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CULTURE METHODS FOR GROWING THE CLAM MERCENARIA MERCENARIA.*

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INTRODUCTION

A pilot-scale experimental clam farming operation has been carried out since 1975 by the Virginia Institute of Marine Science of the College of William and Mary at Wachapreague, Virginia, on the mid Atlantic coast of the United States. The bivalve Mercenaria mercenaria (Linné, 1758) grown in this experiment is a commercially-important mollusk found principally in the central latitudes of the Western Atlantic. Mariculture of this species is desirable for the following reasons:

1. Total U.S. landings (based on harvest of natural populations) have decreased from over 9.5 million kilograms of meat in 1950 to 4.9 million kilograms in 1980.
2. Landing values have dramatically increased from $7.3 million (U.S.) in 1950 to $441.1 million in 1980 (NMFS, 1981). When adjusted for inflation, the real dollar value of Mercenaria has more than tripled in the last 30 years.
3. M. mercenaria is somewhat unusual among fishery products in that the smaller clams bring much higher prices than the larger ones. For example, the size categories are based on the depth (thickness of the intact shells of the whole animals) as follows:

Size designation	Size range (mm)	Approximate price per clam (U.S.$)
Little neck	25–35	0.12
Cherrystone	36–41	0.08
Chowder	42>	0.05

This market-demand price structure creates an ideal situation for an aquaculturist since the clams reach their minimum marketable size and maximum value at the same time.

The culture methods described here are simple, inexpensive, and have been proven successful. These same methods with little or no modification have been used for growing other bivalves and can undoubtably be adapted to species endemic to Chile.

The hatchery is located on a coastal lagoon aproximately 9.6 km from the Atlantic Ocean. The salinities range annually from 17 to 34 ppt with a mean of 29.5 ppt. Water temperature annual range is 2.5 to 26.5°C. The quality of the water is perhaps the most crucial factor in successful culture of mollusks. The lagoon abounds with natural beds of clams and oysters, attesting to the excellent water quality of the location.

Culture of M. mercenaria is carried out in three stages: hatchery production of larvae, nursery production of seed, and field grow-out of little neck size marketable clams. The time spent in each phase is dependent on ambient water temperature, amount and type of natural food in the water, and other factors. On the average, a sibling group of clams

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will spend approximately 12 days in the hatchery, 5 months in the nursery, and 24 months in the grow-out phase.

HATCHERY PHASE

Egg and larval production

The spawning stock is selected from beds of cultured clams, offspring of parents previously selected for fast growth, or from wild stock whose shell characteristics indicate rapid growth.

The selected spawning stocks held in natural waters are brought into the hatchery from April through July (spring and early summer) for spawning. During this period the water temperature is usually between 20 and 25°C and the gonadal development of clams is well advanced. The clams can be induced to spawn using methods described by Loosanoff and Davis (1963), Breese and Robinson (1981), and Castagna and Kraeuter (1981). Raising and lowering of water temperature and adding a suspension of gonadal products stripped from a sacrificed wild clam are usually used as spawning stimuli. In order to prevent unwanted wild crosses with the select spawners, the stripped sperm or ova are first rendered inactive (sterile) by subjecting the suspension to pasteurization or freezing. Spawning is usually carried out in a trough of filtered seawater using about 50 broodstock clams. Approximately 10 to 30% of these spawn on a given day. The spawners are not segregated by sex and fertilization takes place within a few minutes after spawning. Shortly after fertilization, the egg-seawater suspension is drained from the spawning trough and poured through a series of sieves arranged in descending sizes (53 µm, 44 µm, 35 µm, and 25 µm) to sort the eggs by size. Larger eggs develop into more successful larvae (Kraeuter et al., 1982); therefore, the larger eggs are cultured and the smaller eggs are discarded.

The fertilized eggs develop into larvae in fiberglass or plastic containers filled with seawater filtered through a 10 µm polypropylene bag filter. The larvae are grown in filtered seawater which is sometimes exposed to solar radiation in a greenhouse facility using the Glancy method to stimulate multiplication of the phytoplankton (Castagna and Kraeuter, 1981). Every other day the water is drained from the containers and the larvae are collected on sieves. They are then concentrated, graded by pouring through a series of sieves arranged in descending sizes, and the slowest growing and non-growing larvae are discarded. The other larvae are returned to a clean container filled with seawater recently filtered or filtered and exposed to solar radiation. The density of the larvae are reduced from 16 to 4 per ml as they grow larger.

The veliger larvae develop into pediveligers, then plantigrades (Carriker, 1961) and settle to the bottom where they attach to the container by their byssal threads. Metamorphosis and setting usually occurs within 8 to 12 days when larvae have reached a length of 150 to 200 µm. The hatchery phase of bivalve aquaculture is a reasonably dependable procedure as long as the water supply is free of anthropogenic or natural toxins and adequate bacterial control methods are maintained (Castagna and Kraeuter, 1981).

Production of seed

The newly-set plantigrades can be rinsed from the container, concentrated, and then moved from the hatchery to the nursery. During the nursery phase the post-set clams are grown to a size large enough for field planting. They are placed in fiberglass trays (2.45 x 0.55 m) with a plastic standpipe to adjust

the water depth, and consequently water volume, so that clam densities are approximately 23,000 m^{-2}. Continuously-flowing seawater, filtered through a 50 µm bag filter, enters the tray at about 1 L min^{-1} for early post-set clams. This volume is increased to 8 to 12 L min^{-1} as the clam biomass increases. The depth is kept relatively shallow to insure good distribution of food. An appropriately-sized sieve is placed below the outlet to catch smaller clams that might occasionally wash away. These can be rinsed back into the tray. The 50 µm bag filters reduce silt, detritus, fouling, and the number of competitors and predators that enter the trays. However, filters become impractical at higher flow rates and are eliminated when the clams reach 1 to 2 mm in length (Castagna and Kraeuter, 1981).

Upflow water columns often replace trays in clam nurseries (Manzi et al., 1983). A column is usually constructed of large diameter PVC pipe fitted with a bottom cap, valve and inlet pipe. Water flows up the pipe to a slip coupling which holds a screen on which the clams are placed several centimeters deep. The water flows past the clams and out the top of the pipe. Bayes (1981) describes some shellfish-growing containers designed so that seawater flows upward through partially fluidized beds of clams and oysters.

Crowding, competition, disease, and fouling problems

Post-set clams held at high densities often suffer from competition and disease. Crowding and competition can slow the clams' growth because of the lack of food or poor distribution of food due to overgrazing by densely-packed clams. When a reduction in growth rate indicates overcrowding, the number of clams per container is reduced or the flow rate of seawater per unit of clams is increased. The situation can also be ameliorated by separating the clams by size using sieves, then segregating the sizes at more suitable densities (i.e. smaller clams at higher densities, larger clams at lower densities).

Bacterial infections often spread among post-set clams, especially if they are held in crowded conditions. Daily inspections are made to identify this problem and steps taken to reduce losses due to disease. A high percentage of gaping clams, empty shells, or the appearance of spots of black mud among the clams are indications of disease (Castagna and Kraeuter, 1981).

Clams with bacterial infections are treated with antibiotics or sodium hipochlorite. The seed clams are collected on a sieve and immersed for one hour in 10 L of seawater in which a dose of 200,000 units of penicillin G and 0.25 g of dihydrostreptomycin or the equivalent has been added. The clams are then rinsed and returned to clean tables or containers. A solution of 0.5 ml sodium hypochlorite L^{-1} of seawater can also be used following the same procedure; however, sodium hypochlorite cannot be used on very young post-set clams (Castagna and Kraeuter, 1981).

Fouling often becomes a problem when clams are held in flowing seawater. Sea squirts, mussels, marine worms, etc. can reduce the growth rate and survival of post-set clams by competing for food, space, and oxygen. Some fouling organisms smother clams by attaching to them or entangling them in tentacles or byssal threads. They also cause increased deposition which sometimes inhibits growth and can cause smothering (Castagna and Kraeuter, 1981).

Fouling is reduced by using bag filters or by draining and air-drying for one hour daily. This treatment is quite effective for young post-set clams. After the clams have reached 1 mm in size,

fouling is controlled by draining the clam troughs about once each 7 to 10 days and flooding the container with fresh tap water.The freshwater is allowed to remain standing for 1/2 hour. Flowing seawater can then be continued with no further treatment for the next 7 to 10 days. Early stages of most fouling organisms (less than 10 days old) cannot survive freshwater immersion and the clams show no ill effects from the treatment (Castagna and Kraeuter, 1981).

The length of time the clams spend in the nursery is dependent on a number of factors such as the size seed needed for planting or growth rate. Most clams remain in the nursery about 5 months (June to October). If clams have been placed in submerged trays and are not overcrowded, they can be left for about a year before being moved to the final grow-out phase.

Culturists often take meticulous care of the clams in the larval-hatchery phase, and then greatly reduce the amount of vigilance and care in the nursery phase. This can have disastrous results. It is common to find mortalities of over 90% in the first 10 days after settlement. Needless to say, a successful clam farm must reduce these mortalities in order to ensure adequate seed production and to improve profits.

Field grow-out

Space and food requirements increase geometrically as clam size increases. As clams grow larger, it becomes less economical to grow them in containers or to pump sufficient quantities of seawater to furnish enough food for growth or survival; therefore, the clams are planted in natural waters. They can be distributed in prepared beds, trays or floats at densities of 250 to 2000 m^{-2}, depending on the area. Overcrowding can cause the clams to grow slowly, becoming blunt edged or stunted. Densities are decreased if this occurs.

A number of investigators have found that smaller size clam seed experience higher predation and lower survival than larger size seed (Godwin, 1968; Carr, 1976; Kraeuter and Castagna, 1977; Eldridge, 1978; Eldridgde et al., 1979; Karney, 1980). It is necessary to use seed that is large enough to ensure an adequate survival rate in order to make the operation profitable. Kraeuter and Castagna (1977) found that 8 mm shell height or larger seed was required for high survival rates when planted in aggregate and net protected natural areas in Virginia. Smaller sized seed (4 to 6 mm shell height) planted in trays or screened containers often do as well.

This pilot clam project has demonstrated the success of seed planting in natural bottoms. Clams are protected with a cover of crushed stone aggregate (2 cm average size) 3-4 cm deep and 7 or 12 mm mesh light density Conwed netting loosely stretched over the aggregate. Plantings of 8 mm height seed have over 70% survival to market size (Kraeuter and Castagna, 1977; Castagna and Kraeuter, 1981).

Clams with shell lengths in excess of 2 mm are often grown in wood boxes of 2.44 x 1.22 x 0.15 m dimensions with 1.5 mm mesh screen tops and bottoms, similar to the trays described by Karney (1980). These boxes have 0.15 m legs to hold them off the bottom which helps ensure good circulation. The boxes are weighted and submerged in sheltered natural areas, held in place by anchors or tied to mooring poles driven into the substrate. Although the expense of pumping seawater can be eliminated by this method, the manpower required to clean and tend boxes of clams are increased. Fouling problems can be reduced by painting the trays with copper antifouling paint or periodically air drying the trays. Tributyl tin fluoride (TBTF)

antifouling paint proved to be lethal to clams when used on trays.

The total length of time to grow hard clams from egg to marketable littleneck size is about 28 to 30 months in Virginia.

CONCLUSIONS

A pilot scale clam culture experiment at the Virginia Institute of Marine Science has established the effectiveness of a three-phase clam farming operation. The hatchery phase is relatively dependable and economical using existing technology. The most difficult and costly step in culturing clams appears to be the nursery phase where seed clams are grown to a size large enough to be successfully reared to market size in the field. Diligent prevention of disease and fouling is necessary in the nursery phase, while effective predator exclusion is necessary in the field grow-out phase.

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