different species of phytoplankters in order to provide the varied rations required by the larvae, post-set and broodstock. A detailed description of the Milford method is presented in Part III of this manual.

The quantity of phytoplankton needed is dependent on the seed production goals of the hatchery. Algal consumption rates for different size clams is presented in Table 2. Fifty broodstock (a minimum for a spawning) will require approximately 1.5 X 10^11 algal cells a day, which will be 30–50 liters of dense algal culture (~5 X 10^6 cells/ml). One million veliger larvae will consume 1 X 10^6 cells/day (1 liter), setting size larvae 50 times as much. A million post-set will require 3–4 times as much algae as the broodstock (200 liters/day). Algal culture is probably the most time-consuming element of the hatchery but is essential to its success.

<table>
<thead>
<tr>
<th>Life Stage</th>
<th>Age or Size</th>
<th>Consumption range* (algal cells/clam/day)</th>
<th>Food concentration (algal cells/ml of culture water)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>Early veliger</td>
<td>1-2 days</td>
<td>1,000-5,000</td>
<td>10,000-25,000</td>
</tr>
<tr>
<td></td>
<td>3-5 days</td>
<td>5,000-10,000</td>
<td></td>
</tr>
<tr>
<td>Mid veliger</td>
<td>5-8 days</td>
<td>10,000-15,000</td>
<td></td>
</tr>
<tr>
<td>Late veliger</td>
<td>8-14 days</td>
<td>15,000-30,000</td>
<td></td>
</tr>
<tr>
<td>Pediveliger</td>
<td>14-21 days</td>
<td>30,000-50,000</td>
<td></td>
</tr>
<tr>
<td>Early post-set</td>
<td>300-400 μm</td>
<td>50,000-75,000</td>
<td>25,000-50,000</td>
</tr>
<tr>
<td>Mid post-set</td>
<td>400-600 μm</td>
<td>75,000-150,000</td>
<td></td>
</tr>
<tr>
<td>Late post-set</td>
<td>600-1000 μm</td>
<td>150,000-500,000</td>
<td></td>
</tr>
<tr>
<td>Broodstock</td>
<td>&gt;35 mm</td>
<td>1 X 10^8 - 3 X 10^9</td>
<td>50,000-100,000</td>
</tr>
</tbody>
</table>

* Based on feeding Isochrysis galbana
NURSERY CULTURE

When post-set reach a size of \(\approx 1\) mm SL (retained on a 710 \(\mu\)m screen) they may be transferred to a nursery system. The purpose of a nursery is to provide a protected environment for small seed until they reach a size (8–10 mm) suitable for field grow-out. Studies have shown that survival in field grow-out increases with seed size (Manzi et al. 1980; Kraeuter and Castagna 1985). However, it is difficult to maintain clams in a nursery beyond a size of 10 mm because of space and water flow limitations. Some growers plant their seed at smaller sizes (6–7 mm) but survival will be variable and generally much lower than for larger seed (Kraeuter and Castagna 1989).

There are many types of nursery systems in use. These can be roughly divided into land-based and field-based systems. Land-based systems in common use are raceways and upwelling systems. Field-based systems include a variety of on-bottom and off-bottom containers, floating rafts, and floating upwellers. Also included under field-based systems are nurseries located in protected areas such as impoundments and ponds.

Field-based systems are relatively inexpensive to construct and operate but have high maintenance requirements, offer limited predator protection, may be subject to environmental damage, and have unreliable production. Land-based systems are more expensive to construct and operate but provide almost complete predator control, ease of access, and near-optimal conditions for growth and survival of seed clams. In this section we will briefly describe a variety of nursery systems which may be suitable for use in South Carolina and general concepts of nursery culture. Part IV of this manual is a detailed description of a land-based upwelling nursery.

Land-based systems

A land-based nursery provides a semi-controlled environment for culture of juvenile clams. Water is usually not treated except for gross (\(\approx 200\) \(\mu\)m) filtration to reduce the influx of fouling organisms (e.g. barnacles and oysters) and the natural food supply is unsupplemented. However, predators are excluded, fouling organisms are controlled, and conditions for rapid growth are provided. Clams can be introduced into a nursery at a size of 1 mm or larger and are usually grown to a size of at least 8 mm before transfer to field grow-out. During the rapid growing season (in South Carolina, March through October minus a few weeks in July-August), clams will grow approximately 2 mm per month. Therefore, it will take 3–4 months (at least) for a 1 mm clam to reach 8 mm, and another month for each 2 mm above that size (see Table 3).

There are two basic types of onshore or land-based nursery systems, raceways and upwelling systems. Both are energy-intensive, requiring continuous pumping of large volumes of high quality estuarine water. Both require considerable capital
investment for waterfront property and infrastructure. Both are labor-intensive requiring daily cleaning and frequent monitoring of the seed. Despite all these negatives, onshore nurseries are popular because they provide conditions for rapid growth with high seed survival.

**Raceway systems**

Raceways are shallow rectangular trays which may be stacked in tiers. Water is introduced at one end, flows over the seed clams, and exits at the other end through a drain. Ten to 20 liters of water per minute (L/min) should be supplied for each liter of large seed clams (8 mm). Although raceways produce rapid growth and high survival (Hadley and Manzi 1984), they are not well-suited to South Carolina because of the high load of fine silt present in our estuarine waters. This silt settles in the raceways, creating labor-intensive maintenance problems. If not cleaned daily, small seed clams suffocate in this fine silt. Cleaning is particularly difficult if the seed are very small (<4 mm). Another drawback with raceways is that clams near

<table>
<thead>
<tr>
<th>Stage</th>
<th>US Standard Sieve Size</th>
<th>Mesh Opening</th>
<th>Length (mm)</th>
<th>Count (# clams/ml)</th>
<th>Age (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Veliger</td>
<td>No. 25</td>
<td>710 μm</td>
<td>0.1</td>
<td>—</td>
<td>1</td>
</tr>
<tr>
<td>Pediveliger</td>
<td>No. 100</td>
<td>150 μm</td>
<td>0.2</td>
<td>—</td>
<td>14-21</td>
</tr>
<tr>
<td>Post-set</td>
<td>No. 70</td>
<td>212 μm</td>
<td>0.3</td>
<td>99,000</td>
<td>18-24</td>
</tr>
<tr>
<td></td>
<td>No. 45</td>
<td>335 μm</td>
<td>0.5</td>
<td>21,000</td>
<td>30-45</td>
</tr>
<tr>
<td>Seed</td>
<td>No. 25</td>
<td>710 μm</td>
<td>1</td>
<td>3,000</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>No. 14</td>
<td>1.4 mm</td>
<td>2</td>
<td>300</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>No. 10</td>
<td>2.0 mm</td>
<td>3</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>No. 7</td>
<td>2.8 mm</td>
<td>4</td>
<td>40</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>No. 6</td>
<td>3.35 mm</td>
<td>5</td>
<td>20</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td>No. 5</td>
<td>4.0 mm</td>
<td>6</td>
<td>12</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>No. 4</td>
<td>4.75 mm</td>
<td>7-8</td>
<td>7</td>
<td>165</td>
</tr>
<tr>
<td></td>
<td>½&quot;</td>
<td>6.3 mm</td>
<td>9-10</td>
<td>3</td>
<td>195</td>
</tr>
<tr>
<td></td>
<td>0.265&quot;</td>
<td>6.7 mm</td>
<td>10-11</td>
<td>2</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td>¾&quot;</td>
<td>8.0 mm</td>
<td>12-13</td>
<td>1.5</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>½&quot;</td>
<td>9.5 mm</td>
<td>14-15</td>
<td>1</td>
<td>270-290</td>
</tr>
</tbody>
</table>
the drain end receive only water which has already passed over all the other seed and is largely devoid of usable food. Thus the seed must be rotated in the raceway to achieve uniform growth. Finally, raceways cannot support high biomasses of seed. A typical raceway can support about 0.2 L of large seed per 0.1 m² (≈1 ft²). This is about 1400 seed at 8 mm SL or 700 at 10–12 mm SL. Raceways probably should not be used for seed smaller than 4 mm SL because of the cleaning difficulties. Seed require approximately 2 months to grow from 4 to 8 mm in raceways.

Upwelling systems

Upwelling systems are probably the most widely-used land-based nursery systems. Although they share the drawbacks of high capital cost and energy expense, upwellers provide rapid uniform growth of seed, are easier to maintain than raceways, and make more efficient use of space. An upwelling system consists of a reservoir, usually rectangular and about 2 feet deep, containing multiple culture units (Fig. 4). Each culture unit ("silo") has a screen bottom which supports the seed clams. The silos are placed so that their sides project above the water level and the bottom screen is several centimeters above the reservoir bottom. A drainpipe near the top of the silo extends through the silo wall and the reservoir wall, emptying into an external common drain. Water is pumped into the reservoir and rises up through the screens and the seed clams, exiting out the drains near the top. The vertical water flow supports much higher biomasses of clams than the horizontal raceway flow. Each 0.1 m² of upwell screen can support 1.0–1.5 liters of planting size seed (~7000–10,000 seed at 8 mm SL). The water flow requirements for upwellers are similar to those for raceways. Each liter of large (7 mm) seed requires 10-20 L/min flow and very small seed (<3 mm) should receive 10 times that much. Details of operating an upwelling nursery are given in Part IV.

Field-based systems

Field-based nurseries are not as reliable as land-based systems, but require less capital investment and are less expensive to operate. They do not provide as complete predator protection and are more susceptible to environmental damage (e.g. from storms). They are less accessible and consequently more difficult to maintain, but the maintenance is done less frequently. The water flow (and thus food supply) to the seed may be variable resulting in less uniform growth. However, some of the recently developed floating systems rival land-based nurseries in production capability and are relatively inexpensive to build and operate.

Floating upwelling systems

Three floating upwelling systems have been used to some extent in South Carolina. Two of these are powered by airlifts, and one is tidal-powered. Operation and maintenance is similar to that for a land-based system. Floating upwellers have been used with very small seed (~1 mm), but success is dependent on proper site selection.
Figure 4.
Land-based upwelling nursery system
Both airlift systems are designed to be used in protected waters, such as salt-water ponds or impoundments. They can also be moored to a dock in a tidal creek if they will not be exposed to heavy wave action. One airlift system is based on a system developed in Florida. A raft of 4-inch PVC pipe serves as both the silo support system and an air manifold. The manifold is pressurized with a small air blower. Silos are suspended within the raft and water is circulated through the silos with airlifts (Fig. 5). The second airlift system consists of a reservoir (tank) which is floated in a pond or adjacent to a dock. Water is pumped into the reservoir with a large airlift or with a submersible pump and flows out the silo drains just as in a land-based system.

Recently a tidal-powered upwelling nursery, modified from one developed in Maine (Mook 1988; Mook and Johnson 1988), has been tested in South Carolina. The nursery consists of a raft with a scoop on one end and an interior chamber where upwellers are housed (Fig. 6). The raft is tethered from the scoop end so that it

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**Figure 5.**

*Floating upwelling nursery system*
swings to point the scoop into the current. Water is directed by the scoop into the silo chamber and flows out through sideports at the water level. In pilot testing, this system appeared to foster more rapid growth than a land-based nursery. It offers the obvious advantage of low operating costs (maintenance only), but is vulnerable to storm action. A construction and operations manual (Baldwin et al. 1995) is available from S.C. Sea Grant Consortium (see Appendix A).

**Bottom culture**

A number of bottom culture nursery systems have been tested and some are in use in South Carolina. These include trays supported off the bottom on racks in subtidal areas, trays planted on or just above the bottom in intertidal and shallow subtidal areas, and “soft” bags or pens. All bottom culture systems require frequent maintenance to remove silt, fouling organisms, and predators.

The subtidal rack and tray system must be deployed in deep water in order not to represent a navigation hazard. Therefore it requires a large boat to deploy, maintain and harvest the trays. Trays are a wood frame with screening top and bottom. Several trays are supported on one rack in a tiered arrangement with space between the trays for water circulation. A rack and tray system is labor-intensive to maintain but, if properly sited, provides good growth and survival even for very small seed (1 mm and up). Small seed (1–2 mm) may be planted at very high densities (50,000-
150,000/m² = 5,000-15,000/ft²) initially, but must be thinned as the seed grow. The fine mesh which must be used to retain very small seed requires weekly cleaning to remove fouling organisms and silt.

Smaller trays may be deployed in intertidal or shallow subtidal areas if substrate is firm (sand or shell). The trays are buried so that their tops are level with the surrounding substrate, filled with sand, and covered with screening (~6 mm or 1/4" openings). If the trays are buried too deep they may be covered over by shifting sand or silt deposition. If they are not buried deep enough, they may create scouring currents which will wash out the tray. Screens must be checked frequently and any silt removed from the top screen. There are a limited number of sites in South Carolina where this method will work, because in most places the silt load is too heavy. Banks which have sandy substrate are often subject to strong currents which may wash substrate out of the trays. These trays are probably not suitable for very small seed (<2 mm).

Trays or polyethylene mesh bags may be placed on racks in intertidal or shallow subtidal areas. Racks may be constructed of wood, rebar or PVC. Trays may have a solid bottom and be filled with sand or similar substrate. Bags will not retain substrate. These will only work in well-protected sites with no waves or strong currents and are not well-suited to seed <4 mm.

"Soft" bags are used extensively in Florida for nursery culture (Harbor Branch 1989; Vaughan and Creswell 1990). They have recently been tried in South Carolina with mixed success. The bags are made of woven polyester (e.g. Fablok®) in an appropriate mesh size to contain the seed (Fig. 7a). Bags are anchored to the bottom with a weighted rope, rebar, or stakes. A float placed inside the bag holds the upper side above the seed. In Florida, cages with several tiers of bags have also been tried.

In South Carolina, the float is often not adequate to prevent silt from collecting on the top of the bag. Therefore, a modification, referred to as a "soft pen" has been developed (Fig. 7b). These pens are constructed of the same soft woven material but have a rigid frame which supports the upper edge 25–36 cm (12–18") above the substrate. The frame may be made of PVC pipe placed either on the inside or outside of the mesh. A recent development is the use of a vinyl covered wire (14 gauge, 1/2" openings) skirt to support the soft bag (Fig. 7c). The wire fencing provides additional predator protection. Pens are constructed with a removable top which may be fabricated of the same soft mesh or may be made of lighter weight plastic netting. The lid must have a mesh size small enough to exclude most crabs and must fit securely over the edge of the bag so that there is no gap where crabs can enter. These systems are not suitable for small seed (<4 mm) because the mesh size required to retain such little seed would foul rapidly and restrict water flow.
Figure 7.
Soft bags and pens for field-based nursery culture
Pond culture

Ponds and impoundments may be used as nurseries to some advantage. They provide some protection from environmental perturbations and predation and are usually more accessible than field sites while being less expensive to operate than land-based nurseries. However, the cost of constructing a pond is considerable, so this is probably only an option for those who have access to an existing pond.

Pond culture offers the possibility of enhancing the natural food supply by managing for algal blooms. However, pond management is complex and poorly understood, particularly as relates to bivalve culture requirements. In addition to the food supply, the pond manager must consider many other factors which will affect clam growth and survival, including dissolved oxygen, pH, temperature, and waste-products.

Pond culture research is being conducted at the Waddell Mariculture Center in Bluffton, SC. Various sizes of seed have been planted in a variety of containment systems including airlift-driven upwellers, trays and bags supported on racks, trays and bags placed on the bottom, and pond-side upwellers to which water was pumped. Seed have also been planted on window-screening placed directly on the pond bottom. For pond culture, containers are used primarily to facilitate handling and harvesting the seed, as predators are usually physically excluded from the pond. Results of these studies have been variable and no system tested to date has consistently provided high survival and rapid growth.

FIELD GROW-OUT

The final and longest stage in clam culture is grow-out to market size, which may require 18–30 months, depending in part on the seed size at planting. Grow-out is almost always done in natural bodies of water (e.g. tidal creeks), because providing enough space and water flow in an onshore system would be prohibitively expensive. Grow-out methodology is less well-defined than either hatchery or nursery methodology. Many different methods are in use and new ones are continuously being developed. In this overview, factors affecting field culture success will be discussed and several systems described. There are several chapters with relevance to field culture in *Clam Culture in North America* (Manzi and Castagna 1989).

Site selection

Clams require a relatively low energy environment. Sites subject to large waves, heavy boat traffic or strong tidal currents should be avoided. Also to be avoided are sources of bacterial and chemical pollution (marinas, sewage treatment plants, industrial sites, agriculture sites, golf courses, etc.). Accessibility may also be a factor, although there are probably not very many sites in South Carolina which can be reached without a boat.
Basic site requirements include high salinity (averaging >24 ppt) and sufficient tidal flushing. Avoid areas which are subject to freshets after heavy rainfall, such as rivers draining large watersheds. Tidal flow is requisite for delivering food and oxygen and removing wastes, as well as for maintaining the needed salinity. Too much flow may wash clams away or smother them in waves of sand. Too little flow not only may provide inadequate food but also may result in silt accumulation which necessitates frequent cleaning in order to avoid smothering of the clams.

Most substrates are suitable for clam culture, but really soft mud is not only difficult to work in but is indicative of a high siltation rate which will necessitate more frequent cleaning. A mixture of sand and mud, firm enough to support your weight but loose enough for raking, is perfect. However, there are a limited number of sites in South Carolina which meet this criteria and most growers will have to make do with somewhat less-than-perfect substrates.

One way to choose a good site is to look for native clams. Try to find topneck or smaller clams (<60 mm long and 30 mm thick). Clams of this size should be actively growing, as evidenced by a light-colored margin. (Do your survey anytime other than the winter as little growth occurs from December through February). Distance between rings on the shell is also some indication of growth rate. The farther apart the rings, the faster the clam has been growing. If native clams do not show signs of rapid growth, that particular site may have inadequate food supply. If no clams are present on the site, there may be other problems which make the site biologically unsuitable.

Although clams can be grown subtidally, there are many advantages to intertidal culture. Aerial exposure will dry out macroalgae and prevent or retard growth of most fouling organisms. Exposure provides partial protection from some predators and parasites (e.g. boring sponge). The clams are visible for inspection at low tide. Drawbacks to intertidal planting are possibly slower growth (less feeding time); visibility (which may lead to vandalism, poaching or complaints from nearby residents or other waterway users); and limitation of working time due to tidal cycle. Also, many intertidal areas are characterized by soft soupy substrates, making maintenance more difficult. Planting in shallow subtidal areas (where the clams are visible but still slightly submerged at low tide) circumvents some of these problems.

Deep subtidal planting will require equipment (e.g. large boat, mechanical hoist) which is not needed for intertidal or shallow planting. Subtidal cages may be rapidly covered with surface fouling such as macroalgae, tunicates, bryozoans, and hydroids. Heavy fouling greatly reduces the water flow through the cages, resulting in poor clam growth. Therefore subtidal cages require frequent cleaning, perhaps even weekly.
Predator protection

Seed may be field-planted for grow-out at a size of 7–8 mm. Survival of field-planted seed increases dramatically with size. Therefore, it may be more profitable to plant larger seed, even though initial costs will be increased. Also, the smaller the seed initially, the greater the size variation at harvest.

Even at larger sizes (e.g. 10–12 mm), seed must be protected from predators. Without protection, predation would claim virtually 100%. The major predator of clams in South Carolina is the blue crab, but other crabs (mud crabs, stone crabs, etc.), whelks, oyster drills, and moon snails also prey on clams. Blue crabs can prey on clams with shell lengths up to about 40 mm (1½") and may eat as many as 300 clams per day. Mud crabs are major predators of small seed (up to about 15 mm) and may eat more than 100 seed a day.

The most effective way to control predation is to completely enclose the clams with predator-excluding mesh. Enclosures may be box-like structures built of rigid plastic or vinyl-coated wire mesh, pens like those described for field nurseries, or wooden trays with mesh over the top. A 12 mm (½") opening provides adequate water flow and excludes most predators. However, seed <18 mm SL will not stay on this size mesh. Therefore, you must either start with a smaller mesh size, increasing it later as the clams grow, or line the container with a smaller mesh which can be removed later. For wooden trays, window screening or lightweight flexible netting (6–12 mm openings) may be used as the top covering.

Clams grow better in substrate, preferably sand or sandy mud. Any space between the substrate and the top covering will promote crab growth. Small crabs, which may enter as larvae, are protected from predators and have a captive food supply. This must be considered when designing trays or cages, selecting initial seed size, and determining inspection frequency.

For subtidal culture and intertidal culture on firm bottom, wooden trays with a top covering are suitable containers. These should be filled with sand or sandy mud prior to planting the seed. Trays may be supported on racks, as described for field nursery culture, or placed directly on the bottom. Small trays may be buried in firm substrate if they are checked frequently to remove silt from the surface.

In soft, muddy bottoms, cages built entirely of mesh and “soft” pens, like those described for nursery culture, are used. These are allowed to accumulate silt prior to planting the seed, but must be checked frequently to prevent silt from covering the top of the cage and to remove predators. Because of the heavy silt load, the cages are usually at least 15 cm (6 inches) deep, with 10–12 cm (4–5 inches) of silt inside. Unfortunately, this leaves room for crabs to grow in the space between the silt and the top cover, necessitating frequent predator removal. However, if the cages are filled completely with silt, they must be cleaned.
frequently (perhaps even daily!) to remove overlying silt which will smother the clams.

In other states, clams are often planted with only a top covering. This may be suitable for some firm bottom sites in South Carolina. The substrate is raked to loosen it and aggregate (gravel or crushed shell) may be placed on the bed to provide some protection from crabs. Seed clams are then scattered on the surface at a rate of 500–1000/m² (50–100/ft²) and additional substrate (sand or shell-sand mixture) may be sprinkled on top of the seed. A light mesh (usually 6–12 mm or 1/4–1/2" openings) is then placed over the seed and anchored around the edges, using leadline, rebar or sandbags. Floats may be placed under the netting at intervals to reduce silt buildup on the covers. This planting method does not work on soft, muddy sites because the top mesh silts over too quickly, smothering the clams.

In addition to exclusion methods of predator control, some growers place crab traps in or around their culture areas. These are only lightly baited, in order not to attract crabs from any distance. If you are placing more than 2 traps, you may need a commercial boat license ($20–25) and a license for each pot. These are issued by the S.C. Department of Natural Resources, Commercial License Office. Another method of predator control which some growers have found effective is to place oyster toadfish in the culture units. These fish will eat crabs and their very presence may keep crabs away.

Regardless of the type of predator protection, frequent inspections are mandatory to remove crabs which may have entered as larvae and to repair tears in the mesh. Clams inspected weekly may have survival rates twice as high as those inspected only monthly. Outlook is poor for any seed not inspected at least monthly.

**Planting density**

Seed clams (7–8 mm) may be planted at very high densities (up to 5000/m², =500/ft²). However, these densities are too high for the entire grow-out cycle, necessitating labor-intensive thinning. A suitable density for the complete grow-out cycle is 500–650/m² (=50–65/ft²). Small seed (<15 mm) may be planted at almost 10 times this density (4000–5000/m²) and thinned to the lower density after 6–12 months, or when the average size is about 20 mm. There is some evidence that survival of small seed is improved by planting at high densities (Eldridge et al. 1979; Manzi et al. 1980). However, if allowed to remain at high densities beyond a size of about 20 mm, the clams will be stunted and survival may be poor.

**Growth rate**

Growth rates vary seasonally as well as between individual clams. They also vary between sites. An annual average of 1.5–2.0 mm/month can probably be expected in South Carolina, although some sites may consistently produce better growth than this. Thus it may require 18–30 months to grow a seed clam from 10 mm
to 45 mm SL. Clams should be examined regularly in conjunction with cleaning and predator removal and harvested when about 80% of the population reaches the target size. After grading, the sub-market clams can be returned to the field for additional growth. Some culturists have established markets for these smaller clams. Although the market value will be lower, the labor of replanting and harvesting will be avoided. (South Carolina does not have a minimum size limit for aquaculture-produced clams. Regulations may differ in other states.)

PROCURING SEED CLAMS

One of the first decisions to be made in starting a clam culture business is whether to include a hatchery. There are advantages to producing your own seed. These include the ability to control production to match your planting needs, the elimination of potential problems associated with importing seed from other states, and the ability to develop a breeding program to produce seed tailored to your operation. However, hatcheries are expensive to build and operate and require a degree of technical expertise.

If you have no prior experience it might be advisable to start with only a grow-out operation. Later, once you have some cash flow, a nursery could be added. Finally, once you have experience in handling seed in the nursery, a hatchery might be included. This decision will depend on many factors, including your experience level and your financial situation. Before making this decision, we recommend that you read “Investing in Commercial Hard Clam Culture” (Adams et al. 1991), a guide to the economics of clam farming which is available from most state Sea Grant offices.

There are a number of commercial hatcheries and nurseries which sell clam seed in a range of sizes from less than 1 mm up to planting size (>8 mm). A list of seed sources is provided in Appendix B. The list includes hatcheries and nurseries, so not all sizes may be available from all suppliers. Some of the companies deal primarily in oysters, but will produce clam seed if there is a demand. Many of the sources listed produce seed primarily for their own use and only sell to other parties if they have excess. This is as complete a list as we could obtain but new enterprises seem to appear each year. You may be able to obtain additional information on seed sources from the information resources listed in Appendix A or from other growers. We do not imply endorsement of any particular hatchery or nursery.

Seed prices increase with size and vary from year to year. Figure 8 shows 1993 prices for various size categories. Some suppliers will provide a discount for large orders, and end of season discounts are often available in the fall, particularly from the more northern hatcheries. If you are not going to include a nursery, you must purchase seed that are at least 8 mm SL. If you plan to use a field nursery, purchase 5–6 mm seed. For a land-based nursery or
Figure 8.
Clam seed prices, 1993
floating upwellers you can purchase seed as small as 1 mm. Call well in advance so the grower can schedule production of your seed. Many hatcheries require orders and prepayments several months in advance of shipment.

In deciding how many seed to order, count on 50% survival in the field grow-out stage, 75% survival in a land-based nursery or floating upwellers, and 50% survival in other field nurseries. Thus, if you wish to harvest 50,000 clams, you will need to plant 100,000 seed. To produce that many planting size seed in a land-based nursery, you should start with 135,000. A field nursery should be stocked with 150,000.

When selecting a seed supplier there are a number of important considerations. These include the ability of the supplier to meet your demand, both in terms of quantity and schedule; the quality of the seed; and the suitability of the seed for your particular operation. If possible, obtain names of other customers from your area and check these references. Before purchasing seed from an out-of-state hatchery, check with the S.C. Department of Natural Resources, Office of Fisheries Management, concerning regulations on importation of seed. There are risks involved with importing seed and you may be required to have the seed tested for certain diseases.

One factor affecting the suitability of the seed for your operation is the geographic origin of the broodstock used to produce the seed. Clams produced from northern broodstock may be unable to tolerate high water temperatures while those produced from Florida stock may be intolerant of cold winters. If the parental stock are from Florida, you will want to inquire whether they are *M. mercenaria*, *M. campechiensis* or a hybrid. *M. campechiensis* is reputed to have a poor shelf life and therefore is difficult to market. Hybrids have performed well for some growers and usually grow faster than *M. mercenaria* but have not been extensively tested in South Carolina. Stock from your own geographic area are most likely to be well-adapted to the growing conditions they will encounter in your operation.

It would also be desirable to know the history of the broodstock used to produce your seed. If the stock has been bred over many generations in the hatchery, it may have improved performance (if the hatchery has used a good breeding program) or it may actually have poorer performance than wildstock. You need to know what characters (if any) the hatchery has targeted in its selection program (e.g. fast growth; high survival; shell markings) and when the selection was performed. Then you can determine whether those characters are ones you consider important. For example, if a breeder has selected for fastest growth in the hatchery (by discarding the slower growers), that may be of no interest to you (since you are buying the seed after the hatchery phase). Fast growth in the field is the character which will have the most bearing on your operation. Bear in mind that a clam selected to grow rapidly in Florida or Maine may not grow rapidly in South Carolina.
Determine when the seed were spawned. By referring to Table 3 you can tell whether growth has been reasonable. You would prefer not to receive the slowest growing clams from a particular spawn, unless you are getting a cut-rate price. Also, ask whether the clams have any unusual characteristics of which you should be aware. We once purchased seed which could not tolerate being rinsed with freshwater. You would certainly want to know that.

**SHIPPING AND STORAGE OF CLAMS**

One of the advantages of clams as an aquaculture species is that they survive extended periods of time without water. This is very convenient when shipping clam seed and broodstock and when transferring clams from the nursery to the field. This section addresses methods of storing, packing and shipping larval, juvenile and broodstock clams. These are not methods for storing and shipping clams to market, which are specified by FDA guidelines. The South Carolina Department of Health and Environmental Control (SCDHEC) regulates transport of shellfish. Interstate shipment of clams may be restricted in some cases. Make sure proper permits are obtained before making shipping arrangements. In South Carolina, contact SCDHEC for assistance (see Appendix A).

**Storing clams out of water**

Seed clams may be held out of water for several days if they are kept cool and moist. They should never be allowed to stand in water, such as ice melt, but neither should they be allowed to dehydrate. It is usually sufficient to place them in an ice chest with damp newspaper on top. The ice chest may be refrigerated or one or two frozen gel packs may be placed on top. Do not let the frozen gel packs contact the clams directly. Survival of clams under refrigeration will depend in large part on the physiological condition of the clams when removed from water and the water temperature to which they are acclimated. Survival time will be shorter in the summer and any time the clams have been under stress. Small clams (<3 mm) can survive a few days of refrigeration, while adult clams may survive 10 days or more. Allow the clams to warm to water temperature before returning them to water.

**Shipping clams**

Late-stage larvae and post-set clams may be shipped by methods developed for remote setting of oysters. The clams are shipped damp in a nylon mesh of appropriate pore size. The clams are concentrated in the center of a small square of mesh and the corners of the mesh are folded up and tied. This damp ball is wrapped in several layers of wet paper and may be placed in a plastic bag (not sealed) to retain moisture. The package is placed in an insulated shipping carton with a frozen gel pack and shipped by overnight express. Younger
larvae may be packed and shipped like tropical fish.

Small seed clams and small quantities of larger clams are best shipped by air, using commercial carriers such as UPS, Federal Express, or airline package express services. They should be packed in heavy-duty insulated (e.g. styrofoam) cartons with frozen gel packs. Line the box with damp newspaper. (If the box is not watertight, line with a large plastic bag first). You want the paper wet enough to keep the clams moist but not so wet that water will drain out of it. Add the clams and shake gently to settle them. If the clams don’t fill the carton, use additional crumpled paper, styrofoam nuggets, or damp seaweed to fill up the extra space. Cover with damp newspaper. Wrap a frozen gel pack (or several, depending on carton size) in dry newspaper and place it on top. Do not use regular ice because it will melt sooner and the clams will be sitting in water. The gel packs should be separated from the clams by dry newspaper to avoid freezing the animals themselves. Limit the time in transit to a day or two.

It may be more economical to send large shipments by refrigerated truck. However, there is a risk in shipping clams by that method as trucks are routinely inspected for compliance with interstate shipping regulations. There is often no recognition of the fact that conditions for delivering a cultured clam with the least stress may not be the same as conditions for preventing human health problems. If the truck temperature does not meet the standards set for human health purposes, your valuable broodstock or seed may be destroyed along with consignments which were actually destined for the market. Also, seed clams have sometimes been confiscated by inspection officials because they were below the size limit for wild-caught clams. If you are going to ship by truck make sure all your packages are clearly labelled as culture-derived stock. Contact appropriate agencies in all states the truck will pass through (in South Carolina, SCDNR and SCDHEC) for current regulations on shipping seed, as these may be subject to change. For refrigerated truck shipment, clams are usually packaged in onion or grapefruit bags.

Clams that are being transported to planting sites in the field, even though the time in transit is usually much shorter, should be treated in much the same way. Clams should be removed from the culture containers, rinsed with freshwater, and loosely packed into coolers. Place damp newspaper on top to prevent dehydration. If they will be subjected to heat in transit, add frozen gel packs wrapped in dry newspaper. If weather is mild and the trip is short, just let them sit at ambient temperature. However, be sure not to let them sit in direct sun.

**Handling clams after shipment**

When a shipment of clams is received, it should be processed immediately. Open the box and remove the gel pack(s). Examine the clams to determine their condition, removing any obvious dead
ones. For larger seed and broodstock, examine them for the presence of fouling organisms, associated species, etc. and remove these if possible. Common nuisance species which could arrive with clams include small mussels, sea squirts, and oyster drills. Clams could be also be harboring bacteria, fungi, parasites or any of a number of other potential problems. Soaking the clams in freshwater or a dilute chlorine bath (1 ml household bleach in 1 liter freshwater) will eliminate many of these and is a good precaution. Freshwater soaks may be used for clams as small as 250 \( \mu \)m. Small seed (1–2 mm) can tolerate a 5-minute chlorine soak; larger seed can be soaked for an hour or more as long as the water is not warm. Chlorine soaks should not be used on clams <1 mm. If the clams are still cold, let them warm up to the temperature of the water before placing them in the culture system. Otherwise, put them in water immediately or, if that is not possible, refrigerate. (However, avoid repetitive warming up and cooling down as this will badly stress the clams). It is advisable to examine the clams 24 hours after introduction to your system to determine if any additional mortality has occurred. If possible, keep the new arrivals segregated from any clams already in your system until you are sure they are healthy.

**PERMITS AND LICENSES**

**Mariculture permit**

Clam mariculture is regulated by the South Carolina Department of Natural Resources (DNR), Office of Fisheries Management (OFM). Grow-out operations will require a mariculture permit from this office. Permits are granted for five years at an annual rental rate of $5.00/acre and may be renewed. Tidelands in the state are considered public trust properties and are, for the most part, available for shellfish culture. Exceptions are intertidal grounds ceded to individuals or estates as king’s or legislative grants. Also, no mariculture permits are allowed in areas where water quality prohibits shellfish harvesting. Mariculture pens or containers are not allowed to cover or encroach on natural shellfish populations, inhibit navigation, or impede normal commercial and recreational uses of the tidelands.

Mariculture permits are different from shellfish culture permits, which used to be called oyster leases. Shellfish culture permits are issued to individuals or businesses for commercial harvest of native shellfish (in most cases, oysters) in a specific area. Mariculture permits may be allowed within the boundaries of existing shellfish culture permits if the uses are compatible. If the area proposed for a mariculture permit is already designated as a shellfish culture permit area, you should obtain a memorandum of understanding from the shellfish culture permit holder indicating that party’s willingness to allow
dual use of the permit area. The Shellfish Management Program office at DNR will assist you in identifying existing shellfish culture permit areas.

Prior to applying for a mariculture permit, you should contact the DNR’s Shellfish Management Program (see Appendix A) to discuss your plans and potential permit sites. Detailed maps of state shellfish grounds are available and any conflicting uses can be identified. After a potential site is selected, biologists will perform a preliminary site investigation. This will save time and money by preventing an application that has little chance of approval for biological or other reasons. It is also advisable to obtain a copy of Marine Fisheries and Related Laws, available from DNR. Of specific interest are the sections pertaining to shellfish (Chapter 17, Article 3) and aquaculture (Chapter 18).

After a potential site for the grow-out operation is selected, an application for a mariculture permit is filed with the DNR, Office of Fisheries Management. There is a $25.00 non-refundable application fee. Supporting documentation in the form of maps of the desired permit area and a detailed operations plan are required. An outline of a generic mariculture operations plan may be obtained from OFM, Shellfish Management Program. This office will also assist in map preparation.

Conditional approval is granted to the applicant if all permit criteria are met and a sound operations plan is presented. At this point, the applicant must advertise in the local newspaper for three weeks, during which time written objections may be submitted to DNR’s Shellfish Permit Committee. This is also the appropriate time to apply for other needed permits (see next section). The committee will usually be able to render a final decision within a month after the advertising period. However, this final approval will not be granted until all other required permits are received. The mariculture permit process requires approximately three to six months, if the applicant meets requirements in a timely fashion and no objections are received.

No planting or harvest requirements are placed on mariculture permits. However, an annual operations plan and activities report must be submitted to the Shellfish Management Program. Once harvest begins, monthly production reports are required by the DNR’s Fisheries Statistics Program.

**Critical zone and discharge permits**

Grow-out operations may require permits from the Office of Ocean and Coastal Resources Management (OCRM), a division of the South Carolina Department of Health and Environmental Control (SCDHEC), and the U.S. Army Corps of Engineers to conduct activities in the “critical zone”. These agencies use a joint application and permitting process. Specific requirements or conditions may be placed on the permit to avoid environmental degradation, prevent use conflicts, and
avoid navigational interference. Hatcheries, nurseries and ponds or impoundments which will discharge into natural waterways will require discharge (NPDES) permits from the SCDHEC.

Even if the above permits are not necessary for a specific operation, written exemptions from these agencies must be obtained before the DNR will issue a mariculture permit.

**Purchasing, harvesting and selling clams**

In order to import seed clams or to be in possession of seed clams, you will need an additional permit from DNR. This no-cost permit is only issued to persons who are already in possession of a mariculture permit and therefore have a legitimate reason to be in possession of undersized clams (<1" thick). You must carry this permit whenever you are in possession of seed clams (e.g. in transporting them to field grow-out areas). This will protect you from seizure of your clams should a law enforcement officer challenge you. If you ship seed clams, a copy of the permit should be enclosed with the shipment.

Before harvesting your clams, you must obtain a harvest permit from DNR. These annual no-cost permits are primarily for your protection. The permit specifies the area from which you are authorized to harvest. Anyone harvesting clams in your mariculture permit area without a harvest permit could be subject to legal action. Any illegal activities on your permit area (e.g. poaching, vandalism) should be reported to DNR's District 9 law enforcement office (see Appendix A). Harvesting of cultured clams is permitted year-round.

Before marketing your clams you will need a land and sell license, which allows you to sell to wholesale dealers. If you wish to sell directly to the public you will also need a wholesale dealer's license. Both of these licenses are obtained from the commercial license office of SCDNR.

A wholesale dealer must have a certified shellfish holding facility. Holding facilities are certified by SCDHEC, which will perform periodic inspections to insure adherence to FDA guidelines, including cleanliness and refrigeration requirements. SCDHEC also inspects vehicles used for the transport of shellfish. All shellfish must be bagged and tagged, identifying area and date of harvest. Accurate records must be kept to substantiate harvests and shipments. Contact SCDHEC for details on storage, shipping and tagging requirements.

**Other permits**

It is difficult to specify all permits and licenses which you may need, because this will vary depending on the type and location of the culture operation (e.g. see DeVoe and Whetstone, 1987). For instance, you may need local zoning permits, building permits, etc. Also, regulations may change, so it is imperative to check on current permit and license requirements. Assistance in identifying permit requirements may be obtained from the SCDNR.
Shellfish Management Program, S.C.
Department of Agriculture Aquaculture
Permit Assistance Office, and the S.C. Sea
Grant Consortium (see Appendix A).