# NORTH CAROLINA UNDER DOCK OYSTER CULTURE PROGRAM

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## What is the UDOC Program?

In 2004, the North Carolina General Assembly created the Under-Dock Oyster Culture Program to allow North Carolina residents the opportunity to grow oysters under their coastal docks or piers. The program allows qualified permit holders to attach up to 90 square feet (or 45 cubic feet) of oyster cultivation containers to their docks or piers. The N.C. Division of Marine Fisheries (NCDMF)- Habitat and Enhancement Section, in conjunction with North Carolina Sea Grant, administers the program.

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This document is designed to educate potential oyster gardeners on the program's legal requirements, as well as how to begin and maintain the oyster culture process. (See Appendix A to review applicable statutes and rules.)

## Permit requirements

Because adverse health consequences may result if oysters are harvested and eaten under certain conditions, prospective oyster gardeners must review, and be tested on, the materials in this publication. To receive an Under-Dock Oyster Culture (UDOC) Permit, applicants must first pass a test to show that they understand the legal requirements and safety precautions that must be taken when culturing and harvesting oysters. The test is attached at the end of this publication.

Problems with theft or vandalism of a permit holder's oysters or containers should be reported to local law enforcement agencies. The N.C. Marine Patrol does not have jurisdiction over theft or vandalism of private property.

## Permit renewal

Permits are valid for one year from the time of issuance. Permits must be renewed upon expiration to continue operation. To be eligible for renewal, the permittee and the dock location must continue to meet the permit requirements and the permittee must document they have attempted to grow oysters on a continuous basis. Required documentation of permit activities for the previous year include:

- Number of oysters deployed into the containers, number of oysters removed from the containers, reason for removal (e.g., eaten, given away) and number of mortalities.
- Documentation of the source of the oysters (must have a *Permit to Introduce, Transfer, or Hold Marine and Estuarine Organisms* if the oyster seed or spat is from out-of-state).

## Getting to know the oyster

Understanding basic oyster biology will help you be successful in your efforts to grow them. The scientific classification of the eastern oyster is:

Phylum: **Mollusca**
Class: **Bivalvia**
Order: **Ostreoida**
Family: **Ostreidae**
Genus: ***Crassostrea***
Species: ***virginica***

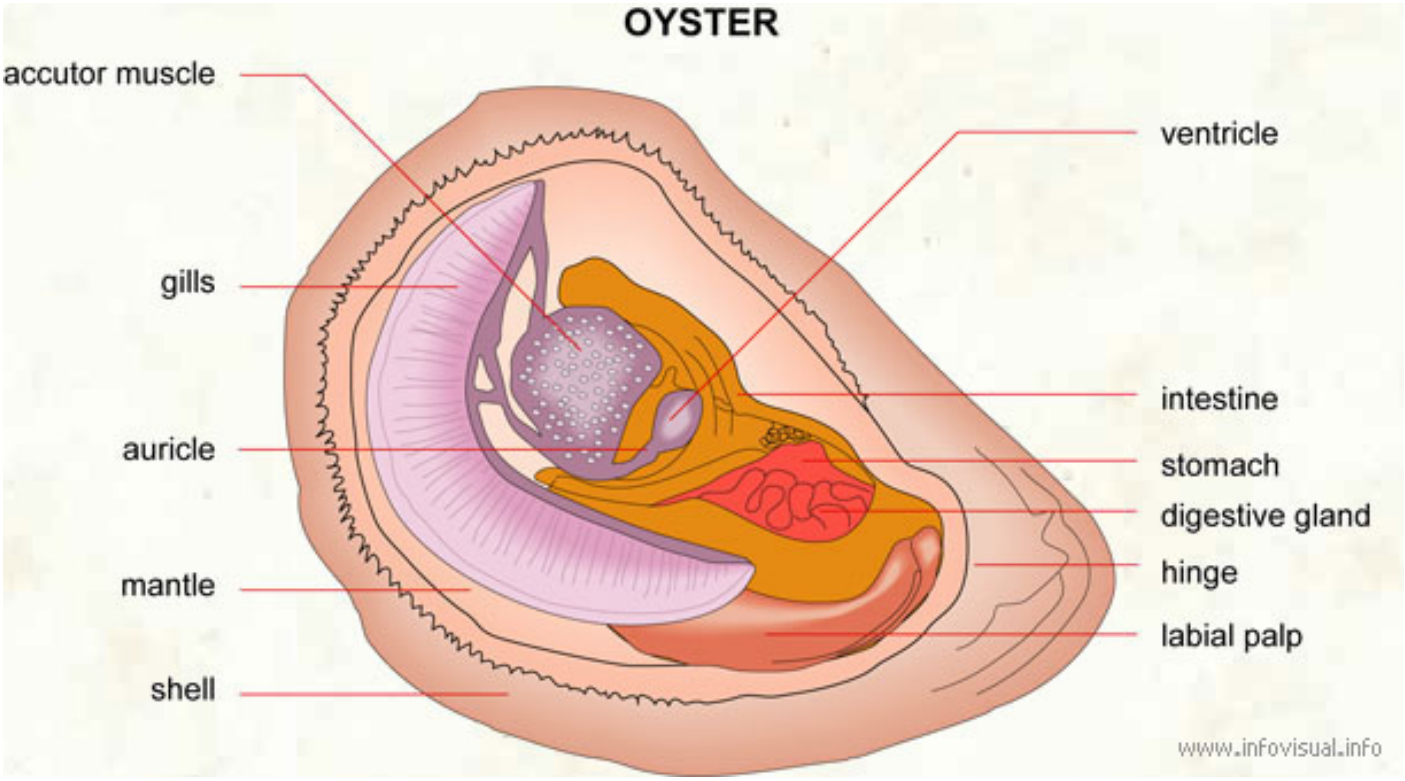


Figure 1. Eastern oyster (*Crassostrea virginica*). Basic biology of the organism.

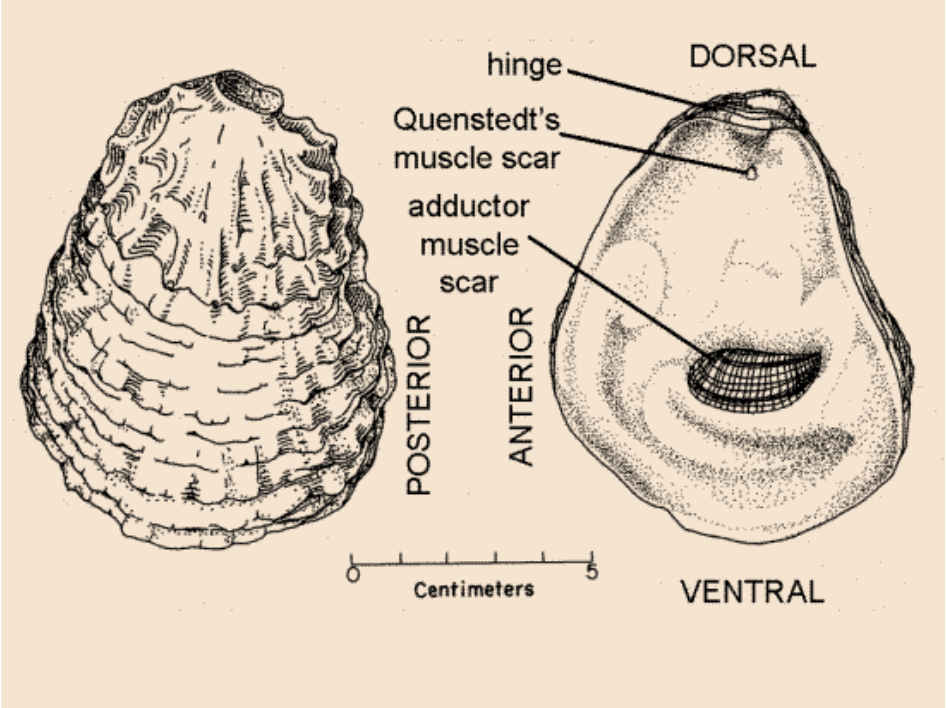


Figure 2. Eastern oyster (*Crassostrea virginica*). Outside of left (lower) valve and inner of right (upper) valve (from Galtsoff, 1964).

The oyster, like other typical bivalves, has two shells covering its body. These shells are normally gray in color, often stained with patches of light brown from algae and other fouling organisms, sedimentation, or tannins. Shell shape varies. The two oyster shells fit together tightly but are not identical as in clams, mussels, and most other bivalves. The left valve is almost always heavier than the right and more deeply cupped. The bottom shell is usually cemented to a rock, shell or other solid object. The top shell and the shell margins grow in irregular bumps and twists so no two oysters look exactly alike.

Oysters can grow to approximately 8 inches in length, with a typical life span of 5 to 10 years, though they can live longer. Oysters eat by filtering food from the surrounding water through their gills. They are most efficient removing particles that are only 0.0001 inches in size. It has been estimated that an adult oyster can filter 13 to 50 gallons of water per day.

## Reproduction

Under natural conditions, oysters spawn as water temperatures rise in the spring, and again when they fall in the autumn. In North Carolina, spawning occurs at temperatures of 68°F (20°C) or above. Some spawning occurs throughout the summer. Sperm and eggs are released at the same time and fertilization occurs in the water column. A female can release between 23 and 86 million eggs per spawn. A fertilized egg develops rapidly into a microscopic swimming trochophore (Fig. 3). After 24 to 48 hours, the trochophore develops into the feeding veliger stage. After two to three weeks from the original spawning, the larvae seek a solid surface, exude a drop of cement to keep them permanently attached and become “spat.” Spat are mostly male and grow rapidly, maturing sexually within 4 months. Oysters start out male and switch gender back and forth during their life span.

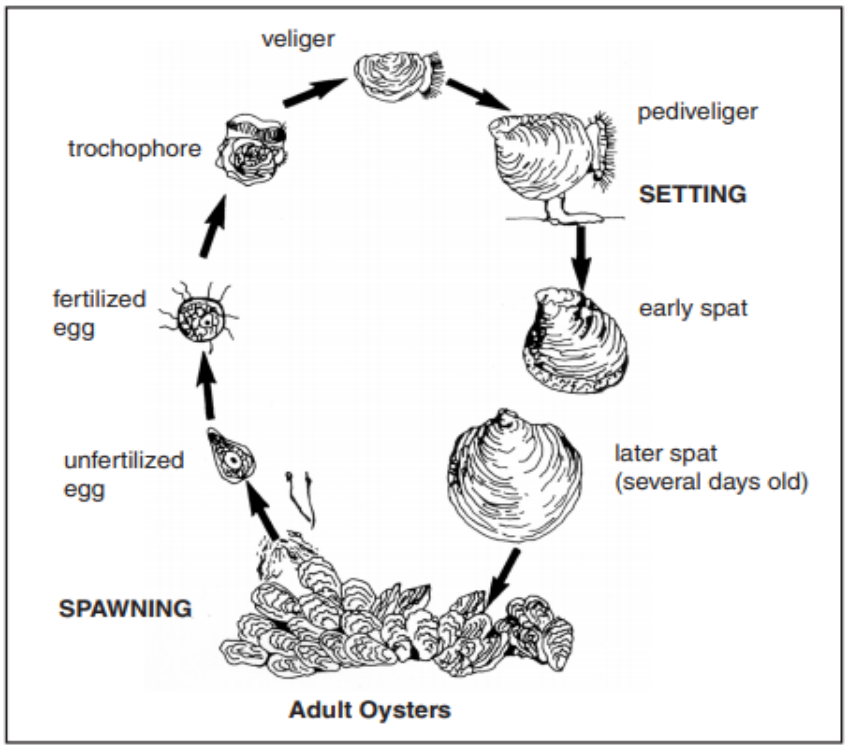


Figure 3. Eastern oyster (*Crassostrea virginica*). Typical life cycle.

In nature oyster larvae typically settle on other oyster shells. In some states culturing clumped oysters is popular and is achieved by planting spat on shell on the bottom. In water column farming using cultivation containers such as practiced in the UDOC Program, single oyster seed is stocked. Single oyster seen is produced by setting oyster larvae on finely ground oyster shell particles capable of setting only one oyster larvae per particle.

Seed available for purchase can either be diploid or triploid. Diploid seed occur in the wild and contain two sets of chromosomes. Triploid seed contain three sets of chromosomes and are sterile. Triploid oysters are **not** genetically modified organisms (GMOs) as their genetic material has not been altered. In fact, triploid oysters are similar to other agricultural products such as seedless watermelons. Because triploid oysters are sterile they grow faster and have consistent meat quality throughout the year compared to diploid oysters.

## Conditions for growth/environmental needs

In North Carolina, the eastern oyster typically lives in shallow estuaries that have a relatively firm and stable substrate, fluctuating temperatures, low to high salinities, and clear to muddy waters. Growth to harvestable size (3 inches, 75mm) can take from 9 to 36 months, depending on temperature, salinity, food supply. whether seed are diploid or triploid (described above). Understanding such variability can help in deciding whether to grow oysters. Several additional factors may be closely associated, such as disease and predators. Make sure you assess the characteristics of your site before you attempt to grow oysters. Following are the optimal conditions for oyster growth:

- **Salinity: Optimal salinity 15 – 18 ppt**

Salinity refers to the total amount of salt dissolved in water and is measured in parts per thousand (ppt). For reference, the ocean is approximately 35 ppt, whereas distilled water is 0 ppt. Oysters may survive in salinities ranging from 5-35 ppt, however rates of survivorship and growth are highest between 15 and 18 ppt. Environmental stressors such as predation or disease (in higher salinity areas) and episodic rainfall (in lower salinity areas) can lead to increased mortality. Oysters can survive wide fluctuations in salinity, but regular fluctuations can be stressful. Oysters exposed to prolonged periods of low salinities close their shells and die of anoxia (no oxygen). Areas with large, regular, or prolonged fluctuations in salinity should be avoided. Areas with active tidal flushing and small watersheds typically support more consistent salinity and therefore better environmental conditions for oysters.

- **Temperature: Optimal temperature range**

Adults exist generally within a range of water temperatures from 15-30$^{o}$C. Oysters tolerate freezing of their tissues and can revive after thawing. Optimal water temperatures for growth, reproduction, and survival of oysters range from about 21 to 29$^{o}$C, and the response of oysters to temperature changes and extremes depend on an interaction of environmental conditions. The rate that water is pumped through the oyster's gill system is determined in part by temperature. A water temperature range of 20 to 30$^{o}$C results in favorable pumping rates for supplying needs for oxygen, food, and waste disposal. Feeding activity is greatest when water temperatures are above 10°C, but greatly reduced above 35$^{o}$C. Oysters are relatively inactive below 15$^{o}$C, while temperatures above 45$^{o}$C are not suitable for survival.

- **Water Flow: Optimal tidal range should be above 12 inches**

Adequate tidal flushing ensures a mixing of the water, delivers food, removes wastes and stabilizes the salinity. Too much flow may wash away cages or floats; too little flow may cause excessive silting. The ideal site would provide plenty of water flow to transport food but not excessive energy; for example, near a creek or marsh that ebbs and flows with the tides. Ideally the tidal range should be above 12 inches in intertidal areas.

- **Oxygen: Optimal condition greater than 5 mg/l**

The rate of oxygen consumption by oysters increases as temperature increases and salinity decreases. Oysters can survive daily exposure to low oxygen and can survive anaerobically (without oxygen) for up to three days, but they grow best when oxygen concentrations remain greater than 5 mg/l. Although they can tolerate relatively low dissolved oxygen levels in water, their growth will be poor, and they will become more susceptible to disease. At low oxygen levels, oysters expend more energy pumping water through their bodies to get the necessary oxygen; therefore, less energy is available for growth. Usually, water will contain adequate dissolved oxygen in the upper portions of a water column or if subject to mixing by tides, current, or winds.

- **Sedimentation: Overabundance can kill oysters**

Oysters can tolerate large amounts of suspended solids, but the pumping rate decreases with extreme levels of Total Suspended Solids (TSS)s. As suspension feeding bivalves, oysters require phytoplankton in the particulate load of the water column. However, extreme suspension of solids can clog gills, and reduce filtration. Typically, a reduction in filtration begins at approximately 25 mg/l TSS. Storms and hurricanes can destroy oyster reefs by covering them with sediment.

## Oyster Diseases

- **Dermo**

Many diseases can infect and kill oysters. Probably the most common, and the one blamed for the widest spread mortality in North Carolina, is dermo, caused by the pathogen *Perkinsis marinus*. This disease is invasive and destructive to oysters, including those in aquaculture situations. It is thought by some to have been introduced into east coast waters in the 1950s with the limited introduction of *Crassostrea gigas* oysters from the Pacific Coast. The relationship between dermo and salinity is well established; low temperature/low salinity combinations retard dermo development. Oysters can exist and grow vigorously in salinities slightly lower than the minimum tolerated by dermo. Dermo is a warm temperature disease with outbreaks and mortalities occurring in the summer months. The disease does not cause serious mortalities below salinities of 12 to 15 ppt, but can persist in over-wintering oysters in salinities below 5 ppt.

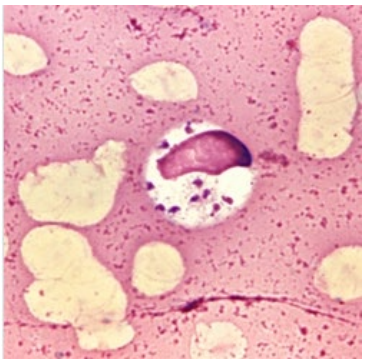

Figure 4. *Perkinsus marinus* (from the laboratory of Gerardo R. Vasta, PhD, University of Maryland, Baltimore)

Raising oysters off bottom may promote faster growth and better health, which may help them resist the lethal effects of dermo during years with normal and above average rainfall. It seems to be one of the few management strategies that work to strengthen oysters against the disease.

Drought and high salinity can result in heavy infestations of sea squirts and barnacles, heavy over-spatting, and infestation of mud worms and flatworms, weakening the crop and setting the stage for dermo to attack. The result can be high mortality and a loss to the crop.

When oysters contract dermo, their growth rate is reduced. By the time they are ready for harvest, the oysters are unmarketable due to emaciation, gaping, and pale digestive glands.

From the Pamlico Sound south, dermo attacks and weakens aged oysters causing high mortality rates. Generally, this occurs after the second summer when the water is hottest and saltiest. Perhaps not coincidentally, dermo occurs during periods of drought when most organisms that attack oysters thrive. During an extended drought, there is little one can do other than try to save what few oysters manage to survive. Interestingly, a tropical storm or glancing blow from a hurricane causes a dramatic drop in salinity and for a period stems the flow of dermo and the growth of organisms that kill oysters. If the storms are not severe enough to destroy the in-water facilities, this situation can potentially allow oysters to grow fast and fat.

- **MSX (multi-nucleated unknown)**

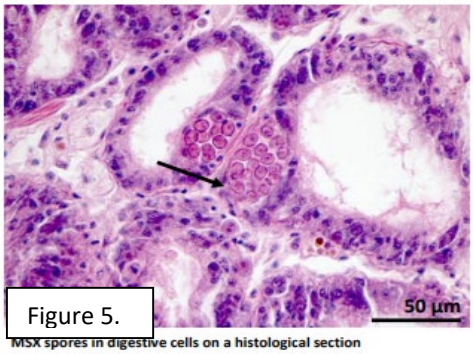


Figure 5.
MSX spores in digestive cells on a histological section
(Antonio Villalba)

MSX is a disease caused by the pathogen *Haplosporidium nelsoni* that has devastated the oyster population in the Chesapeake Bay. It is present in North Carolina waters, but to a much lesser degree. It has been reported as far south as the Florida Keys, but there have been no reported widespread mortalities. Its destructive effect begins at the Virginia border and extends north into Canada.

- **SSO Disease**

SSO, a disease caused by the pathogen *Haplosporidium costale*, was discovered during a search for MSX along the Atlantic Coast in Virginia and Maryland. It has caused heavy mortalities in that area, but so far has not been a problem in the Carolinas and to the south.

- **ROD (**Roseovarius Oyster Disease, previously called Juvenile Oyster Disease**)**

Figure 6.
**Deformed shells of ROD-infected seed oysters.** (Inke Sunila)

ROD affects hatchery-raised seed of *Crassostrea virginica,* mostly on the northern portions of the east coast. The species colonizes within the oyster to retard growth, and cause unequal shell growth and cupping in the left valve. ROD often leads to mortality of up to 90% in oysters under 25 mm in size. Infected surviving oysters have conchiolin rings on the inside of the shell. Disease outbreaks have thus far been limited to higher salinity waters with temperatures exceeding 68ºF (20ºC), and appear related to high-density conditions.

If you suspect that your oysters may be affected by disease contact: Frank Lopez, NC Sea Grant.

## Consumer Health

- **Bacteria**

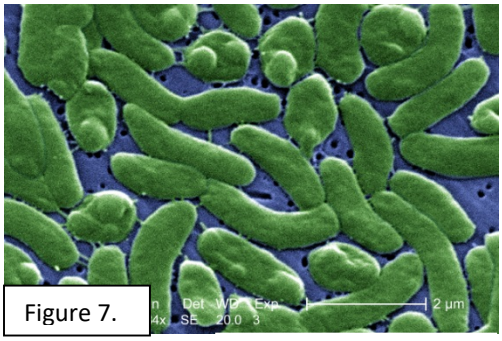


Figure 7.

CDC/James Gathany

**Vibrio infection:** *Vibrio vulnificus*, *Vibrio parahaemolyticus*, and certain other Vibrio species are unrelated to pollution, and are common and naturally occur in marine and brackish environments. They are more abundant in the months when water temperatures are warmer, such as summer and early fall. Although individuals with compromised health and weakened immune systems are especially vulnerable, Vibrio can also cause gastrointestinal illness in healthy individuals. In rare cases, even death can occur in people with certain medical conditions, such as cancer, diabetes, liver disease, stomach disorders, otherwise weakened immune systems, or use of medicine to lower stomach acid levels, such as antacids and proton pump inhibitors. Consult your doctor if you are unsure of your risk.

Oysters should be promptly cooled and stored under refrigeration after harvest, as Vibrio bacteria can grow rapidly post-harvest. Similarly, Vibrio bacteria can grow rapidly during cage cleaning and other out-of-water activities if exposed to the sun or warm air temperatures. Oysters that have been exposed to warm temperatures during these activities should be re-submerged for later harvest so that the levels of Vibrio in the oyster can be reduced.

The risk of Vibrio infection can be reduced by avoiding raw or undercooked shellfish. For more information, visit https://www.foodsafety.gov/blog/2017/07/vibriosis-101-oyster-food-safety.html.

- **Growing areas**

Shellfish are filter feeders, and pump water through their gills constantly. Through this pumping action, oysters gather food particles, but they also take up any bacteria, viruses, or other pollutants present in the water. These pollutants can quickly build up to dangerous levels within the flesh of the oyster. If oysters containing high concentrations of bacteria or viruses are consumed raw or undercooked, they can cause severe illness in the consumer. The NCDMF Shellfish Sanitation Section is charged with monitoring oyster-growing areas, and the NCDMF closes those waters that have the potential for causing illness.

All oyster-growing areas are closely inspected every three years to document existing or potential pollution sources. In addition, water samples are collected at least six times per year and tested for bacteria. Annual reviews of bacteriological data and pollution sources are also conducted. This information is then used to classify each oyster-growing area as either approved, conditionally approved, restricted, or prohibited. Approved areas are consistently open to shellfishing, while prohibited areas are permanently closed. Conditionally approved areas are

generally open to shellfishing, but can be closed temporarily after a significant rainfall. The area is closed until water sampling indicates a return to acceptable bacteria levels.

The current classification and management plan for your area can be determined easily by calling or visiting the Shellfish Sanitation Section of the NCDMF in Morehead City (252-726-6827). Maps are available online (http://portal.ncdenr.org/web/mf/shellfish-closure-maps) showing classifications, and staff can identify the classification of your area over the phone if necessary. It is important to regularly monitor the status of your area, as the status can change quickly due to temporary closures after rainfall, due to high results of bacteriological sampling, or due to unexpected pollution events. These changes are made by proclamation of the NCDMF, which can be received via email listserv, or viewed on the web at http://portal.ncdenr.org/web/mf/proclamations-polluted-areas. The status of waters can also be obtained via automated voicemail by calling the Shellfish Sanitation Section, or by checking the interactive closure map at: https://ncdenr.maps.arcgis.com/apps/webappviewer/index.html?id=5759aa19d7484a3b82a8e440fba643aa.

Under piers or docks, water flow may be significantly reduced, and bacteria and other pollutants have the potential to build up much more rapidly than in open waters. Significant sources of bacteria, including birds, pets, stormwater drains, and septic tanks, are typically located near docks, and fecal contamination can quickly reach the water directly or can be washed in after rainfall. Therefore, it is recommended that great care be taken in monitoring and maintaining the area surrounding your under-dock oyster garden. Pet waste should be removed from any area near the water as quickly as possible, and you should keep a careful eye both on your own and surrounding septic tanks for any signs of problems. If possible, the presence of birds should be minimized on and around the dock, and any bird waste should be washed away by a method that does not send it directly into the water around your oysters. If care is taken to minimize the amount of pollution entering the water around your garden, then you can help keep your oysters clean and ready to eat.

Local conditions can change water quality rapidly and in very small areas that normal testing will not detect. Concerns you need to note:

- Stormwater run-off that empties near a growing site can bring contaminants for short periods during rains.
- At the latter part of ebb tide (intertidal areas) in coves and creeks, upland contaminants are least diluted. Therefore, shellfish are more likely to be exposed to higher levels of runoff bacteria.
- If there has been a heavy rainfall, growers should not harvest their oysters if the waters surrounding their garden are temporarily closed. Even if there is not a temporary closure, growers can delay harvest for a few days after the rain to let the oysters flush potential contamination – just to add a measure of safety. Call the NCDMF Shellfish Sanitation Section to check the status of your area, or check the maps and proclamations discussed above.
- Marine toilet discharges are obvious sources of concern.

## Oyster gardening

- **Seed sources**

Ideally, obtain your oyster seed directly from in-state commercial or research hatcheries or nurseries to avoid additional required permits for out-of-state oysters such as the Permit to Introduce, Transfer, or Hold Marine and Estuarine Organisms. These permits require the seed to be tested for disease prior to shipment. Importers are encouraged to apply for the permit at least a month before the expected shipment date and to ensure that the out-of-state supplier understands exactly what is required.

As a participant in the program, you will start with young oysters, called "seed" or "spat" that have been spawned and reared in a hatchery. Contact the NC Shellfish Growers Association or the Shellfish Gardeners of NC for suggested seed sources, and for information about timing and techniques of successful oyster culture (see Appendix B).

A gardener can purchase small, 6 to 8 mm seed, and grow them in bags or trays until they are large enough to put into a grow-out system. Because of the oysters' small size, the bags must be fine-meshed enough to hold the oysters until they grow a bit. An easier option is to purchase ready-to-plant oyster seed at 25 mm or greater, and plant them in 1/2 inch or larger cages, which would serve as the final grow out system.

Whatever the case, young seed will require some sorting to cull out dead oysters and, if necessary, the double and triple clusters. A good salt bath and drying helps control predators and some diseases. Thinning the rapidly growing small seed to control crowding, and thereby improve growth and lessen mortality, is essential. About a quart of seed per cage will allow plenty of room for growth.

Seed or spat obtained from a hatchery should be acclimated to the salinity of the water they are going to live in. If your seed sources are in high salinity areas, and you are in a low salinity area, this can affect you. Discuss this with your seed source or other program participants in your area. Oyster seed stock will survive in water of a different salinity, but they will take a couple days to get comfortable with their new surroundings.

Figure 8. Spat on Shell – Chesapeake Bay Program

- **Cultivation Containers**

There are several major advantages to growing oysters in the water column in containers. Because the oysters are contained, they can be brought up on the dock and counted, checked for health, measured, and some cleaning can take place if necessary. Another advantage is better water flow, resulting in better food availability and faster growth.

There are a variety of oyster cultivation containers available commercially (see Figs. below). For more information, contact NC Sea Grant's Marine Aquaculture Specialist or consult with other oyster growers.

Figure 9. Floating bags

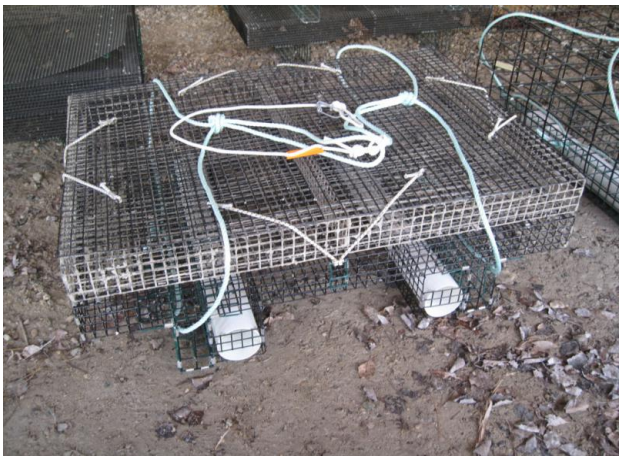

Figure 10. Floating cage

Figure 11. Floating cage

Figure 12. Long-line cage

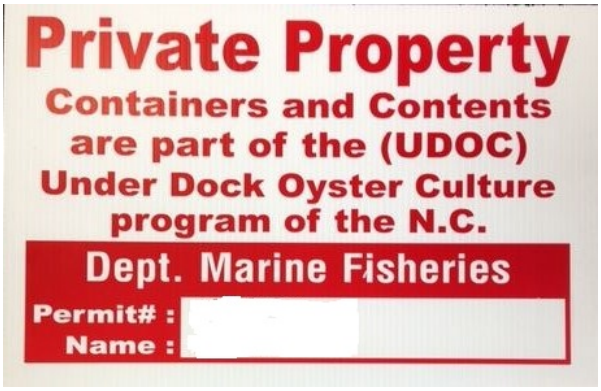


Figure 13. Example of Required Signage

Oyster cages are usually hung horizontally to give the oysters plenty of room and to maximize their growth rates. The cage should be tied off so the oysters sit about one foot below the surface of the water at low tide. The top of the cage may be exposed during the lowest tides, however, this invites birds. The objective is to keep cages as high in the water column as possible, where the supply of plankton and oxygen is plentiful, without risking exposure to freezing air temperatures. In the winter, it is essential that your cages remain under water. This is because oysters exposed to freezing air temperatures may die. Oysters are fine if they are in water, even if they freeze into a solid block of ice. It is recommended that cages be lowered to just above the bottom late in the fall, and left there until all risk of freezing air temperatures has passed.

During the warmer months, you can raise your cages back closer to the water surface. Oysters will benefit from drying out a bit when exposed to air during the occasional extremely-low tides once all risk of freezing has passed. Just make sure they are not exposed to hot, direct sunlight for longer than three or four hours at a time. Re-submergence prior to harvest is advised if oysters have been out of the water for greater than 5 hours.

Cages can be secured to the dock in any number of ways. Each cage can be suspended between pilings or hung by tying a line around a plank on your dock. Some gardeners drill four small holes through dock planks and thread one cage line through each hole. Your system will depend on your dock site. The important point here is to make sure the cages do not bang against pilings – banging can cause oysters to close and stop feeding.

- **Stocking densities**

Regardless of the size of seed oysters when they are purchased, the size of the container and its mesh dictates the size of seed that can be planted. As a rule of thumb, use a seed size that is about three times the mesh size. Smaller seed tend to either slip through or grow into the mesh. Generally, the larger the seed the better the crop. By reaching maturity faster, larger seed can avoid some of the problems with barnacles, over-spatting, and the like. The table below provides suggested oyster stocking densities peer given mesh sizes of a typical floating bag. Keep in mind densities will need to be adjusted for containers of different sizes. For more information, contact NC Sea Grant's Marine Aquaculture Specialist or consult with other oyster growers.

| Seed Size | Cage Size | Oysters per Cage |
|---|---|---|
| Up to 15 mm - 0.6" | 3/16" mesh | 2 Quarts |
| 40mm - 1.5" | 3/8" mesh | 600 |
| 50mm - 2" | 5/8" mesh | 500 |
| 63mm - 2.5" | 5/8" mesh | 450 |

**Stocking Density for 18"x36"x4" hard cages.**

Figure 14. Typical oyster stocking densities for a 18"x36"x4" floating bag

- **Growth rates**

Although oysters can exhibit rapid growth – sometimes reaching one inch (25 mm) in two to three months after settlement – growth is extremely variable and depends on many factors, including salinity, temperature, food availability, and water quality. Data you collect about your garden will provide valuable insight for oyster restoration projects and for other oyster gardeners.

- **Care and maintenance – Fouling organisms**

It is good practice to periodically pull your containers up on the dock and clean fouling organisms from the cages to allow better water flow, which also brings oxygen and food to the oysters. Check containers for condition at the same time. Clean containers mean good water flow. Overcrowding of oysters can also affect water flow, growth, and health of the oysters. As oysters grow, the transfer of some to other containers may be necessary.

## Predators, Pests, Competitors, and Fouling Organisms

A wide variety of predators, pests, and competitors can attack or starve oysters. With a good understanding of these nuisances, along with effective management strategies implemented during the lifespan of the oysters, an oyster gardener can manage the crop with the best degree of predictability possible, minimize crop loss, and head-off disaster.

- **Oyster drills**

Oyster drills are among the most common predators of oysters. After clinging to an oyster, they secrete a chemical that slowly softens the oyster shell. Abrasive action then erodes the shell, weakens it, and eventually bores a hole through to the oyster. The oyster drill then inserts its mouthparts through the hole, feeds on, extracts, and kills the oyster.

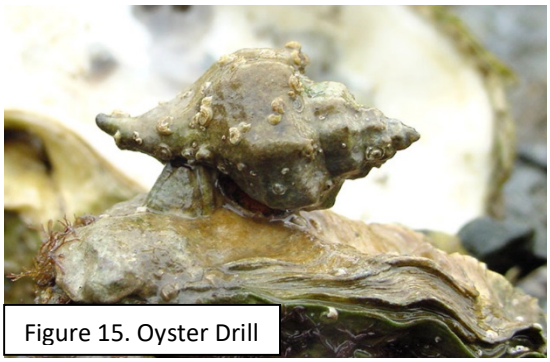

Figure 15. Oyster Drill

Salinity is one of the main forces that determine the distribution of oyster drills. Generally, they are limited to salinities greater than 15 ppt, depending on water temperature. They also can tolerate exposure to unfavorable environmental conditions for short periods of time by tightly closing and insulating themselves from their surroundings. Drills can tolerate short-term fluctuations in salinity better than long-term exposure to low salinity. At low salinity, their activity decreases.

An extreme in temperature limits the activity of drills. Feeding ceases below 50°F and decreases above 86°F. Under flood conditions with a sustained salinity below15 ppt, the drills are eliminated. At low salinity and temperature, they tend to bury themselves in the substrate and leave the oysters alone.

Various methods of controlling drill infestations have had little success. Physically trapping or using small oysters as bait have had limited success, as have other biological introductions of predators such as moon snails. A saltwater brine dip with follow-up air drying will rid containers of most of the snails and drills. Perhaps the only practical way to control drills that have infested a cage is to bring the container to the surface, dry it, pick out the drills, and move it to a different area of bottom or to an off-bottom situation.

- **Crabs**

Crabs kill oysters, especially spat and juveniles, by crushing the shell and eating the meat. Blue crabs crush small oysters and chip the lips of larger oysters to extract the meat. Stone crabs crush even large, market-sized oysters. While stone crabs are intolerant of low salinity water, blue crabs tolerate a much greater range of salinity. Thus, it is likely that some type of crab population will be a predator at any site that supports oyster culture.

Crabs are a very mobile species. They can and will enter containers as juveniles, feed off whatever is available, and grow to substantial size preying on small fishes, oysters, and seed.

Trapping can reduce the general crab population, but the best control is to check containers periodically and physically remove the crabs.

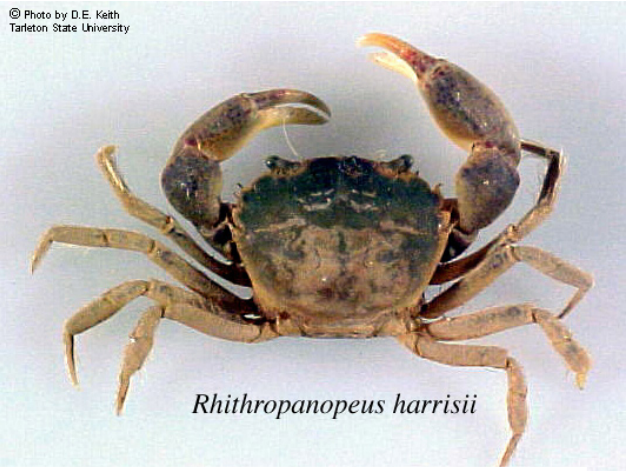


Figure 16. Common names include the Zuiderzee crab, dwarf crab, estuarine mud crab, Harris mud crab, white-fingered mud crab, and white-tipped mud crab.

Figure 17. Photo by Caroline Kanaskie

- **Flatworms**

Flatworms, also called oyster leech and *Stylochus*, are thin, flat, elliptical, and reproduce extremely rapidly. In one known instance, a flatworm laid 39,000 eggs in 48 hours. They mature sexually in about two months, and live for about a year. They flourish in a salinity greater than 15 ppt but can tolerate salinity as low as 6 ppt. Flatworms enter an oyster through a partially gaping mouth and generally prefer small (less than ¼ inch) oysters. Though they do not generally attack large oysters, in one lab experiment, three flatworms killed and ate an adult oyster in a week. They prefer barnacles, but can cause extensive mortality in crowded growing conditions.

Figure 18. Photo by Robert Aguilar, SERC

Control of flatworms is not difficult. Either a freshwater or highly saline water bath will immediately eliminate the flatworms. However, neither will protect against re-infestation when the oysters are returned to their habitat. Containers with large mesh (5/8 inch) will allow small fish to enter the container and eat the flatworms.

- **Barnacles**

Barnacles are a competitor that can become so invasive they must be removed from the oyster shell by hand to make the oysters marketable. They tend to reside in the upper portion of the water column and settle on subtidal oysters more than intertidal. Barnacles can be controlled to a degree by giving the oysters a heavy salt water bath as described in the section on salt baths.

Figure 19. nwnature.net

- **Sponges**

Sponges are among the most common intertidal pests of oysters. They attack the shell by very slowly boring holes using both mechanical and chemical etching action. In some older oysters, sponges may bore completely through an oyster and kill it. However, most commonly the damage to the oysters is in the outer shell, producing unsightly holes. If the oyster shell is penetrated completely, the oyster will quickly create another layer to prevent contact between the oyster and the sponge. In severe cases, the oyster will not rebuild its shell quickly enough to protect against the sponge, and the sponge can form adhesions to the oyster tissue, weaken it, reduce its ability to reproduce, and eventually kill it.

Cultured oysters are not immune from a sponge infestation, but they usually grow to maturity before the sponges can significantly deteriorate the shell. Giving mature seed a salt bath and drying will deter most boring sponges.

Figure 20. Bernard Picton


Figure 21. Mark A. Wilson, College of Wooster

- **Mud worms (*Polydora*)**

Mud worms lay encapsulated eggs that are attached to the inner surface of a tube on the outside shell of the oyster. The eggs develop in four to eight days depending on the temperature, settle on the outer surface of the shell, make their way to the shell lip of the oyster and bore into the shell using a chemical agent.

Mud worms do not directly attack the tissues of the oyster but force it to rebuild the inner shell over and over. As it does so, the oyster produces an unsightly black and yellow blister on the inner shell. When mud worms attack, the oyster puts its energy into shell maintenance, thereby reducing the energy it puts into growth and reproduction. Poor health and a brittle shell lead to a susceptibility to disease and predator attacks.

Figure 22. Bahia State Foundation for Research Support.

An effective control for mud worms is a simple saturation of the juvenile seed (over one inch) in a salt bath (see section on salt baths). This procedure has proven effective for a variety of problems that tend to devalue the oyster crop and should be a regular part of seed maintenance performed during the late fall, winter, or early spring of the first year.

- **Sea squirts (*tunicates*)**

Sea squirts thrive in high salinity waters and can become very destructive during extended periods of drought. Sea squirts attach themselves to oysters and oyster containers, and can become so densely packed that they choke the oysters and rob them of available food.

Sea squirts can be controlled by physically removing them from containers and through regular maintenance with a freshwater wash and heavy saltwater bath followed by a period of drying. Containers and other intertidal devices that get daily drying should remain relatively free of tunicates.

- **Over-spatting**

Over-spatting occurs when small spat attach to growing or mature oysters. While this poses a minor problem of competition, the cumulative effect – plus the effect of barnacles, sea squirts and other competitors – can lead to stunted growth, a weakened crop, and susceptibility to disease. Oysters that become over-spatted must be cleaned by rubbing and washing at harvest time, as is done with overgrowth of barnacles. Some control of over-spatting can be gained with a late fall or early winter salt bath and drying. The heavy salt

Figure 23. Lisa Kellogg/VIMS

solution will kill most of the small spat.

## Salt Baths

Salt baths use one-part salt to three-parts water, stirring to speed the dissolution process. Oysters should soak 20 minutes and then dry for at least 20 minutes. You should be able to see and taste the salt on the shell when it dries.

The salt bath is as much an art as a science. Oyster gardeners who have used this technique praise the drying process as the critical part; that's when the invading organisms die. High mortality can occur if oysters are left to dry too long, and it is possible to undo the effects of the salt bath by not letting the oysters dry long enough. Also, bacteria can grow rapidly during out-of-water activities if exposed to the sun or warm air temperatures while out of water. Smaller seed, less than one inch, may not tolerate such a concentrated solution.

When working in the hot sun, 20 minutes is plenty of time. On cooler, cloud covered days, you can be a bit more liberal and let them dry for an hour or so. Keep an eye on the oysters. If they are gaping, then it's probably time to get them back into the water. Otherwise, longer drying will produce better results.

Winter is a good time to do this chore. The organisms you are trying to keep off the shells are still young and die easily. If you give them a salt bath too early, the seed may not be able to handle the stress, and the fouling organisms would probably come back soon after the oysters go back into the water. Of course, this is not a permanent solution and fouling organisms will eventually resettle on the oyster.

## Enjoy your garden

Most of all, enjoy your new hobby. It takes work, but can be fruitful, fun, and delicious if tended well.

# Appendix A

- **Authority**

Enabling North Carolina General Statute 113 - 210 and the North Carolina Marine Fisheries Commission Rules under 15A NCAC 03O.0503 allow for the permitting and regulating of under dock oyster culture. The general statute and rules provide the authority to develop the permit and educational materials, apply appropriate conditions to the permit, and issue the permit.

- **Specific permit conditions**

Because there can be adverse health consequences if oysters are harvested and eaten under certain conditions, prospective gardeners must review and be tested on the materials in the UDOC Manual. To receive an Under-Dock Oyster Culture (UDOC) Permit, applicants must first pass a test to ensure they understand the legal requirements and safety precautions that must be taken when harvesting oysters. Test information and directions are attached at the end of the manual.

Vibrio bacteria are common and occur naturally in marine environments, especially in the months when water temperatures are warmer. Vibrio can cause gastrointestinal illness in healthy individuals, or in rare cases even death in people with certain medical conditions, such as cancer, diabetes, liver disease, stomach disorders, or weakened immune systems. The risk of Vibrio infection can be reduced by avoiding raw or undercooked shellfish. Oysters should be promptly stored under refrigeration after harvest. Please contact the Shellfish Sanitation and Recreational Water Quality Section of DMF at 252-726-6827 for more information.

• The permit holder must own the dock or pier where the oyster containers will be attached.

• The dock or pier cannot be in an area the state health director has recommended be closed to shellfish harvest due to pollution, or that has been closed to harvest by statute, rule, or proclamation due to suspected pollution.

• If the permit holder obtains oyster seed or spat from an out-of-state source, they must receive a Permit to Introduce, Transfer, and Hold Marine and Estuarine Species from the N.C. DMF to ensure adequate disease testing has been conducted.

• The permit holder shall only grow the Eastern oyster, *Crassostrea virginica*. Non-native oysters are not allowed in the UDOC Program.

• Permit holders can attach up to 90 square feet of oyster cultivation containers to a dock or pier owned by the permit holder. The containers shall be limited to a 6-inch maximum height allowing a maximum volume of 45 cubic feet.

• Permit holders shall comply with the biological data sampling and survey programs of the Marine Fisheries Commission and the Division of Marine Fisheries.

- Permit holders shall post signs indicating the presence of oyster cultivation containers and that the containers and their contents are private property. Signs shall include the permittee's name and permit number.

- UDOC permit holders may consume oysters they grow, but they are prohibited from selling their oysters.

- Permit holders must attempt to cultivate oysters on a continuous basis.

- A UDOC Permit is not assignable or transferable.

- If the permit holder fails to comply with the above requirements, the director of the Division of Marine Fisheries may revoke the permit, and the owner of the dock or pier shall remove the oyster cultivation containers within 15 days of revocation.

- The permit holder shall provide a severe weather response plan (tropical, winter, ice, etc.) and is responsible for implementing the plan when conditions warrant.

- Action by a permit holder to encroach on or usurp the legal rights of the public to access public trust resources in coastal fishing waters shall result in permit revocation.

- The permit holder is responsible for the maintenance, removal, and clean-up of the culture containers.

- No one shall take or attempt to take shellfish from the permitted containers without written notarized authorization from the permit holder.

Problems with theft or vandalism of oysters or containers should be reported to local law enforcement agencies. The N.C. Marine Patrol does not have jurisdiction over theft or vandalism of private property.

- **General Permit Conditions**

The following conditions apply to all permits issued by the DMF Director:

- It is unlawful to operate under the permit except in areas, at times, and under conditions specified on the permit;

- It is unlawful to operate under a permit without having the permit or copy thereof in possession of the permittee or his or her designees at all times of operation and shall be ready at hand for inspection, except for Pound Net Permits;

- It is unlawful to operate under a permit without having a current picture identification in possession and ready at hand for inspection. It is unlawful to refuse to allow inspection and sampling of a permitted activity by an agent of the division;

- It is unlawful to fail to provide complete and accurate information requested by the division in connection with the permitted activity;

- It is unlawful to hold a permit issued by the DMF Director when not eligible to hold any license required as a condition for that permit as stated in 15A NCAC 3O.0501;

- It is unlawful to fail to provide reports within the timeframe required by the specific permit conditions;

- It is unlawful to fail to keep such records and accounts as required by the rules in this chapter for determination of conservation policy, equitable and efficient administration and enforcement, or promotion of commercial or recreational fisheries;

- It is unlawful to assign or transfer permits issued by the DMF Director, except for Pound Net Permits as authorized by 15A NCAC 3J .0504;

- The DMF Director, or his agent, may, by conditions of the permit, specify any or all of the following for the permitted purposes:

- Species Time period Means and methods Disposition of resources

- Quantity or size Location Harvest conditions Marking requirements

- Unless specifically stated as a condition on the permit, all statutes, rules and proclamations shall apply to the permittee and his or her designees.

As a condition of accepting a permit from the Fisheries Director, the permittee agrees to abide by all conditions of the permit and agrees, that if specific conditions of the permit as identified on the permit are violated, or if false information was provided in the application for initial issuance, renewal or transfer, the permit may be suspended or revoked by the Fisheries Director.

Violation of any Rule Condition or items on the permit may result in suspension or revocation of the permit.

- **Permit Renewal**

- Permits must be renewed on an annual basis. To be eligible for renewal, the permit holder and the dock location must meet the permit requirements listed above and the permittee must document they have attempted to grow oysters on a continuous basis. The permit holder must provide documentation of permit activities for the previous year, which includes:

- Number of oysters deployed into the containers, number of oysters removed from the containers.

- Documentation of the source of the oysters (must have a valid Permit to Introduce or Transfer Marine and Estuarine Organisms if the oyster seed or spat is from out-of-state).

- Document the disposition of oysters grown under this permit (e.g., eaten, given away, mortalities, remaining).

## Appendix B

- **Resources**

Shellfish Gardeners of North Carolina
https://www.oystergardenersnc.com/

The NC Under Dock Oyster Culture Program
https://ncseagrant.ncsu.edu/ncseagrant_docs/aq/conf/2016/17_Gagnon_under_dock.pdf

NC Wildlife – Oyster Gardening
https://www.ncwildlife.org/Portals/0/Learning/documents/WINC/Sample_04/sample_sep04.pdf

NC Division of Marine Fisheries
http://portal.ncdenr.org/web/mf/

NC Shellfish Growers Association
http://www.ncshellfish.org/

NC Sea Grant
https://ncseagrant.ncsu.edu/

* Various internet sources were consulted in the update to this document. The resources referenced in the initial document are shown below:

-Galtsoff, P. S. 1964. The American oyster *Crassostrea virginica* (Gmelin). U.S. Fish Wildl. Serv. Fish. Bull. 64:1-480
-Goldsborough, W. and D. Meritt. 2001. Oyster Gardening for restoration and education. A publication of the Oyster Alliance. Publ. UM-SG-SGEP-99-05. http://www.mdsg.umd.edu/oysters/garden/garden.pdf
-Hamilton, K. and B. Page. 2004. Mobile Bay Oyster Gardening Program Training Manual. Project of the Mobile Bay National Estuary Program. 76 pp. Kim Hamilton and Blan Page (Auburn Marine Extension designed the Page Cage and the Mobile Bay Float).
-Luckenbach, M.W., F.X. O'Beirn & J. Taylor. 1999. An Introduction to Culturing Oysters in Virginia. Virginia Institute of Marine Sciences. 24 pp. http://www.vims.edu/oystergarden/CulturingOysters.pdf
-National Sea Grant College Program. 1998. Restoring Oysters to U. S. Coastal Waters. MD Sea Grant UM-SG-TS-03 & VA Sea Grant VSG-98-05. 20 pp. http://www.mdsg.umd.edu/oysters/disease/
-Perkins, B.E. 1995. Aquacultured Oyster Products. Southern Regional Aquaculture Center. SRAC Publ. No. 434. 4pp.
-Stanley, J.G. & M. A. Sellers. 1986. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic) -- American oyster. U.S. Dept of the Interior. U.S. Fish Wildl. Serv. Biol. Rpt 82 (11.65)
-Swartzenberg, J. and S. Kemp. 2004 Culturing oysters in North Carolina. North Carolina Fishery Resource Grant # 01-AM-04. CD. UNC-SG-04-12. CD available from NC Sea Grant. $ 5.00
-Talley, Jason. 2004. The Amazing Oyster: A Keystone Species for the Health of Our Coast. (DVD). North Carolina Sea Grant UNC-SG-04-01. DVD available from NC Sea Grant. $ 10.00
-Wallace, R.K. 2001. Cultivating the eastern oyster, *Crassostrea virginica*. Southern Regional Aquaculture Center. SRAC Publ. No. 432. 4pp.