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## Grow-out Culture of the Bay Scallop

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The rapid growth rate, high market value, and declining wild stocks of the bay scallop *Argopecten irradians* easily explain private growers' rising interest to culture the species to market size (Figure 1).



Figure 1. The highly-priced bay scallop, *Argopecten irradians*.

Attempts at private aquaculture enterprises resulted in few success stories until 1983, when twenty-six scallops survived a shipment to China and were spawned successfully. From this humble beginning, Chinese bay

scallop aquaculture yielded 300,000 metric tons of product in 1998, grown on 7,000 hectares of embayment. The Chinese bay scallop has since been readily available in U.S. markets at a much lower price than the wild domestic product (Figure 2). In the U.S., the first and only successful bay scallop culture enterprise is run by Taylor Seafood of Fairhaven, Massachusetts.

The limited success of scallop aquaculture in the US has been attributed to high labor costs and winter mortalities associated with the "grow-out" phase of the culture cycle. Once the bay scallop has achieved a juvenile



Figure 2. The Chinese cultured bay scallop is available in U.S. markets.

size of 5 to 10 mm within the nursery system, it needs to be reared in the field to a size that is sufficient for marketing.

While the information in this document summarizes successful grow-out strategies, it is important to note that no two culture systems are alike. Grow-out methods are dependent on both the site and the resources available to the culturist. Readers are encouraged to use the current information as a starting point but not be afraid to experiment to identify a system that is best suited for their site and conditions.

## Siting

Two criteria are important in terms of farm siting: food concentration and flow regime. The combination of the two factors determines the amount of food being supplied to the growing scallop. Current flow can be too slow, thus not providing enough food particles to the dense population of scallops in a culture device, or it can be too quick resulting in the inability of the scallop to filter the particles from the surrounding waters.

Scallops will feed at an optimum rate in a flow of 1 to 5cm/s. Keep in mind that any structure surrounding the scallop will interfere with the flow. Depending on the containment device, higher overall current speeds may be necessary to achieve optimal food flux within the device. As submerged gear becomes fouled, the food flux is reduced leading to suboptimal growth. Unfortunately for the scallop farmer, the more productive the water, the more abundant will the fouling organisms be (Figure 3). What advantages are gained in increased



Figure 3. Biofouled gear will limit food flow.

scallop growth may be countered by the need for increased labor to control fouling.

Field site selection criteria vary according to the growout technology being employed. If the scallops are being held in a suspended system then water depth should be 10 meters or more. Also, the overall site needs to be in an area protected from high-energy storm events. If the scallops are planted on the bottom or placed in bottom cages, then the substrate should be muddy-sand to sand with little risk of particulate resuspension or transport. Also if the culture period extends into the winter months, the equipment and site need to be selected with ice management in mind.

The grow-out of bay scallops can be achieved with a variety of techniques. These include bottom ranching, suspended nets (pearl, pocket, and lantern), ear hanging, or cages (bottom or floating). Recent work has also investigated gluing scallops to material suspended in the water column. A brief description of each of these techniques are presented below.

Prior to any bay scallop culture activity, all local, state and federal permits must be in place. Depending on state or local regulations, these permits may include a license to hold sub-legal sized scallops, a permit for placement of physical structures in the navigable waters, and allowance for the sale of scallops outside of the normal wild harvest season or at a sub-legal size.

## Bottom Ranching

The unprotected release of juvenile scallops onto the bottom is a common strategy for rearing scallops and is primarily used for restoration and enhancement programs (Figure 4 and 5).



Figure 4. Scallop seed ready for planting.





Figure 5. Scallop growing in eelgrass on the bottom.

The success of this method of growout is dependent on the overall size of the released juveniles and the suite of predators found in the release area. The objective is to nursery rear the juvenile scallops beyond the size threshold for direct predation. It is generally thought that juvenile scallops greater than 35 mm are large enough to minimize predation risk. Holding juveniles until 40-50 mm provides even more protection.

When free planting on the bottom, target planting densities should be in the range of 5-10 individuals/m<sup>2</sup>. Higher levels can lead to food limitations and reduced growth. Other impacts of high planting density are lower muscle weight and reduced egg production. Also remember that if scallops are stocked at densities that are too high, their swimming activity will increase and they will distribute themselves over a wider area.

## Suspended Culture

Culturing scallops in hanging devices is a common technology adopted from Asia. The primary apparatus used are lantern nets with mesh sizes of 15 and 21 mm (Figure 6). Lantern nets commonly have 5, 10, or 15 tiers.

They are generally suspended from a floating or submerged longline that is anchored at both ends and held at or below the surface by floats placed along the backbone. As the scallops grow and the gear becomes fouled the longlines become heavier and farmers need to maintain buoyancy through the addition of extra floats. Lantern nets can also be suspended from floating rafts that offer both flotation and a working platform to maintain the gear.

An important consideration when suspending scallop culture gear is the depth of deployment. The nets



Figure 6. Clean lantern net with seed ready for deployment.

need to be hung below the critical level of light penetration to reduce the amount of algal biofouling but need to be well above the sea floor at the lowest tides so that bottom dwelling predators cannot gain access to the nets. Generally, two meters below the surface is considered appropriate although higher depths are recommended when the site allows it.

Of equal importance is the net's stocking density. If the density is too high, the scallops will continually contact each other inflicting damage and disrupting feeding. Bay scallops will also compete with each other for food resulting in a drop in the growth rate.

Scallop size dictates stocking density and is based on the surface area of the gear, keeping in mind that scallops primarily rest on the bottom of the containment device. If the scallop is greater than 28mm valve width, the stock density should be maintained at approximately 25/ft<sup>2</sup> (833/m<sup>2</sup>). When less than 28mm, stocking density can be increased to up to 100/ft<sup>2</sup> (3,332/m<sup>2</sup>). When overwintering where low water temperature reduces scallop activity, stocking density can be increased to a maximum of 133/ft<sup>2</sup>.

Bay scallops can also be grown in pocket nets, a rectangular sheet of mesh hung vertically in the water column with pockets of mesh stitched on one side. Each level holds 2 to 4 pockets stitched on three sides and open at the top. The pocket is designed to allow the scallop to open its valves wide enough for feeding and respiration but not wide enough to swim up and out of the pocket. The pocket net is especially interesting in high-energy environment as it prevents the scallops from damaging each other with repetitive contact.

The more structure immersed in the water to contain the scallop, the more surface area is available for fouling organisms to colonize. To reduce labor costs associated with fouling, two suspended culture strategies have been developed with reduced surface area.

The first is known as ear-hanging and consists of suspending scallops directly from a rope by drilling a small hole in the ear or wing and stringing a thread between the hole and the backbone rope. Ear-hanging works well with larger scallop species but has been unsuccessful for bay scallops. Due to the small size of the ear, the underlying mantle is often damaged during drilling resulting in the ear being deformed and/or reduced in size and the integrity of the ear compromised. Scallops are lost when they grow and the shell supporting the scallop fails.

To counter this, recent experiments have been undertaken to glue bay scallops to a sheet of mesh and suspending it in the water column (Figure 7). Recent work has demonstrated that Prism 454® (Henkel Loctite, Rocky Hill, Connecticut) or Ceramcrete® holds promise for adhering live bay scallops to a plastic mesh material.

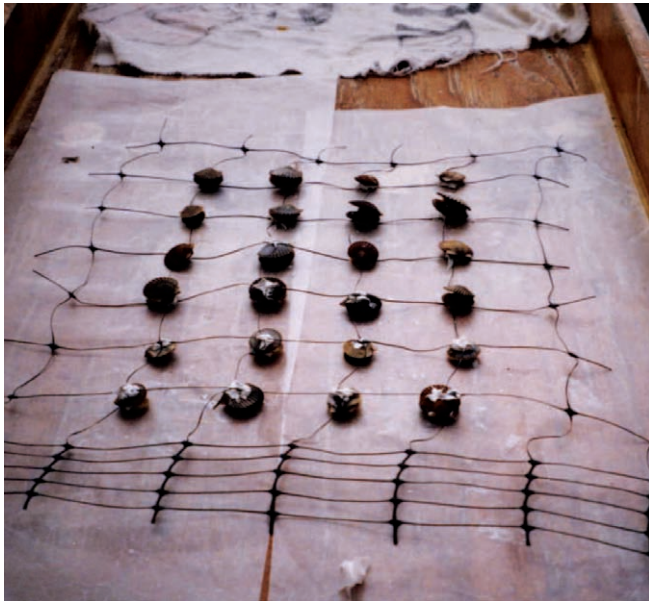


Figure 7. Adhering scallops to plastic mesh to reduce fouling.

## Cage Culture

Floating or bottom cages are routinely used to grow bay scallops to market size.

## Floating Cages

The original floating scallop cage was constructed as a wooden frame with plastic mesh covering the sides. The development of plastic coated wire led to the creation of a floating scallop cage that is reminiscent of the Taylor Float, commonly used for oyster gardening (Figure 8).



Figure 8. Scallop floating cage reminiscent of Taylor floats.

More recently, another oyster growout method has been adapted for scallop culture. This consists of a plastic mesh bag with two flotation “logs” arranged along the sides of the bag. The flotation logs range from children’s foam swim “noodles” to rigid plastic cylinders designed for this application (Figure 9).



Figure 9. ADPI bags equipped with floating noodles.



Growing scallops in floating devices is particularly interesting in temperate climates where the warmer and more productive surface water is well suited for scallops. In southern climates however, surface cages are not recommended as they may expose scallops to stressfully high water temperatures.

## Bottom Cages

Bottom cages are generally constructed from plastic coated wire and provide a rigid frame with a series of shelves holding semi-rigid polyethylene bags (Figure 10). Bottom cages allow the grower to construct a single structure with a fixed mesh size, generally 1 to 3” square mesh – with less surface available for biofouling, while still having the capacity to change the mesh size of the containment as the scallops grow.



Figure 10. Stainless steel bottom cage.

Bags come in a variety of sizes ranging from 5 to 25mm (3/16 to 1 in) and generally measure 90 x 50cm (36 x 20 inches) (Figure 11). Cages should be designed to optimize the number of scallops held, allow adequate water movement through the bags and elevate the bags off the bottom to prevent sediments from smothering the scallops.

Limitations to scallop grow-out cage size are governed primarily by the capabilities of the grower to handle the system, i.e. hoist them out of the water.

As noted for suspended nets, stocking density of cages, bags, floating trays or any flat-bottom grow-out system without internal structures should be gauged by the available surface area. A good rule of thumb is not to



Figure 11. ADPI bag holding scallops for growout.

cover more than 50% of the available bottom surface area with living scallops. Stocking densities of 25 up to 600/ft<sup>2</sup> are acceptable target densities for growout, depending on scallop valve size (Table 1).

**Table 1: Stocking rates for bay scallop grow-out based on 50% surface area coverage (from Leavitt & Karney 2005).**

Scallop size (mm)	Number per ft <sup>2</sup>	Number per m <sup>2</sup>
10	592	6,369
20	148	1,592
30	66	708
40	37	398
50	25	255

Because optimal stocking densities depend on local conditions, they should be established through trial and error for each grow out area.

## Husbandry

Because bay scallops are a fast growing organism, the most critical factor in maintaining a healthy population is to provide adequate food.

In terms of husbandry, this translates to controlling biofouling on the containment devices to ensure proper

food flux through the system. In addition to physically restricting water flux, most fouling organisms will compete with the scallop for food as they also filter feed from the water column. Therefore removing fouling organisms is a critical concern with bay scallop growout.

Most fouling control methods used in oyster culture, such as brine dips or pressure washing with the animals still in the bag or cage, are not acceptable for scallops due to their inability to close tightly to protect the soft tissue. Pressure washing can be used after removing the scallops from the fouled gear.

The method of choice is the use of redundant holding gear where the scallops are transferred from fouled gear to clean gear (Figure 12).



Figure 12. Transferring scallops into a clean lantern net.

During the warm months, this may be required on a biweekly or monthly basis. The fouled gear can then be returned to the shore and cleaned before cycling back into the growout system. Fouling can also be reduced by placing the growout gear in deeper waters to reduce sunlight exposure leading to reduced macroalgal growth.

A second concern when trying to maintain an optimal grow-out environment is overcrowding. Overcrowding can lead to competition for food resources and increased swimming activity causing physical injuries through “knifing” where the scallop shell of one scallop cuts the soft tissue of another. Bay scallops grow relatively fast and as they grow they will need to be thinned often to maintain the surface area coverage at the recommended 50% (Table 1, p.5).

## Growth and Survival

Average reported growth rates for bay scallops approach 0.25mm/d for small scallops held at 20°C and jumps to 0.37 mm/d at 24°C. Of course, this is dictated by the food availability and culture conditions and will vary from site to site. As bay scallops grow larger, the mortality risk decreases so that by the time the scallop reaches 15 to 20mm, mortality, under optimal conditions, should range between 5 and 10% per year. Of course, optimal conditions are hard to identify and even harder to achieve in an open environment often resulting in higher mortality rates.

One significant mortality risk, which has stalled scallop culture to market size in northern areas, is a phenomenon known as “over-wintering mortality”. This phenomenon is seen in the spring when scallops activity increases due to rising temperatures but food resources are not yet sufficient to allow the scallops to recover from the energy drain that occurs during the winter. Over-wintering mortality can claim up to 98% of a population, with an average of 40-60% mortality in Massachusetts. Several strategies have been developed to counter this significant mortality problem. These include:

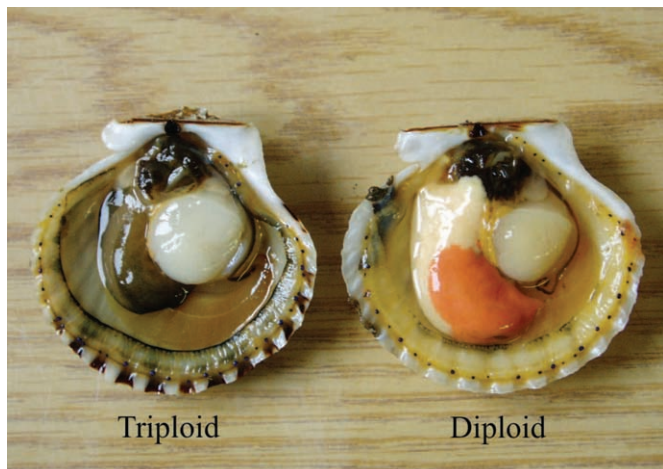
- Early conditioning and spawn of scallops in the hatchery allowing early post-set juveniles and grow-out to market size within one growing season,
- Selection or development of faster growing and more robust scallop strains,
- Over-wintering site selection to minimize stress and mortality.

Starting the scallop production early in the season has been a strategy of choice for northern bay scallop growers. However, since post-set scallops do not grow until the water temperature reaches 15°C, early deployment is still limited by seasonal temperatures and few scallops will grow to market size (45-50mm) within a 6-9 month grow-out season.

The development of domesticated scallop strains is in its early days and to date, little differences in growth and survival have been shown among selected strains. Triploid scallops, because of their enhanced growth rates, have also been considered as a way to grow scallops to market size in a single season. However, previous work has shown that their increased overall growth, muscle mass and general hardiness observed when compared to their diploid counterparts comes from redirecting the energy usually used for reproduction towards somatic growth. This increase in perform-



ance therefore only happens when they reach sexual maturity during the second growing season (Figure 13).



**Figure 13.** Sterile triploid (left) shows undeveloped gonad and a larger adductor muscle than its diploid counterpart (right).

Site selection has also proven to significantly lower over-wintering mortality. A series of site testing on Cape Cod, Massachusetts resulted in an increased over-wintering survival approaching 90%. The sites demonstrating higher survival (75% and above) showed common characteristics, including:

- Elevated on-bottom cage configuration,
- Hard (sandy) bottom with little silt,
- Strong water flow ensuring adequate food flux during the critical spring transition period,
- Sufficient water depth to prevent damage from heavy sea ice conditions,
- Protection from disturbance by severe winter storms, wind, wave and turbulence.
- When several grow-out sites are available, the grower may consider testing each site to identify the best location for a dedicated over-wintering plot where the above conditions are met. This site might be independent from the summer production site.

## Harvesting

When bay scallops are ranched on the bottom, they can be harvested either by hand or by mechanized methods.

Hand harvesting in shallow waters requires the use of a glass-bottomed view box and a dip net while in deeper waters, skin-diving or scuba gear is usually used (Figure 14).



**Figure 14.** Hand harvesting with a view box in the foreground, mechanical harvesting with boat and dredge in the background.

Mechanized harvesting traditionally requires a boat and a bay scallop dredge. Dredges can vary in size and design depending on bottom type, local traditions and the power available to haul the dredge onto the boat. Whether you can use a dredge for harvest may be subject to local or state regulations.

Generally composed of a cutter bar in the front that sweeps the scallops up and into a trailing bag, dredges are frequently fished in multiples of two to balance the load on the boat and to maximize catch per trawl (Figure 15). Powered dredging may have a negative impact on seagrass beds and result in loss of scallop habitat. To minimize this impact, harvesting efforts should rotate between mechanized and non-mechanized techniques annually or bi-annually within a specific area.



**Figure 15.** Scallop dredge on culling board.

Harvesting scallops held in culture systems simply consists in retrieving the containment system, i.e. bag, net or cage, and removing the scallops from the device.

Timing is an important factor to consider when planning a harvest. As with oysters, the season can affect both the quality and weight of the product. Gonad development and reproduction requires a large portion of the scallop's energy reserves. During the reproductive period, the scallop will consume most of the glycogen stored in its adductor muscle resulting in poor market quality. The best yield and meat quality occurs after the scallop ceases to be reproductively active in the late summer or fall. Depending on the geographical location of the bay scallop population, this peak harvesting period begins in August in Florida and October in New York and Massachusetts populations.

## Processing & Marketing

In the U.S., only the single adductor muscle of the scallop or "eye" is traditionally marketed. This product requires a special knife and a three-step hand processing method called "shucking" where in three single movements, the valves are separated, the viscera removed and the single muscle detached from the shell into a container (Figure 16).



Figure 16. Scallop shucker flinging the adductor muscle into a bowl.

Experienced shuckers can process around 2 bushels of bay scallops per hour where 1 bushel yields approximately 7-8 pounds of meats (60-100 meats per lb). A bushel is a traditional measure equivalent to 4 pecks or 40 quarts and holds about 600 live bay scallops.

While the interest for commercial bay scallop aquaculture has grown in the U.S., a new way of marketing bay scallops has emerged. The new "in-the-shell" product, a smaller bay scallop (45-55mm) sold and eaten as a whole live animal, could allow growers to harvest at the end of the first growing season therefore avoiding the risk of over-wintering losses (Figure 17).



Figure 17. A new product emerges: bay scallops cooked whole "in the shell."

The new "in the shell" will likely require a significant effort to gain consumer acceptance. This product also raises regulatory issues as it is impossible to differentiate a small cultured scallop from a sub-legal wild one and marketing the whole animal makes scallops subject to harvest restrictions as part of the National Shellfish Sanitation Program.

## Risks:

Besides overwinter mortality, the major risks to bay scallop culture in the field are predation, disease and harmful algal blooms. To prevent these factors from causing significant crop losses, the scallop grower can implement unique management strategies.

## Predation Management

The principal predators posing a threat to scallop aquaculture are gastropods, sea stars, crustaceans, fishes, birds and marine mammals.

An efficient predator management strategy is to physically protect the juvenile scallops within the grow-out apparatus. Containment devices described in the previous sections, not only hold the mobile scallops in place but also prevent predators from preying on them. Deployed gear should be maintained and monitored regularly to remove small predators entering the containment apparatus before they grow into a size capable of harming the scallops (Figure 18).

When the scallops are ranched on the bottom, predation control is more challenging. One management strategy available is to release the juveniles as late as possible, after they have reached the 35 mm threshold and have a better chance to resist an attack. Releasing





**Figure 18.** The invasive green crab *Carcinus maenas* sometimes finds its way into scallop cages.

the juveniles in the late fall when the temperatures start dropping also helps minimize losses as it coincides with a decrease in predator activity. Scallops may also be fenced in to lessen attacks from mobile predators.

### **Disease Management:**

Because cultured scallops are held at very high densities, disease organisms that would not necessarily present a significant threat in the wild can have a dramatic effect when introduced into the system. The primary means to prevent introducing these organisms to the system is to develop and follow quarantine and disease assessment protocols whenever new scallops are introduced. In addition, a stringent health evaluation including histopathological assessment is necessary. Testing 60 individuals is generally accepted as a significantly relevant number to detect a threshold of 2-3% infection. These protocols must be followed under all circumstance to prevent catastrophic disease outbreaks.

### **Harmful Algal Blooms**

The primary management strategy to avoid exposure of cultured bay scallops to harmful algal blooms is site selection. Blooms tend to occur in the same areas from one year to the next (Figure 19).

Every U.S. coastal state with a commercial shellfish industry is required to monitor harmful algal blooms of consequence to human health under the National Shellfish Sanitation Program Model Ordinance (NSSP



**Figure 19.** A bloom of *Cochlodinium polykrikoides* on the island of Nantucket, MA.

1999). These data must be consulted when planning for bay scallop culture site location. Unfortunately, not all of the HABs that impact bay scallops are considered human health risks and those that are not are less documented. Therefore, the potential culturist should also consult with marine resource managers, aquaculture extension agents or local marine research scientists for more relevant information.

For more information on scallop diseases and HABs, see the NRAC publication #214-2010, "Biology of the Bay Scallop."

Despite a rising interest from private growers and a steady decline of wild stocks, bay scallop are still not successfully cultured to market size on a commercial scale in the United States. Roadblocks like overwintering mortalities and high labor costs will hopefully soon be overcome by the emergence of new marketing strategies and new technologies that increase production and reduce costs creating economic opportunities for our marine farmers and a new aquaculture commodity in the U.S.

For an expanded version of this bulletin, please refer to: Leavitt, D.F. and R.C. Karney. 2005. Cultivation of the bay scallop. Pages 25-109 in A.M. Kelly and J. Silverstein (eds.) *Aquaculture in the 21<sup>st</sup> Century*. American Fisheries Society Symposium 46, Bethesda, MD.

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