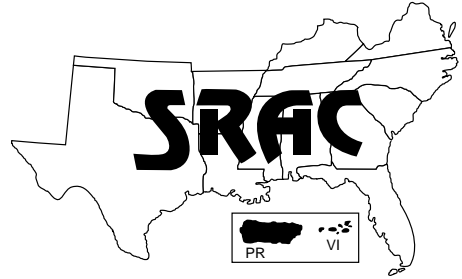


**Southern  
Regional  
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# Biology and Culture of the Northern Quahog Clam

## *(Mercenaria mercenaria)*

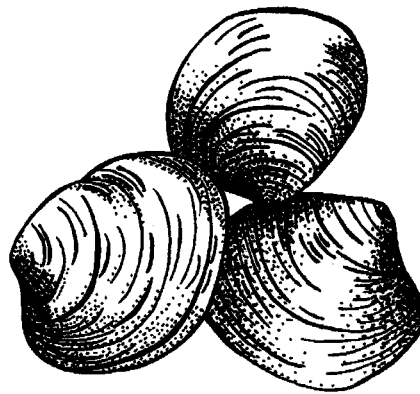
Wendell J. Lorio and Sandra Malone\*

The hard clam industry is the largest and most valuable of the other clam species and represents 7 percent of all clams harvested but accounts for 53 percent of the dockside value.

Hard clams are bivalve mollusks that live in saline waters and cannot tolerate fresh water for any extended period of time. Natural distribution of hard clams is 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. Hard clams have been established along the West Coast of the United States, in the British Isles and parts of France.

Distribution of hard clams is determined by hydrodynamic factors that affect various pre- and post-settlement processes and may be related to geographic locations such as sediment types and depth. Sediment characteristics and type affect the number and types of invertebrate and fish predators by their adaptation to various bottom types. Hard clams support a major commercial fishery in the New England and Mid-Atlantic Coastal states. New York, Rhode Island, New Jersey and

*The northern quahog is commonly called the hard clam and will be referenced as such in this report. Mercenaria mercenaria is one of 14 species that are harvested in the United States. The scientific name comes from the Latin word mercenaris which means "hired for wages" or "hired one."*



Virginia are leading states for hard clam commercial landings. There is still a small commercial clam fishery along the eastern coast of Florida.

### Life history

#### Reproduction cycle

Spawning of hard clams generally occurs annually in the spring, summer or fall. Clams spawning naturally or spawned in hatchery conditions have a larvae stage that lasts 8 to 15 days. Spawning of

hard clams is stimulated by water temperatures above 79°F or 26°C. The optimal range of water temperature occurs at different times of the year at different latitudes. Clam reproduction occurs earlier in the year at lower latitudes. Dimodal or polymodal spawning takes place in southern populations, and spawning activities may take place more than once per spawning season. Hard clams exhibit latitudinal variability in the timing of gametogenic events.

Gametogenesis or the production of gametes (egg and sperm) is part of the reproductive cycle. 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 individual clam is completely or almost completely lacking gametes and is followed by the early development stage characterized by an increase in the follicle wall thickness and the presence of immature gametes. In the late development stage the follicles are rapidly expanding 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 contain mature ova (eggs), and mature sperm dominate the lumen of male follicles. The germinal ducts

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have begun to expand and may contain a few mature gametes and are therefore ready for actual spawning to take place. The ripe stage is followed by the resting and/or spent stage and the reproductive cycle is now complete. Fertilization occurs externally in the water column, and at the end of 24 hours, the development of the veliger larvae is complete.

These larvae swim and feed, but in general are moved by tidal currents. The larvae achieve a maximum size of 200 to 275 microns. 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. Since the shell provides extra weight, they no longer swim freely and settle to the bottom. Only 10 percent of the originally fertilized eggs survive to this stage. During metamorphosis, the clam "seed" selects a suitable substrate, where it burrows at varying depths and maintains limited mobility. The preferred substrate is a combination of mud and sand but other suitable substrates are pure sand, gravel and mud.

### Larval setting

Many bivalve species are attached to sand grains or other debris by one or several strong byssus threads. Byssus threads are thin strands of material secreted by a gland located in the middle line of the surface of the foot in a byssal pit. 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 their muscular foot to burrow into the bottom sediments. By alternately extending, swelling and contracting the foot, the body is pulled down into the bottom substrate. Generally the complete body 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, which is part of the body, covers the foot and visceral mass. The mantle is connected to the shell by pallial muscles, which are a short distance from the edge of the shell. This line of mantle attachment to the shell is represented on the inner surface of the shell as the pallial scar line.

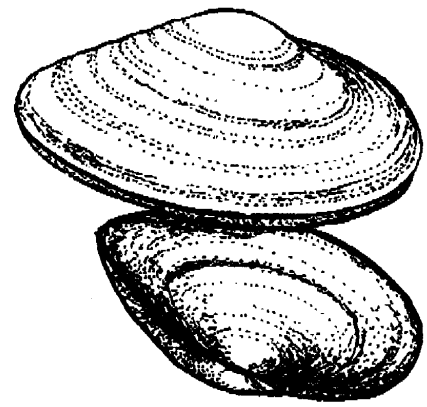
The two valves of the shell are joined dorsally by an elastic hinge ligament, which acts as a spring by exerting on the valves forcing them apart when the adductor muscles relax.

The dorsal margin of each valve bears a prominence point near the hinge ligament called the umbo. This is the oldest part of the shell, and around this part of the shell 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.

An abundance of hard clams have been correlated with sediment types. The highest average of abundance usually occurs on shell-sand sediments. Sediment characteristics also affect predation success on hard clams.

### Respiration and growth

Most clams remain close enough to the surface so that the tips of their siphons are exposed. Siphons, sometimes called the neck, are specialized tubes of the mantle for the entrance and exit of water. The siphons help clams take in oxygen and food. 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. Small food particles are drawn over the gills by the action of cilia covering the gills and mantle. Food is trapped by mucus on the gills and carried vertically by action of the cilia to the food groove along the ventral edge of the gill and then to the palps around the mouth. Filtered water and waste are then expelled by the other siphon.



Growth of hard clams is affected by tidal movement and 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 in limiting growth. Clam shells are formed by the deposition of crystals of calcium carbonate 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. The shell is deposited between the inner shell surface and the mantle epithelium. The extrapallial fluid contains organic matrix components and calcium carbonate which react to form the shell. The mantle secretes and maintains organic and inorganic components in the extrapallial fluid. Shells grow laterally (thickness) under slow growth conditions. Faster growing individuals generally have thinner shells.

All populations of hard clams, whether natural or aquacultured, grow at different rates which may be influenced by genotype or genetics. Hard clams with maximum growth rates attain marketable size in 24 to 36 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 fac-

tor in the aquaculture of hard clams. Approximately 10 percent of any clam population originating from the same spawning matures at the fastest rate. Therefore, it would be of economic benefit if selection could be made for the fastest growing individuals. It has become apparent in clam aquaculture that the removal of slow growing animals from the production system would result in a net reduction in production cost. The value of the animals discarded exceeds the savings realized by confining production to fast growing individuals. Variable growth rates affect production by increasing handling, increasing stress to the animals associated with increased handling, and decreasing the predictability of cash flow.

Environmental factors also influence growth rates. Water temperature, food availability, salinity, water quality and tidal currents provide food and dispense waste products. Density and genetics are major factors that determine the growth rate of hard clams. The hard clam is 1 to 2 inches long at harvest with a meat weight of 18 to 20 grams (at approximately 3 years of age). Growth of clams slows with increasing age. In seven to eight years hard clams may only be three inches long. Hard clams are known to live for 30 years or longer. It has been reported that hard clams exceeds 50 percent of the expected growth by the third year and 20 percent by the fifth year.

### **Predation**

When clams are disturbed they burrow deeper to avoid being preyed upon. Common predators are blue crabs, mud crabs, conch, sting rays, horseshoe crabs and snails. They mostly feed on juvenile or small clams. Wading birds may cause intensive destruction in some areas.

Current techniques used to exclude predators include rafts, trays, cages and nets. Biological control of crab predation has been attempted by stocking toadfish in culture trays. There has been a significant increase in clam sur-

vival with use of toadfish to reduce the total numbers of blue crabs, but the economic feasibility is questionable.

### **Marketing**

Hard clams are marketed in whole form, and approximately 30 percent of the harvested hard clams are shucked. The remainder of the harvested clams are marketed for raw or steamed consumption. This marketing form generates the highest prices on a per clam basis. Hard clam prices are sensitive to changes in hard clam supplies; as supplies increase, prices decrease and vice versa. Higher prices are received for the smaller clams. Size class designations may vary from state to state. Generally the "littleneck" demands the highest price.

"Little-neck" clams are approximately 48 to 50 mm at the longest shell dimension. The availability of edible hard clams is dependent on the stocks of clams, access to production areas, weather conditions, and harvest seasons and upon the bacterial content of their environment.

### **Hard clam aquaculture**

Hard clams are the most commonly cultured of the bivalve species. Clam culture in the United States began with the first successful rearing of larval hard clams 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.

There has been increased attention in culturing hard clams in recent years. Significant advances in production technology during the past decades have played a major role in generating this growing interest. Key innovations and improvements in methodology, especially the development of efficient nursery systems and field growout techniques, have enhanced the economic feasibility of culturing hard clams on a commercial scale.

## **Production process**

The hard clam aquaculture 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 hard clams for the available markets.

### **Hatchery**

The hatchery accomplishes the spawning of broodstock clams and raising the larval clams through the postset stage to 1 mm juveniles or seed clams. Broodstock are held in conditioning tanks with temperatures controlled 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 in the laboratory, along with adequate food.

The spawning process involves manipulating the broodstock, alternating exposures 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.

After spawning occurs, the next phase of the hatchery process is larval culture which lasts through day 7. They are raised in various sizes and types of containers. The larval tanks are supplied with filtered seawater (20 to 30 ppt) at a temperature between 20 and 30°C; usually an antibiotic or bacterial inhibitor is added. The concentration of larvae in the tanks varies, but 30 to 60 larvae per tank have been recommended. During this stage they are fed a diet of cultured algae.

Between day 8 and day 12 the larval clams have developed into the pediveliger stage. They are kept in postset tanks and fed cultured algae. Filtered seawater tempered to 26°C circulates through the system and assures maintenance for optimum survival and growth.

Postset clams are the next phase of production which generally lasts 13 to 35 days. As in earlier stages water temperatures are maintained at 26°C, water is filtered and the postset clams are fed cultured algae.

Under hatchery conditions, newly set clams are placed in shallow raceways or in cylinders with up or down welling water flows. The clam seeds are maintained in the hatchery until they reach approximately 1 mm. At this point, seed is graded and separated by size and maintained in the nursery until ready for planting.

Bivalve aquaculture has long been plagued by an inability to culture 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.

### **Nursery**

The nursery is a critical link in the hard clam grow-out process. Placing seed clams from the hatchery directly into the field grow-out may yield an unacceptably 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 imposed 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. Natural seawater is generally used in these systems. Natural feed is provided by seawater as it moves through the nursery system.

One method of nursery culture is the land-based upflow method. The upflow system utilizes ambient seawater, which is pumped 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 serves to remove waste and prevent suffocating the seed from any accumulated siltation.

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

The third method of nursery culture is the field-based 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 utilized. 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.

Floating nursery trays are a recent innovation. 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 placed in protected shallow water areas so the threat of poaching can be minimized.

These alternative nursery systems vary considerably in terms of investment cost, operational expenses and management skill. The land-based system requires waterfront land and investment in pumps, whereas the field-based system is located on leased bottom without need for controlled water movement. Energy requirements are much higher for the land-based systems. Maintenance costs are lower for the upflow systems than raceways. Replacement and maintenance costs are higher for the field-tray systems because

of location in the water and being subjected to damage by predators, fouling and wave action. Survival rates can be much higher for the land-based systems due to greater control over water quality and lack of predators.

### **Grow-out**

The length of grow-out time will largely depend on water quality, food availability and temperature. Grow-out to 45 to 50mm market clams from 7 to 15mm nursery clams may require from 18 to 36 months.

There are a variety of grow-out culture systems for culturing hard clams for the market. Grow-out systems are stocked at a density of 50 to 75 seed/sq ft at final grow-out. Although land-based grow-out methods such as raceways and tanks have been developed, the field-based grow-out activities are better suited for hard clam production. Most grow-out operations utilize some form of pen, tray or net. Pens, nets and trays are used in intertidal zones and nets in subtidal and intertidal zones. Pens are generally used over soft bottoms while trays and nets are used over hard bottoms such as sand. Pens are harvested by hand rakes or with mechanical harvesters where legal. Trays are harvested by lifting but because of their weight a lifting apparatus is required. Nets are placed over the seed clam planted area and staked down as a means to discourage predators. Harvesting is accomplished by rolling the net from the planted areas and exposing the clams to harvest by legal bottom harvesting methods.

Increasing the chances of high survival rate in clam culture requires the use of seed clams larger than 6mm shell height. The larger the seed the more costly they are and supplies are more limited. As in any aquaculture operation, clam culture is not without risk as there is the slim margin of economic viability. Call on the fisheries or aquaculture specialist in your state for additional information.