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Biology and Culture of the Hard Clam
(*Mercenaria mercenaria*)

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Hard clam aquaculture is the largest and most valuable of the shellfish aquaculture industries on the East Coast. It accounts for more than $50 million in economic value annually.

Hard clams are bivalve mollusks that live in saline (>25 parts per thousand) waters and cannot tolerate low salinities or freshwater for an extended period. Hard clams occur naturally all along the Atlantic coast from Nova Scotia to Florida. They have been introduced along the shore of the Gulf of Mexico from Florida to Yucatan, as well as along the West Coast of the United States, in the British Isles, and in parts of France. The distribution of hard clams is determined by hydrodynamic factors and, possibly, sediment types and depth. Sediment characteristics affect the number and types of both invertebrates and their fish predators. Hard clams support a major commercial fishery along the entire East Coast. New York, Rhode Island, New Jersey and Virginia are the leading states for hard clam commercial landings. The southeastern states are the leading aquaculture producers of hard clams.

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Life history

Reproduction cycle

Hard clams usually spawn in the spring, summer or fall. The optimal range of water temperatures (79 °F or 26 °C) occurs at different times of the year at different latitudes. Clam reproduction occurs earlier in the year at lower latitudes. Dimodal (two peaks) or polymodal (multiple peaks) spawning takes place in southern populations, and spawning may occur more than once per spawning season.

There are several stages in the reproductive cycle, which for discussion purposes may begin with the resting and/or spent stage. In this stage the clam completely or almost completely lacks gametes (eggs and sperm). The resting stage is followed by the early development stage, during which the follicle walls thicken and immature gametes develop. In the late development stage, the follicles rapidly expand to accommodate the larger and more numerous gametes. In the ripe stage, the follicles are fully expanded and thin-walled. The lumen of female follicles contains mature ova (eggs), while mature sperm dominate the lumen of male follicles. The germinal ducts have begun to expand and may contain a few mature gametes. Mature gametes are released and fertilization takes place externally. The ripe stage is followed by the resting and/or spent stage to complete the reproductive cycle.

The development of the veliger larvae is complete 24 hours after fertilization. These larvae swim, but are moved primarily by tidal currents. The larvae grow to a maximum size of 200 to 275 micrometers. By the sixth to tenth day, the skin-like outside tissue, called the mantle, starts to form two shells and the umbo. The umbo is the rounded area of the shell just above the hinge. With the extra weight of the shell, larvae no longer swim freely and settle to the bottom. Only 10 percent of fertilized eggs survive to this stage. During metamorphosis, the clam "seed" burrows into a suitable substrate where it remains mostly immobile. Clams prefer a combination of mud and sand as substrate but other suitable substrates are pure sand, gravel and mud.

Larval setting

Many bivalve species attach to sand grains or other debris by one or several strong byssus threads. Byssus threads are thin strands secreted by a gland in the middle

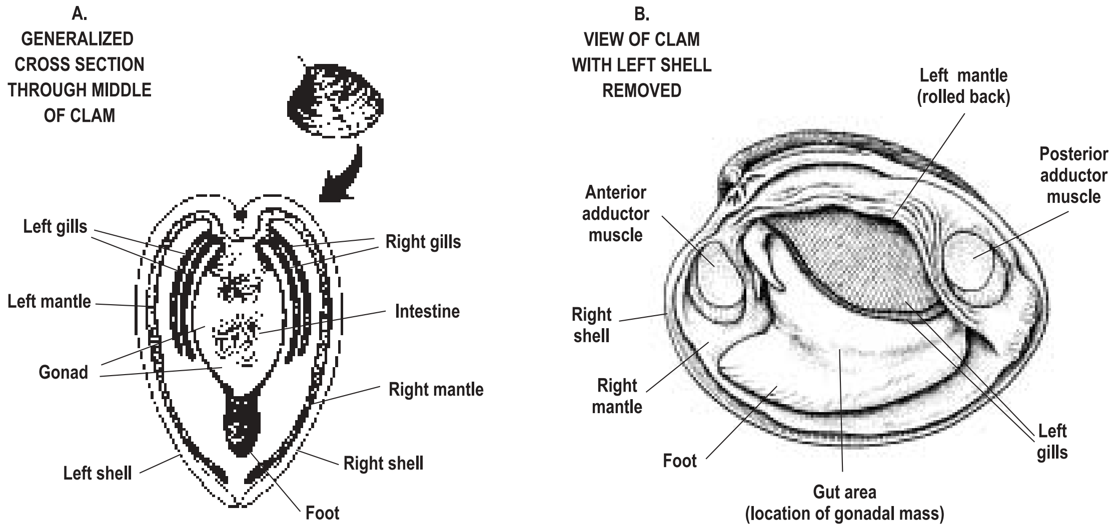

Figure 1. Internal anatomy of the hard clam.
(drawing courtesy of John Norton, South Carolina Sea Grant Consortium)

line of the surface of the foot. Hard clams lose their ability to make byssus as they grow older. Clams may release from this attachment and may crawl or be moved by currents to another location where they attach again. As clams mature, they use the muscular foot to burrow into the bottom sediments. By alternately extending, swelling and contracting the foot, the body is pulled down into the substrate. The whole body usually is below the substrate, except for the incoming and outgoing siphons.

The body of the clam is completely enclosed in a mantle, which is subdivided into lateral lobes that secrete a calcium carbonate shell. The mantle covers the foot and visceral mass and is connected to the shell by pallial muscles close to the edge of the shell. This line of mantle attachment to the shell is seen on the inner surface of the shell as the pallial scar line.

The two valves of the shell are joined dorsally by an elastic hinge ligament, which acts as a spring that forces the valves apart when the adductor muscles relax.

The dorsal margin of each valve bears a prominent point near the hinge ligament called the umbo. This is the oldest part of the shell, and around it are the concentric lines of shell growth. Each umbo may point slightly to the anterior so that it is usually possible to determine right and left valves.

Respiration and growth

Most clams remain close enough to the surface that the tips of their siphons are exposed. Siphons, sometimes called the neck, are specialized tubes of the mantle. One siphon brings in water that carries oxygen for respiration and food for growth. Incoming water passes over the gills where the oxygen is absorbed and where algae and other food particles are filtered out. Food particles are drawn over the gills by the action of cilia that cover the gills and mantle. Food is trapped by mucus on the gills and carried to the food groove along the ventral edge of the gill, and then to the palos around the mouth. Filtered water and waste are then expelled by the other siphon.

The growth of hard clams is affected by tidal movement and by algal concentrations along the substrate-water interface. Ideal conditions are moderate tidal movement with dense algal concentrations and adequate dissolved oxygen levels—above 4 ppm.

The rate of shell deposition is a major factor affecting growth. Clam shells are formed by the deposition of calcium carbonate crystals on an organic material. Shells grow in rings and/or layers deposited on this organic matrix. Growth is not continuous, but incremental, with periods of shell dissolution. Shell growth occurs only during aerobic respiration when the valve is open. The mantle, which covers the inner surface of the shell, is responsible for shell formation because it secretes organic material that reacts with calcium carbonate to form shell. New shell is deposited between the inner shell surface and the mantle epithelium. Shells grow laterally (in thickness) when growth is slow. Faster growing individuals usually have thinner shells.

All hard clams, whether natural or cultured, grow at different rates. Hard clams with maximum growth rates attain market size in 12 to 24 months. In 10 to 16 months, fast growers may be twice the size of slow growers. The relatively long period of time needed to produce market size clams is an important limiting factor in their aquaculture. Growth rate may be influenced by genotype or genetics, because a percentage of any clam population originating from the same spawning matures at a faster rate. Therefore, scientists have been developing selective breeding programs to establish faster growing genetic lines, which would have economic benefit. It has become apparent that removing slow-growing clams from a production system reduces production costs. When clams grow at varying rates they must be handled more, which increases stress to the animals and decreases the predictability of cash flow.

Environmental factors also influence growth rates. These include water temperature, food availability, salinity, water quality and tidal currents.

Generally, hard clams are 1 to 2 inches long at harvest (at about 2 to 3 years of age), with a meat weight of 18 to 20 grams. Growth slows with increasing age. In 7 to 8 years hard clams may be only 3 inches long. Hard clams are known to live for 30 years or longer.

Predation

When clams are disturbed, they burrow deeper to avoid predators. Common predators are blue crabs, stone crabs, mud crabs, conch, sting rays, horseshoe crabs and snails, which feed mostly on juvenile or small clams.

Producers use rafts, trays, cages, bags and nets to exclude predators. Biological control of crabs has been attempted by stocking toadfish in culture trays. Toadfish do reduce the number of crabs and increase clam survival significantly, but the economic feasibility of stocking them is questionable.

Marketing

Hard clams are marketed whole. About 30 percent are shucked and the remainder are marketed for raw or steamed consumption. Unshucked clams command the highest prices on a per clam basis. Higher prices are paid for clams designated in the market as littleneck and topneck clams, which range from 1 to 1 ¼ inches thick. Size class designations may vary from state to state.

Hard clam prices fluctuate with the supply, which is dependent on the stocks of clams, access to production areas, weather conditions, harvest seasons, and the bacterial content of the growing environment. In most southern states, farm-raised clams may be harvested year round, which offers a marketing advantage over wild-harvested clams in some states. Check with your state natural resources agency about regulations for harvesting cultured clams.

Hard clam aquaculture

Hard clams are the most commonly cultured of the bivalve species. Clam culture in the U.S. began in the early 1920s. Broodstock management is a vital step in fulfilling the potential of hard clam aquaculture. Efforts to produce genetically improved bivalve broodstock are probably as old as bivalve mariculture itself.

The hard clam production process consists of three consecutive stages: **hatchery, nursery** and **grow out**. Each stage is designed to produce a specific size clam. The ultimate objective is to produce market size clams. Farmers may develop any or all the production stages into viable businesses.

Hatchery

The hatchery is where broodstock clams spawn and larval clams are raised through the post-set stage to 1 mm juveniles or seed clams. Broodstock are held in conditioning tanks at 19 °C and fed a diet of cultured algae. Hard clams can be stimulated into spawning in colder months by conditioning them gradually to increasing temperatures and by providing adequate food.

Broodstock are manipulated by alternately exposing them to chilled (18 to 24 °C) and warmed (28 to 30 °C) seawater containing a suspension of hard clam sperm. After several cycles, the clams will spawn, with the male usually spawning first. The eggs are sieved, collected and placed in growing tanks where they develop into larvae. Females average 1 million eggs per spawn.

The next phase of the hatchery process is larval culture, which lasts through day 7. Larvae are raised in various sizes and types of

Figure 2. Algal production in hard clam hatchery.

Figure 3. Broodstock tempering.

containers. The larval tanks are supplied with filtered seawater (20 to 30 ppt) at a temperature of 20 to 30 °C. The concentration of larvae in the tanks varies, but 20 to 30 larvae per ml is recommended. During this stage, they are fed a diet of cultured algae.

A major requirement of hatchery production is producing algae to feed young clams. For the first 7 to 10 days clams are fed small flagellates (*Isochrysis*), followed by diatoms such as *Chaetoceros* and *Skeletonema*. The initial feeding rate is 25,000 algal cells per ml or 1,000 cells per clam larva. The larval stocking density and algal feeding rate fluctuate through the larval grow-out cycle. Generally, the clam larval density is reduced and the feeding rate per clam larva is increased as the clams grow larger.

Between day 8 and day 12, the larval clams develop into the pediveliger stage. They are kept in post-set tanks and fed cultured algae. Filtered seawater at 26 °C circulates through the system to ensure optimum survival and growth.

Post-set clam production is the next phase of production; it generally lasts 13 to 35 days. As in earlier stages, water temperature is maintained at 26 °C, water is filtered, and the post-set clams are fed cultured algae. Newly set clams are placed in shallow raceways or in cylinders with up- or down-welling water flows. The clam seeds are kept in the hatchery until they reach about 1 mm. At this point, the seed is graded and separated by size and maintained in the nursery until ready for planting.

One of the long-standing problems in bivalve aquaculture is the difficulty of culturing massive quantities of suitable algal species economically. Algae are needed to grow seed to the proper size for field planting. The cost of producing this algal biomass is relatively high compared to the cost of seed clam production or the projected annual gross revenue of this aquaculture venture.

Permitting

The nursery and growout phases of clam culture require permits from state regulatory agencies if clams are grown and harvested from state-owned waters or bottoms. In addition, any hard structures will require permits from the state regulatory agencies. Hatcheries may need permits for water intakes, docks and outfalls if structures are in public waters. Recent EPA regulations do not require National Pollutant Discharge Elimination System Permits for shellfish aquaculture. A prospective grower should begin site selection and permitting as early as possible so that good sites are selected and regulatory holdups are avoided.

Nursery

The nursery is a critical link in the hard clam grow-out process. Placing seed clams from the hatchery directly into the field for grow out can cause a high level of mortality. The nursery provides a controlled, intermediate step, whereby the hatchery-reared seed clams are nurtured to a size less vulnerable to the stress and predation found in the field grow-out phase. It would not be cost effective to grow seed to the size required for the grow-out stage within an intensive hatchery environment using cultured algae. So, natural seawater is generally used in these systems. Natural feed is provided by seawater as it moves through the nursery system.

Figure 4. Land-based raceway nursery system.

Figure 5. Floating upweller for clam seed production.

The oldest method of nursery culture is called the land-based raceway method. The raceway system typically uses long, shallow, wooden trays lined with plastic or covered with epoxy resin or other protective coating. A thin layer of sand covers the bottom of each tray, and the seed clams are distributed over it. Raw seawater is pumped into one end of the tray at a prescribed rate to establish a horizontal flow across the seed clams.

Another method of nursery culture is the land-based upweller method. The upweller system pumps seawater to reservoir tanks and upflow cylinders, which provide vertical flow for the seed clams. The flow of water can be forced up through the seed clams or pulled down through the seed clams. The seed clams rest on a fine-mesh screen. The movement of water removes waste and prevents the seed from being suffocated by any accumulated silt.

Floating upwellers are a recent innovation. These are similar in design to land-based upwellers, but can be powered (pumped) by airflow, submerged pumps or tidal flow.

The fourth method of nursery culture is the field-based bottom plant system, which involves placing seed clams directly from the hatchery into the submerged bottom setting. Seed clams smaller than 3 to 4 mm should be used. Traditional designs employ subtidal and intertidal trays made of wood that contain a layer of gravel or sand and have a protective cover to discourage predators.

More recent innovations include bottom bags and systems of bags held together in long belts. The series of bags significantly reduces maintenance and labor expenses. All of these field-based nursery techniques are carried out in protected, shallow water areas so the threat of poaching can be minimized.

These nursery systems vary considerably in terms of investment cost, operational expenses and required management skill. The land-based system requires waterfront land and an investment in pumps, whereas the field-based system is located on leased bottom without the need for controlled water movement. The floating upweller systems are intermediate to land-based and true field bottom plants. Energy requirements are much higher for the land-based systems. Maintenance costs are lower for the upflow systems than for raceways. Replacement and maintenance costs are higher for the floating upweller systems because of their location in the water and the greater risk of damage by predators, fouling and wave action. Survival rates may be higher for the land-based systems because there is greater control over water quality and a lack of predators, but the production cost per clam seed may be less with the in-water systems, particularly if waterfront property is not available.

Figure 7. Market-size clams in a grow-out bag.

Grow-out

The time needed for grow-out will largely depend on water quality, food availability and temperature. Grow-out to 50-mm (2-inch) market clams from 7- to 15-mm nursery clams may require 12 to 24 months.

There are various grow-out culture systems for raising hard clams for the market. Grow-out systems are stocked at a density

Figure 6. Clam grow-out covers in Virginia. (photo courtesy of Virginia Sea Grant Consortium)

of 50 to 70 seed per square foot for final grow out. Although land-based grow-out methods such as raceways and tanks have been developed, the field-based grow-out methods are more economical and better suited to hard clam production. Grow-out operations use some form of hard structures (pens, trays) or soft structures (bags, net covers) to reduce predation and ease harvesting. Pens are harvested by hand rakes or with mechanical harvesters, where legal. A lifting apparatus is required to lift trays from the water. Covers (bottom plants) are placed over the seed clam planted area and staked down to discourage predators. To harvest clams, the net is rolled from the planted areas and the clams exposed. Soft bags resemble 4-foot by 4-foot laundry bags; usually a number of bags are connected together to form a line that is staked to the bottom. Harvesting soft bags is a matter of pulling up the bags because the clams are confined in the bags. To increase the survival rate, seed clams longer than 6 mm should be used, even though larger seed are more costly and are in limited supply.

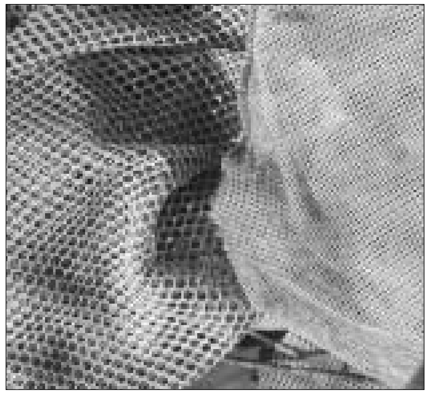

Figure 8. Nursery (right) and grow-out (left) bags.

Figure 9. Harvesting clam bags. (photo courtesy of Leslie Sturmer, University of Florida)

Clam farmers in certain counties in four states—Florida, South Carolina, Virginia and Massachusetts—may participate in the first USDA Pilot Crop Insurance Program in aquaculture. Clams 10 mm and larger are insurable against natural losses in excess of state average mortalities, and farmers may purchase crop insurance with differing deductibles to cover insurable losses and reduce their financial risk.

Clam culture is a risky investment, as is any aquaculture or farming operation. Call on the Extension aquaculture specialist in your state for additional information.

For more detailed information, obtain a copy of:

A Manual for the Culture of the Hard Clam *Mercenaria* spp. in South Carolina. Nancy H. Hadley, John J. Manzi, Arnold G. Eversole, Robert T. Dillon, Colden E. Battey and Nancy M. Peacock. South Carolina Sea Grant Consortium.

SRAC fact sheets are reviewed annually by the Publications, Videos and Computer Software Steering Committee. Fact sheets are revised as new knowledge becomes available. Fact sheets that have not been revised are considered to reflect the current state of knowledge.

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