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Cultivating the Eastern Oyster, *Crassostrea virginica*

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Oysters have been cultivated in one form or another for more than 2,000 years. Early efforts involved little more than transplanting small oysters from one area to another area where they would grow better, be better protected from predators and disease, or be easier to harvest. This simple method of cultivation is still widely practiced today and is a major way of producing the eastern oyster, *Crassostrea virginica*.

The eastern oyster occurs naturally from the Gulf of St. Lawrence in Canada to the Gulf of Mexico, the Caribbean, and the coasts of Brazil and Argentina. It has been introduced on the west coast of North America and in other areas of the world. In recent years the total U.S. harvest of oysters has been 30 million pounds of meats; about 75 percent of the total is the eastern oyster. About 18 million pounds of total oyster production (all species) is by cultivation.

Oyster biology

An understanding of basic oyster biology is essential to any successful culture operation. Under natural conditions, oysters spawn as water temperatures rise in the spring. The temperature at which spawning occurs varies from north to south. Northern oysters spawn at temperatures between 60 and 68 °F (15.5 and 20 °C), while southern oysters spawn at temperatures above 68 °F (20 °C). Spawning can occur throughout the warm months.

Sperm and eggs are released synchronously and fertilization occurs in the water column. A fertilized egg develops rapidly into a microscopic swimming trochophore (Fig. 1). After 24 to 48 hours, the non-feeding trochophore develops into the feed-

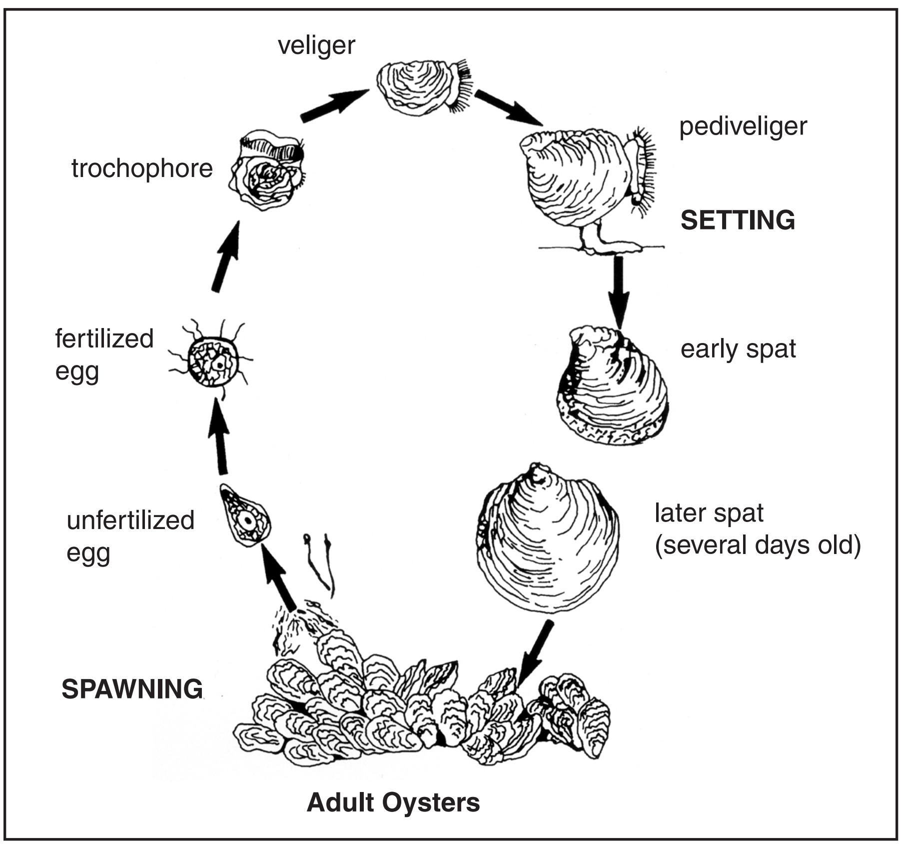

Figure 1. Life cycle of the eastern oyster, Crassostrea virginica.

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ing veliger stage. At this stage the larva has a thin shell and feeds primarily on tiny algae. After 12 to 20 days, the larva develops a foot and eye spots and is referred to as a pediveliger or "eyed larva." Pediveligers settle to the bottom and can crawl short distances to find suitable sites for setting. Setting occurs when the larva cements itself to a hard substrate (usually oyster shells) and metamorphoses into a tiny oyster called a spat.

"Spat" usually refers to a recently metamorphosed oyster, but the term may be applied to any small oyster. Similarly, the term "seed oyster" may be given to oysters that are too small to harvest, but it generally refers to juvenile oysters larger than spat.

Spat are mostly male and grow rapidly. Sexual maturity can occur within 4 months in southern waters. Some males change to females, usually after the first or second spawning, and some females can change back to males. Growth to harvestable size (3 inches, 75mm) can take 12 to 36 months, depending on temperature, water salinity and food supply. Oysters do best in areas where the bottom is relatively firm and stable, salinities are from 10 to 30 ppt (15 to 18 ppt is considered optimal), water flow is adequate to bring food, sediment does not smother oysters, and oxygen concentrations remain greater than 3 ppm (greater than 5 ppm most of the time).

Oyster culture

Methods of oyster culture can range from very simple, with little input or control, to very intensive, with much input and control. The simplest form of oyster culture is to place (plant) oyster shells, clamshells or other appropriate materials (cultch) in an area where oyster larvae are likely to settle. Oysters are then harvested in 1 to 3 years, depending on their growth rate. In some cases, small oysters are moved to areas where growth and survival are expected to be better than in the location where the larvae set. After oysters are harvested, additional cultch is planted to provide substrate where more oyster larvae can set.

The most intensive culture methods involve spawning oysters in a hatchery and growing free-swimming larvae in large tanks supplied with specific algae (e.g., *Isochrysis, Chaetoceros,* or *Tetraselmis*) that are known to be nutritious for larvae. Much of the effort and space in an oyster hatchery is devoted to producing the algae. When larvae are ready to set (14 to 16 days), they are sieved from the large tanks and added to tanks that contain whole oyster shells in large mesh bags.

An alternative method is to set the larvae on microscopic pieces of oyster shell (microcultch) that are held on fine screens in bucket- to barrel-size containers. Generally, only one larva sets on a piece of microcultch. This technique produces a crop of single oysters which are desirable for the oysters-on-the-half-shell market. Oyster larvae also can be shipped to locations far away from the hatchery and set. This process is called "remote setting."

Oysters set on shells

Oyster larvae may be set on whole oyster shells, fragments, or other types of shell (e.g., clams). Typically, well washed oyster shells that have been aged at least 6 months or more are loaded into large mesh (9/16-inch, 1.4-cm) bags that hold about 40 pounds (18.1 kg) of shells (approximately 215 shells). Bags of shells are placed in light colored, aerated tanks containing filtered seawater (50-micron, 0.002-inch filters) with a salinity greater than 10 ppt. Oyster larvae are added at a rate of 100 per shell with a goal of getting an initial set of 20 to 30 spat per shell. Tanks are covered with a tarp to block out light and left for 48 hours. After setting, filtered seawater water can be run through the tanks until the spat are moved to a nursery area. Hatchery-produced algae or commercial algae paste can be used as supplemental feed.

Shell bags are moved from the hatchery to a nursery area in natural waters. The nursery area should be easily accessible for the equipment needed to deploy the bags. It should also be a site where poaching can be kept to a minimum and, most importantly, where oysters will grow rapidly.

Shell bags can be strapped to a pallet and placed in natural waters for the nursery phase. Or, bags can be placed on a hard bottom or suspended from floats or racks. When oysters grow to about an inch along the longest axis, they are emptied from the shell bags onto the growing area. There can be considerable loss from predators such as crabs, oyster drills and flatworms, particularly if seed is damaged in planting. Under good conditions three to five spat per shell should survive to reach market size. Oysters are harvested according to local gear and size regulations.

Single oysters

Single oysters are produced by introducing ready-to-set larvae (600 per square inch, 236/cm^2) into containers with fine mesh (150-micron, 0.006-inch) bottoms that have been covered with finely ground and sieved oyster shells (250-micron diameter, 0.01-inch). The containers are usually suspended in a larger tank or trough of filtered seawater. An airlift pump on each container lifts water from the tank into the container; the water flows out through the mesh bottom. This arrangement is called a downweller; the downward action of the water keeps the larvae in the container until they set. As with larvae set on whole shells, the containers are covered and left for 48 hours while larvae set.

After the larvae set, the flow of the airlift is reversed to create an upweller (Fig. 2) that pulls water through the bottom mesh of the container and out the top. The source water is usually filtered to keep out larger organisms and reduce fouling on the screen bottoms. As the oysters grow, they are usually moved to upwellers

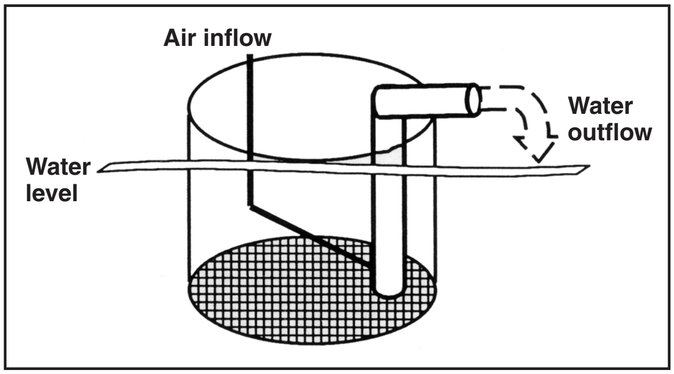

Figure 2. Airlift upweller.

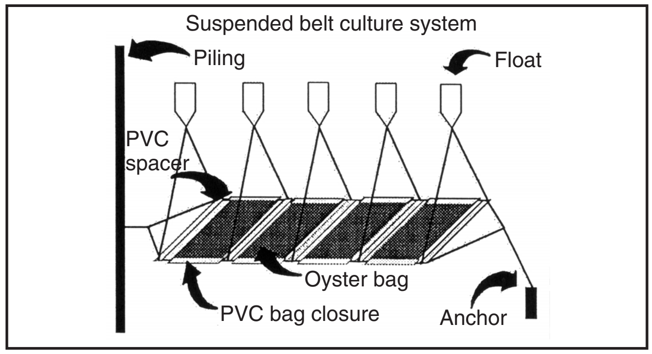

Figure 3. Example of a flexible belt system with flotation. (Illustrated by F. Scott Rikard)

with larger mesh bottoms to increase flow and reduce clogging in the mesh.

Grow-out takes place in natural waters where single oysters are placed in polyethylene mesh bags that are typically 36 x 18 x 3 inches (91 x 46 x 7.6 cm). Single oysters are at great risk from predators if not protected in bags.

Oysters do not all grow at the same rate, so they are sieved in order to be placed in containers of the appropriate mesh size. Representative mesh sizes and stocking densities are shown in Table 1. As oysters grow, they are moved to larger mesh containers at lower densities.

Table 1. Typical mesh size of oyster growing containers (bags) and suggested stocking densities.

BAG MESH (inches)	OYSTERS/BAG
0.75 (19 mm)	250
0.50 (12.7 mm)	500
0.25 (6.4 mm)	1,500
0.13 (3.3 mm)	4,000
0.08 (2 mm)	10,000
0.04 (1 mm)	50,000

Single oysters are generally grown off-bottom so they will not be smothered by soft sediments. Oyster containers can be placed on racks attached to the bottom, on racks suspended from structures, or on floating long lines. A flexible belt apparatus developed at Harbor Branch Oceanographic Institution, Inc. places a large number of bags on two parallel lines (polypropylene ropes) and uses PVC pipes to spread lines and attach bags to the lines. The flexible belts are deployed on suitable hard bottoms or suspended horizontally in the water column with floats (Fig. 3). Another method is to put a float in each bag and link the bags together. As the oysters grow heavier, a considerable amount of flotation is needed for suspended oyster bags.

Oyster bags often become overgrown with marine organisms such as barnacles, mussels, bryozoans, etc. Regular air drying for several hours may help, or bags may need periodic pressure washing.

Many intensively cultivated oysters come from areas where they are completely uncovered at low tide. This regularly dries the oysters, gives easier access to oyster bags, and makes it easier to maintain supporting structures and carry out the harvest.

Site selection

While some oysters have been grown to harvestable size in ponds or in the effluent from other culture operations, most production takes place in natural waters. This means that there is little control over the many variables that affect growth and survival. Therefore, selecting a site that has favorable conditions for oyster culture is essential. These factors should be considered:

1. Status or classification, by a state agency, of the water for safe shellfish harvesting
2. Substrate conditions (soft, hard, shifting, stable)
3. Salinity
4. Prevalence of diseases
5. Tidal range
6. Sedimentation rate
7. Water flow
8. Oxygen concentration
9. Algae concentration (food supply)
10. Prevalence of predators
11. Fouling organisms
12. Accessibility and security

Most potential sites within the southern U. S. are in estuarine areas where conditions are highly variable. For example, water salinity may be within an acceptable range for parts of a year or for several years at a particular site, but may be outside that range for other periods of time. Understanding such variability can help in selecting a good site. Furthermore, several factors may be closely associated, such as salinity, disease and predators. Seek help from local experts and the appropriate state agency when assessing the characteristics of a particular site.

To use a site in public waters you must obtain permits from various agencies. This may involve a lease from the state or other formal arrangement to use water bottoms or the water column. Each state has its own requirements; at a minimum, permitting generally involves the U.S. Army Corp of Engineers, the state natural resources agency, and the state public health department.

Marketing

Oyster production in the U.S. has declined from 40 years ago, while inflation-adjusted prices have remained flat or increased only slightly. This indicates that consumer demand has decreased over time, possibly because of concerns about the safety of eating raw oysters and general changes in people's eating habits.

Oysters can be sold to existing markets at prevailing prices. Some producers have been able to market their oysters under brand names or regional names and obtain a premium in specific markets. A number of post-harvesting techniques that reduce human health concerns are being tried, and these may help rebuild markets. However, markets should be realistically assessed before resources are committed to oyster cultivation.

Significance

The eastern oyster is important both economically and ecologically. Oysters help filter estuarine waters, which are habitat for hundreds of species of marine organisms. Factors such as declining water quality, disease and overharvesting have greatly reduced the economic and ecological benefit of oyster reefs in some areas. Cultivation can increase oyster production and restore the ecological role of oyster reefs.

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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