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Hatchery Culture of the Bay Scallop

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Introduction

Given the recent decline of harvestable wild bay scallop stocks, there has been an increasing interest in the use of hatchery-reared individuals for restoration and restocking efforts. Further, the scarcity of wild stocks has increased the commercial value of bay scallops and stimulated private growers' interest in culturing them to market size. To address that interest, this document provides a short summary of the hatchery methods for culturing the bay scallop *Argopecten irradians*.

Bay scallop culture techniques were first developed by turn of the century biologists, like David Belding in Massachusetts. This was later followed by the work of Michael Castagna and co-workers at the Virginia Institute of Marine Science in the 1970's and more recent work by Widman *et. al*. at the NMFS Milford Laboratory in Connecticut. Those methods have been primarily geared towards scallop restoration efforts.

The actual process of growing bay scallops for restoration or market involves three basic stages: hatchery, nursery, and grow-out. No two culture systems are alike. Methods are dependent on both the site and the resources available to the culturist. This fact sheet will address the hatchery phase of the bay scallop rearing process.

Facilities and Siting

When choosing the location for a hatchery, the most important factors to consider are proximity and quality of the seawater supply (Figure 1). For the bay scallop, the water requirements include minimal risk of contaminants, both anthropogenic (e.g. petroleum hydrocarbons) and natural (noxious algae), a salinity between 25 to 33 ppt and low turbidity.

Figure 1. Martha's Vineyard Solar Shellfish Hatchery sits on the shores of Lagoon pond

Other important parameters can be controlled in the hatchery, including water temperature, water flow rate, oxygen content etc.

Producing and sustaining shellfish in a hatchery requires integrating multiple systems into a single functional unit. These systems include water and aeration delivery, algae production, broodstock conditioning and spawning, larval rearing, setting systems, and a laboratory space equipped with a microscope for counting, monitoring and data collection.

The seawater supply is usually pumped from an open water source and requires filtering, aerating and heating. Seawater wells are also used and have the advantage of providing naturally filtered water.

Seawater pumps and piping are usually designed as dual systems to provide back-up in case of failure but also to control fouling by alternating lines every two to three weeks. While the spare line is shut off, it goes anaerobic and the fouling organisms die inside the pipe. When the line is turned back on, the dead organisms are flushed out effectively cleaning the system.

Upon entering the hatchery, seawater is sometimes passed through a settling tank to precipitate large particles and silt. The water is then filtered by means of sand or cloth filters (Figure 2).

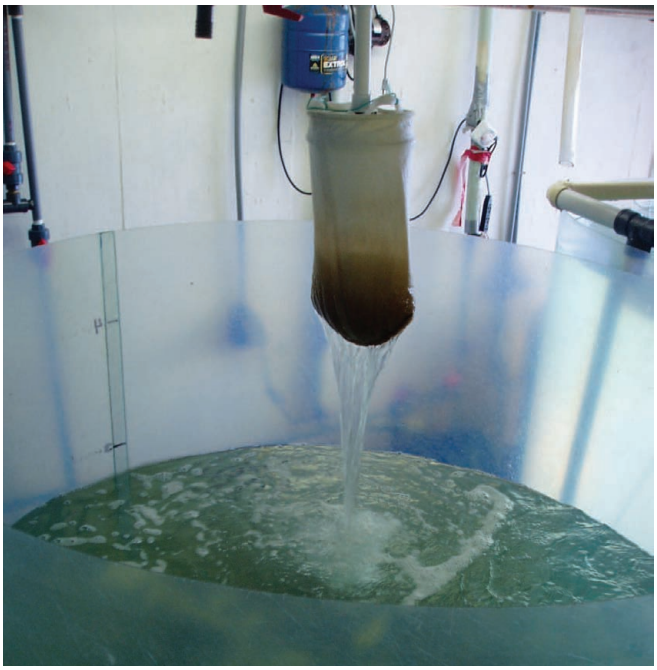

Figure 2. Culture water is filtered through a bag filter.

Depending on the developmental stage of the scallops, different levels of filtration are needed. The smaller the scallops, the finer the filtration should be.

Cleaning protocols are essential in all aspects of scallop hatchery rearing. Tanks and equipment in contact with seawater are exposed to silt, fouling organisms, bacteria, viruses, extraneous larvae and need to be scrubbed with detergent, and chlorine or iodine disinfectant. Stubborn dirt, mineral deposits and stains can be removed with acid washings.

Food

Food production is a time-consuming yet essential aspect of a hatchery operation. To lower production costs, scallops should only be fed cultured phytoplankton when absolutely necessary. The culturist should wean post set juveniles off cultured food and onto natural food in flow-through seawater systems as soon as possible.

In general, microalgae are grown in clean, approaching sterile, conditions (Figure 3). Phytoplankton culture requires a constant source of light, filtered seawater (to 1 mm) enriched with nutrients, and aeration for mixing and gas exchange. Small volumes of phytoplankton are usually cultured under fluorescent lights. Larger volumes are grown in aerated clear fiberglass columns or in mechanically mixed shallow tanks that allow maximum light penetration. Energy savings can be realized by culturing algae in natural sunlight in a greenhouse or outdoors.

The specifics of growing microalgae are detailed in NRAC Fact Sheet No. 160: Growing microalgae to feed bivalve larvae.

Figure 3. Culture of microalgal feed.

Broodstock selection and conditioning

Unlike most bivalves, bay scallops can open their valves wide enough to allow visual grading of the gonad without sacrificing the animal. As the gonad matures, it increases in volume dramatically and loses its black coloration to reveal a bright orange ovary and cream colored testes (Figure 4). After the first spawn, hollow "channels" appear on the surface of the gonad while its volume starts to decrease. A bay scallop will typically spawn several times during the season until its gonad is spent and appears dull, sunken and flaccid.

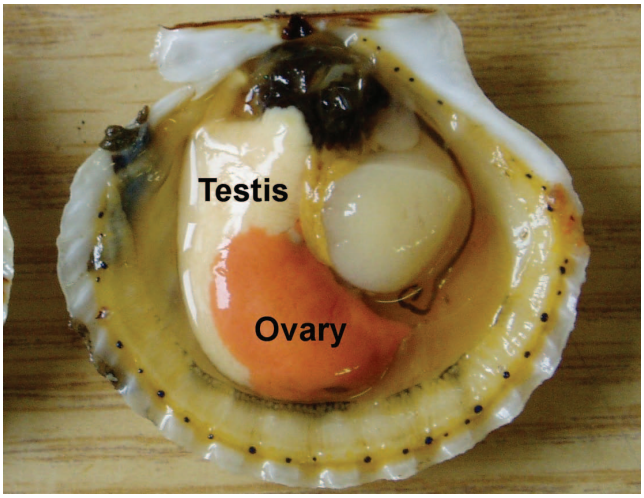

Figure 4. The ripe gonad reveals a bright orange ovary and cream colored testes.

If the operator intends to spawn during the natural spawning cycle of the local population, broodstock can be collected from the wild on the day of the spawn. If not, bay scallops must be artificially ripened through the manipulation of temperature, food, and light.

When selecting broodstock, the culturist should look for well-formed shells with complete mantles extending to the shell margin, plump healthy-looking soft tissue, and solid intact hinges (Figure 5). Larger scallops produce more eggs, so a good size to aim for is a valve height of 50-60 mm.

Broodstock should be scraped and brushed carefully prior to placing in the conditioning system. Care should be taken not to damage the hinge ligament during cleaning.

The overall strategy for conditioning is to raise the ambient water temperature 1°C/day until the target

Figure 5. Broodstock should have well formed shells with complete mantles extending to the shell margin.

temperature is achieved. Some recent research recommends exposing the broodstock to increasing amounts of light to mimic the photoperiod of longer summer days. As the temperature rises and scallops become more active, the rate of feeding should also be increased to keep up with the scallops increasing demand. Generally, feeding is gauged according to the clearance rate of the broodstock and ranges from 1-2 L of concentrated algal culture/scallop/day.

The broodstock should be fed a mixture of algal species. Adult bay scallops prefer larger species such as *Thalassiosira pseudonana* (3-H) or *T. weissflogii,* and *Tetraselmis* sp. Bay scallop gonad development starts at an ambient temperature of 6.6 to 7.8°C. Optimal temperature varies with the geographic source of the individuals, and ranges from 17 to 20°C in the Northeast. The broodstock should be held at the optimal temperature and feeding rate for 4 to 6 weeks until the gonad becomes mature and spawning can be induced.

The conditioning system can either be a static holding system (Figure 6) or a flow-through system, with a salinity greater than 25 ppt, oxygen levels greater than 4 mg/l, a pH between 7.7 and 8.1, and total ammonia nitrogen levels lower than 0.15 mg/l. To achieve these conditions in a static system, water needs to be aerated and changed at least every other day, using preheated water filtered to 5 µm.

When the broodstock is ripe, temperature should be maintained within 1°C of the target temperature as fluctuations of 2 to 3°C could result in accidental spawns.

Figure 6. Broodstock static setup.

Spawning

The preferred method to induce spawning in the hatchery is temperature shock. Other methods reported include adding hydrogen peroxide to the water (3 ml/l seawater of 6% hydrogen peroxide) or injecting the gonad with serotonin (0.4 ml of 3 mM serotonin).

Spawning can take place in individual dishes or in a community tank (mass spawning). Individual dishes present the advantage of allowing the hatchery manager to control the timing and specific crossings of gametes during spawning (Figure 7).

Spawning efforts begin by letting the broodstock acclimate to their new environment for 30 to 60 minutes at the ambient temperature to which they have been accustomed, normally 17-20ºC. Water temperature should then be raised slowly to 26-30ºC over a 20-minute interval. The temperature should not exceed 30ºC. After about an hour, the water is dropped to ambient temperature (17-20ºC) and held for approximately one hour. This process is repeated as often as necessary to stimulate spawning.

The hermaphroditic bay scallop usually releases sperm first before switching to eggs. When ripe, scallops usually spawn quite readily. Sperm is a very powerful stimulus. As soon as the first scallops releases sperm, it should be passed around to stimulate the rest of the scallops. If however, spawning does not start within four or five temperature cycles, sperm can be stripped from a sacrificed adult by repeatedly cutting the male testes (the white area) and collecting the milky fluid released from the damaged tissue. This stripped sperm can be used to stimulate spawning. Unlike clams and oysters, gametes stripped from bay scallops will not result in fertilization. Production of viable embryos requires the natural passage of the gametes through the ducts of the gonad.

Bay scallops can switch back and forth several times between releasing sperm and eggs during a single spawning event. If the scallops are held in individual dishes, they must be watched closely and the sperm removed often (5 to 15 min) to avoid self-fertilization.

An adult bay scallop can release 500,000 to 1,000,000 eggs in one spawning event (Figure 8). To ensure good genetic mixing, broodstock should not be smaller than 40 to 50 individuals as often only 50% of the scallops will spawn during the attempt.

Eggs and sperm should be collected in separate buckets through a catch sieve to remove larger debris.

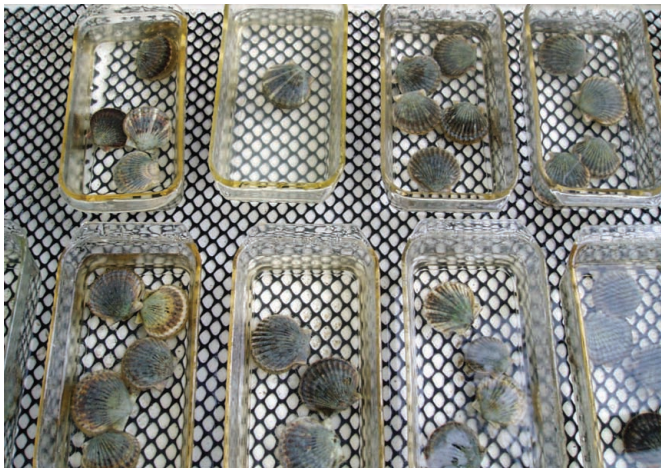

Figure 7. Broodstock in individual spawning dishes.

Figure 8. Bay scallop releasing eggs.

Bay scallop eggs are less hardy than other bivalves' and should be fertilized within the hour following spawning. No more than 5 mls of collected sperm should be added to each liter of egg suspension. Bay scallop eggs do not have the ability to block secondary spermatozoa after they have already been fertilized. Excess sperm will result in polyspermy, leading to low survival and high deformities.

An aliquot of eggs should be observed and counted under the microscope 20 to 30 minutes following fertilization. If less than 80% of the eggs show signs of development such as the extrusion of polar bodies or cell division, another small aliquot of sperm should be added.

Mass spawning is a much simpler process. Generally the ripe broodstock are placed in lantern or pearl nets and suspended in a larval conical filled with filtered seawater heated to 25^{O}C. The scallops are allowed to spawn until a target density of 30 eggs/ml is reached. The fertile eggs are left in the larval tank for 48 hours before the first drain-down.

Although mass spawning is easier, the operator has to relinquish control over fertilization timing, the cross of specific individuals and sperm concentration. Mass spawning therefore runs the risk of high polyspermy and low survival.

Larval Rearing

Because scallops are most fragile during their larval stage it is especially important to optimize larval culture conditions. Healthy, well-fed parents, high water quality, suitable temperature and diet will provide the best opportunity for bay scallop larvae to survive, develop, grow and metamorphose. In optimal conditions, bay scallops will develop from egg to post-set in 10 to 14 days.

Generally, scallop larvae are grown under static conditions. The larval tanks are drained completely every other day, washed thoroughly and refilled with clean, heated filtered seawater.

Bay scallops have been reared in tanks ranging from 50 gallon trash cans to 40,000 gallon tanks. Larval tanks should be smooth and light-colored on the inside to facilitate cleaning. The bottom should be sloped towards a center drain large enough to allow the tank to empty in 30-45 minutes (Figure 9). The tanks should be loosely covered. Covers may be insulated if the air temperature is significantly different from the target water temperature. Although flow-through technology has been developed, it is not commonly used in U.S. hatcheries at this time.

Figure 9. 400 L larval conical tank.

Temperature: Larval bay scallops are more sensitive to temperature than other bivalve larvae. The rearing temperature should range from 19^{O}C to 28^{O}C with an optimal temperature of 25^{O}C. Larvae will develop faster in the higher end of the range although the operator should keep in mind that warmer temperature also increases the risk of bacterial swarming and infection. As the scallop larvae develop, their thermal sensitivity decreases.

Other water requirements: Optimum salinity ranges between 25-28 ppt. Water should be filtered to 5 μm by means of sand cartridge or cloth bag. Some sources suggest treating the water with UV radiation to reduce bacterial loads. This technique, rather than increasing larval health, has been shown to encourage sudden recolonization by opportunistic harmful microbial species. Other water treatments suggested to improve larval survival include supplementing the culture water with vitamins B_1 and B_{12}, or EDTA (3-6 ppm) if heavy metals levels are suspected to be high in the source water.

Although dissolved oxygen rarely drops below the 5 ppm survival threshold when larvae are held at the recommended density, the tanks should still be aerated to maintain oxygen transfer, prevent thermal stratification and keep live food and larvae from concentrating on the bottom of the tank. Low-level illumination (400-700 lux) may also be advantageous to scallop larval culture.

Figure 10. Draining larvae into a "catch" sieve

Every 48 hours, larval tanks should be drained onto a sieve with sufficiently small mesh to capture all of the larvae in the population (Figure 10 & Table 1). The sieve is often placed in a shallow tray to ensure that the larvae do not dry out and impinge on the mesh. When the valve to the larval tank drain is first open, the initial blast of water should be discarded as it contains dead larvae and other debris settled into the drain pipe. Feces, dead larvae and bacteria are also deposited on the bottom surface of the tank and should not be disturbed while the tank drains to avoid contaminating the culture. After the tank has fully drained and the larvae are resuspended in a bucket of clean seawater, the bottom deposits can be collected separately and inspected under the microscope to provide some indication of mortality and disease.

Before introducing fertilized eggs or larvae back into a clean larval tank, they should be passed through a stack of two or more sieves. The top mesh should be large enough to let the eggs or larvae go though while it catches larger debris. The bottom mesh should be small enough to retain the eggs or larvae while small debris and soluble contaminants are rinsed away (Table 1).

Table 1: Sieve mesh size needed to retain specific larval sizes/stages (modified from Widman *et al.* 2001)

Larval Size	Stage	Estimated Age	Mesh Size for Retention
50 µm	fertilized egg	0 hours	35 micron
100 µm	D-stage	48 hours	50 micron
125 µm	D-stage	4 days	75 micron
150 µm	umboned	6 days	100 micron
175 µm	pediveliger	10 days	135 micron

Beyond a "catch sieve" and a "rinse sieve," developing larvae should also be passed through grading sieves at each drain down to allow the culturist to separate the different size classes. Growing these classes separately will ensure better overall growth. Grading also allows the culling of slow growing larvae in the event that the numbers are more than sufficient.

Scallops larvae grow 7 to 23 µm per day depending on rearing conditions and overall health. Optimal stocking density starts at 30/ml for fertilized eggs and drops as the larvae develop to 5/ml by the time pediveligers are ready to set (Table 2).

Table 2: Recommended stocking density for various larval stages in static culture systems (modified from Widman *et al.* 2001).

Larval Size (#/ml)	Stage	Approximate Age	Stocking Density
50 µm	fertilized egg	0 hours	30
100 µm	D-stage	48 hours	20
150 µm	umboned	6 days	10
175 µm	pediveliger	10 days	5

Cleanliness is especially important at the larval stage due the susceptibility of larvae to infection and the fact that static cultures provide better conditions for bacteria proliferation than flow through systems. The primary cause of larval die-offs in shellfish hatcheries is opportunistic bacteria (e.g. *Vibrio* sp.). Washing and disinfecting all materials used reduces the threat of these potential pathogens.

Cultured phytoplankton must be added between 24 and 48 hours after fertilization when the larvae develop velums and begin to filter the water for food. Prior to that, they depend on food stored in the egg cell. Because of their small size, early bay scallop larvae (D-stage veligers, Figure 11) are limited to feeding on small-celled (5 to 6 µm) algae including the naked flagellates (*Isochrysis* sp. (T-ISO and C-ISO) and *Pavlova* sp. (MONO, CCMP609, and CCMP459).

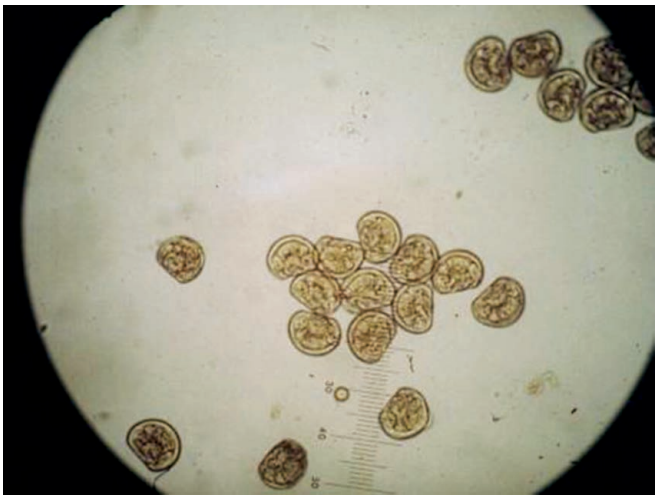

Figure 11. D-Stage or straight hinge veligers.

As the larvae grow, larger unicellular algal species are gradually added to their diet. These species include 7 µm *Chaetoceros calcitrans* (CHAET), 9 µm *Tetraselmis striata* (Plat-P) and 12 µm *Tetraselmis chuii* (PLY429). Different algal strains hold different nutritional value. Some like *Tetraselmis* are high in lipids whereas others like *Chaetoceros* are high in proteins (Figure 12). Feeding a mix of algal cultures will ensure a complete diet and enhance growth.

Bay scallop larvae should be fed an adequate amount daily. Underfeeding the larval culture will result in stunted growth while overfeeding will encourage bacterial proliferation. Recommended daily feeding rates appear to be consistent between hatcheries at 25-50,000 cells/ml for early larvae and 50-100,000 cells/ml for older larvae.

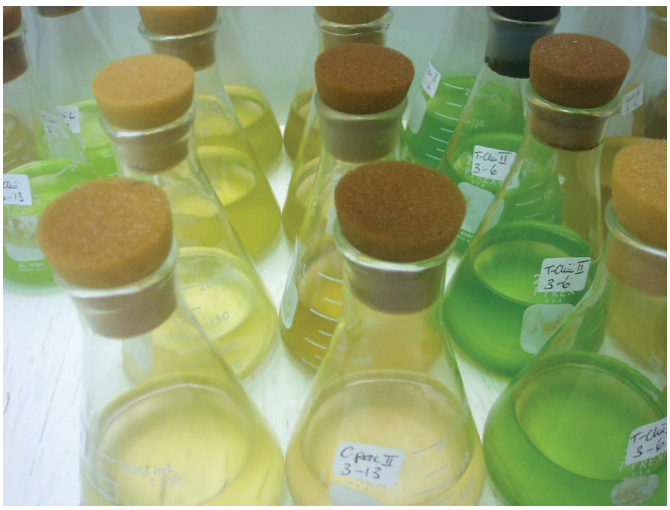

Figure 12. Stock cultures of *Chaetoceros* and *Tetraselmis chuii.*

Monitoring

Larval cultures should be observed and monitored daily. Healthy early larvae tend to swim in the upper and middle section of the tank while later veligers swim lower in the water column. It is advisable to regularly inspect a larval sample under the microscope (Figure 13). Healthy, well-fed scallop larvae are a deep gold or tan color. Their stomach, round and full of algal cells, should be easy to spot.

When first put on the microscope slide, the larvae may be retracted in their shells but soon fully extend their velum and resume swimming in a circular or helical pattern. Erratic, fast-paced, tight circling swimming and/or flip-flopping are indicative of deformed or diseased larvae. The velum's cilia are highly susceptible to bacterial or other noxious environmental conditions and the loss of proper ciliary function is lethal to the larvae. If the larval culture appears compromised and there are a large percentage of sick and dead, it is best to destroy it, and begin anew.

Recordkeeping

Like anywhere else, good recordkeeping in a shellfish hatchery is essential for efficient management. Records should include larval counts generated with every drain-down, larval size (measured with an ocular micrometer), daily feeding rates and microalgal species fed, and any observation or information that will help streamline hatchery performance.

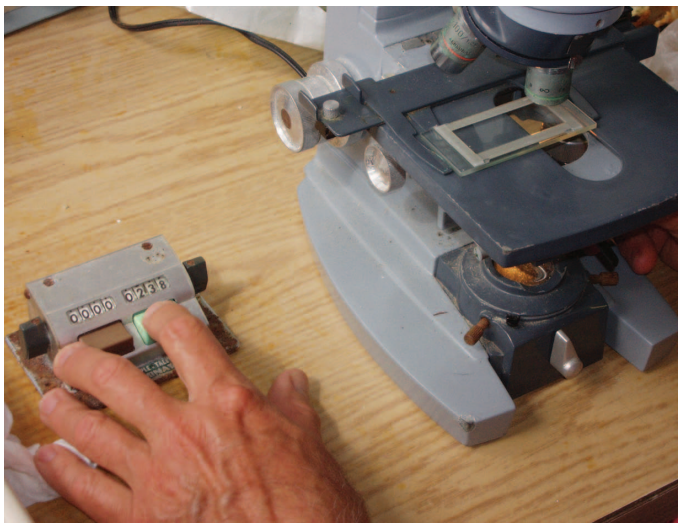

Figure 13. Counting larvae on a Sedgwick-Rafter cell.

Setting

Metamorphosis is a critical time when the scallop transitions from a free-swimming pediveliger larva to a byssally-attached epibenthic juvenile. This transition coincides with a series of profound anatomical and physiological changes and a complete rearrangement of the internal organs and muscles. The most critical of these changes is the loss of the velum soon replaced by the gills, which will take on the tasks of feeding and respiration (Figure 14).

Figure 14. The gills take on the tasks of feeding and respiration.

During this 1 to 2 day transition, the larva stops feeding and has to rely solely on its energy reserves to carry it through. If those reserves are insufficient, the scallop will not survive. It is therefore critical that the larvae be adequately fed prior to metamorphosis. It is possible to assess the energy reserves of larval bivalves through the application of an Oil Red O stain that labels lipids. This method allows the manager to predict the population's potential to survive the transition to post-set juveniles. Food rations need to be reduced during the transition. Uneaten food can lead to a build up in organics that will stimulate bacteria populations at a highly vulnerable time for the scallop.

Other anatomical changes observed at metamorphosis include the appearance of an eyespot, the thickening of the shell margin and the emergence of a foot used for crawling while the scallop searches for appropriate substrate. Under optimal conditions, scallops become competent to metamorphose within 10 to 19 days of fertilization at a size of 175 to 200 μm. Competent larvae will only transition if the temperature is between 13ºC and 32º C and the salinity between 11.7 and 35 ppt. The optimal conditions for setting are a temperature of 25°C and a salinity of 25 ppt.

Bay scallop larvae can be set in "spat collectors" or "downweller" systems.

The spat collector method uses the scallop's affinity to settle on three dimensional structures. Material like rope fibers, burlap, discarded monofilament gill net or polyethylene mesh (Netron®) is clumped together and stuffed into a mesh bag with a pursed closure (Figure 15). The bags are hung in a clean larval tank filled with filtered heated seawater. Competent larvae are then introduced into the tank, fed and allowed to set on the collectors. During the following weeks, the tank should undergo only partial drain downs to prevent any early post-set juveniles from drying out and detaching.

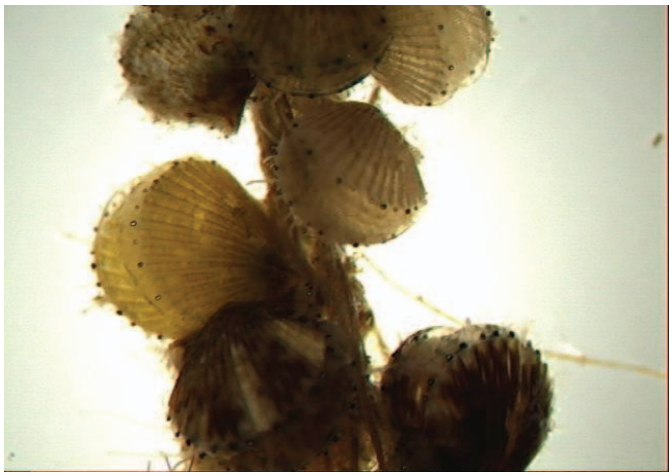

Figure 15. Post sets attached to rope fiber.

Until the setting process is completed, the tank water should be drained onto a sieve to catch any swimming larvae or detached spat. The spat bags are not removed from the culture tanks until the scallops are large enough to remain within the mesh of the bag. At that time the spat bags can be transferred to open water for field nursery culture or kept in the closed system tanks until the scallops reach 2-3 mm and are large enough to handle in other nursery systems.

The downweller method uses large open cylinders with 115-130 μm mesh bottoms similar to the sieves (or "silos") used for trapping larvae during drain-downs (Figure 16). The sieves are immersed about two-thirds of the way in setting tanks to which cultured microalgae is added. Airlifts or electric submersible pumps recirculate water flow from top to bottom in a downwelling movement through the mesh.

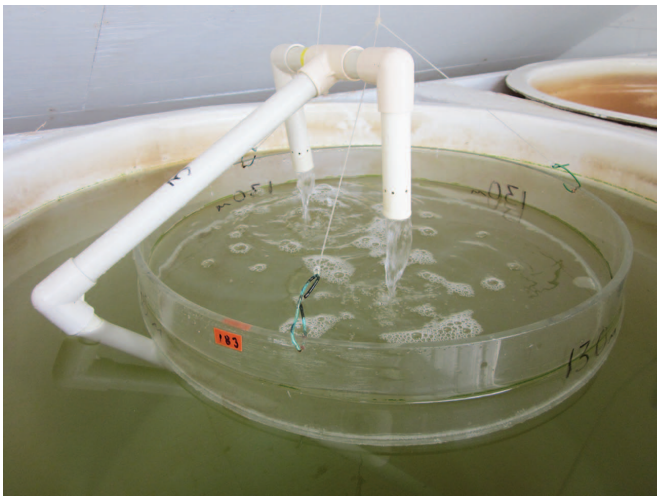

Figure 16. Downweller sieve suspended in a larval tank at drain down.

Figure 17. Downweller sieves with set scallops can be rinsed daily.

This method presents a number of advantages. The setting larvae and eventual spat can be held at higher densities than in the spat bags because of the greater water flow provided by active pumping. Up to a million larvae can be set on an 18 inch diameter downweller sieve. Because the sieves are equipped with a mesh bottom, the uneaten food and feces are flushed through leaving the immediate surroundings of the larvae or post set relatively clean. Further, the sieves holding the scallops can easily be removed from the culture system and rinsed daily, which promotes cleanliness and increased survival (Figure 16).

During the rinsing process, the post-set scallops may break their byssal attachments, and be rinsed out of the downweller sieves for sizing and thinning. Intermittently air drying and rinsing over a period of about half an hour should result in the successful removal of most of the scallops. Note that post-set scallops are very fragile and should not be left to dry for more than 5 minutes at a time.

Any scallops that remain can be gently wiped from the mesh with a paintbrush under a flow of seawater. After sizing, the larger post sets should be transferred to larger mesh silos. Once they are introduced back into the tank, the post sets will readily reattach to the silo's bottom and walls. About once a week, the setting tanks should be drained, cleaned and refilled with clean seawater.

The post-set juveniles can be cultured in the downwelling system until they achieve a 1 mm valve size, when they can be moved into a nursery system (see the NRAC fact sheet "Nursery Culture of the Bay Scallop").

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