SOUTHERN REGIONAL AQUACULTURE CENTER

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Non-Commercial Oyster Culture, or Oyster Gardening

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Non-commercial oyster aquaculture, popularly known as "oyster gardening," has received a great deal of attention throughout the range of the Eastern oyster, *Crassostrea virginica* (Fig. 1). Some people might oyster garden to help restore oyster stocks or improve water quality. (Oysters improve water quality by filtering out algae and sediments, and an adult oyster can pass up to 50 gallons of water per day through its gills.) Other people choose oyster gardening as a way to grow a tasty meal. Regardless of your reasons, oyster gardening can benefit our coastal environment.

Figure 1. The Eastern oyster, *Crassostrea virginica.*

Oyster gardening also can be used in the classroom to give students a hands-on learning experience and to teach research protocols (sampling techniques, record keeping, etc.), biology and ecology, water quality monitoring, and general academic skills. The oyster gardening experience helps connect students with the coast and demonstrates how their actions can affect our natural environment.

The first section of this publication addresses the growing of oysters, while the second contains information for educators who would like to use oyster gardening in their lesson plans.

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Growing oysters

The success of an oyster garden depends on both the site and the amount of effort the gardener puts into it. For those who are interested and able, oyster gardening can be a pleasurable and tasty pastime. Just like a traditional vegetable garden, an oyster garden must be planted with seed, tended during the growing period, protected from pests, and harvested when ready. The most successful gardeners, vegetable or oyster, are those who are best educated about all aspects of their "crop."

Regulatory issues

It is vital that you adhere to all rules and regulations regarding the culture of oysters in your state waters. A permit may be required, and there may be regulations for handling or harvesting oysters. Before starting your garden, contact your local marine resources management agency to find out what regulations apply. Not all coastal states permit individual oyster gardening.

It is important that your oyster garden neither interfere with navigation nor adversely affect natural resources, such as shading submerged aquatic vegetation.

Consuming contaminated oysters can cause serious illness. Commercial shellfish harvesters are strictly regulated to ensure that a wholesome, healthful product is delivered to the public. Oyster gardeners must understand the potential health risks and be prepared to follow the same rules and regulations that govern commercial production. Not doing so can put your health and the welfare of the commercial oyster industry at risk. Contact your state shellfish sanitation control agency (which is usually associated with the state department of health) for their rules and regulations regarding oyster gardening. Your state shellfish sanitation control agency is responsible for classifying waters as to their appropriateness for harvesting oysters for consumption. Raising oysters in "other-than-approved" waters is not advised because they will accumulate bacteria and viruses that could cause illnesses. Even pristine waters can contain bacteria that can cause illnesses at certain times of the year. The website for the Interstate Shellfish Sanitation Conference (*www.issc.org*) contains information on shellfish safety and provides the contact information for state shellfish sanitation control agencies. For more information on the health implications of oyster culture, see SRAC Publication No. 4902, "Shellfish Handling Practices—Shrimp and Molluscs."

Site evaluation

If oyster gardening is a legal pastime in your area, the next step is to determine whether your gardening site is conducive to raising oysters. To evaluate a potential site, consider water salinity, water depth, site exposure, dissolved oxygen, and food availability. The presence of wild oysters at your site is a good sign that your location will support your gardening activities. Additional information can be found in SRAC Publication No. 432, "Cultivating the Eastern Oyster, *Crassostrea virginica*."

Salinity

The salinity of the water at your site will influence the growth rate of your oysters and whether they may become exposed to oyster-specific diseases. Generally, oysters require water salinity of at least 8 parts per thousand (ppt). The higher the salinity, the faster oysters grow.

Water salinity is measured as grams of salt per liter of water, or ppt. You can measure salinity at your location using inexpensive equipment such as a hydrometer, which can be found at pet stores that sell saltwater fish. It is a good idea to keep records of the salinity at different times of the year, under varying environmental conditions (for example, after a rainfall), and at different tidal cycles. This could help you make decisions about your oyster gardening activities.

There are two diseases specific to oysters than can have a devastating effect on your crop, though the diseases do not affect humans. Both diseases are caused by protozoans. The first is MSX (*Haplosporidium nelsoni*), and the second is Dermo (*Perkinsus marinus*). MSX organisms cannot live in salinities below 10 ppt. In fact, the pathogen can be completely eliminated from infected oysters if the oysters are held in salinities below 10 ppt for 2 weeks. Dermo can survive in salinities below 10 ppt, but it will not kill oysters at that level. Should the salinity level rise above 10 ppt, Dermo can become quite deadly to oysters. Fortunately, disease-resistant oyster stocks have been developed that reduce the problems associated with these diseases. More information on these two oyster pathogens and other molluscan shellfish diseases can be found in SRAC Publication No. 4704, "Diseases of Concern in Molluscan Aquaculture."

Water depth and air exposure

As a rule, a minimum of 1 foot of water at lowest tide is considered necessary for normal oyster gardening activities. Plant your garden in a place where the oysters will remain submerged. However, keep in mind that water depth can influence oyster growth, oyster mortality, and the measures you will need to take to protect your oysters from predators (see the section on containment systems). Avoid areas with excessive wave or wind action, which can decrease the growth rate of your oysters and require a more secure containment system.

Although oysters can survive outside of the water for extended periods of time, to grow they must filter algae from the water. If oysters are exposed to the air during low tides it will take more time for them to grow. However, some air exposure may control biofouling (hydroids, bryozoans, sea squirts, etc., that may grow on oysters and containment systems). If it becomes thick enough, biofouling will slow oyster growth and possibly increase oyster mortalities.

Keep oysters in the water during winter months, especially if your oyster garden is in an area that experiences extremely cold temperatures and possibly ice accumulation. You may need to move your oysters to deeper waters during the cold season to make sure they stay submerged and away from the cold air.

Oxygen

Oysters are aerobic animals and require oxygen to survive. A dissolved oxygen level of at least 3.2 mg/L (milligrams per liter) is necessary, though levels of 5.5 mg/L or higher are ideal. In low-oxygen conditions, oysters may close their shells. They can survive with their shells securely closed for short periods of time, but they cannot eat and grow when they are closed. Normally, areas with good water flow will have enough dissolved oxygen for oyster growth and survival. If you are uncertain about oxygen levels at your garden site, easy-to-use kits that measure environmental parameters or nutrients are available from numerous sources; a quick Internet search will identify many options.

Food availability

Oysters consume single-celled micro-algae, known as phytoplankton. The quantity and quality of phytoplankton can vary depending on location and time of year. It is difficult to measure phytoplankton at a growing site, though using a Secchi disc to measure clarity/turbidity can give a rough estimate of the food available. One good indicator of food availability is the presence of other filter-feeding organisms, such as naturally occurring oysters, clams, or mussels. Again, areas with good water flow will usually have adequate food to support your oyster garden.

Figure 2. Oyster seed ready to be planted.

Oyster seed

Oyster gardeners rely upon commercial shellfish hatcheries for their seed (Fig. 2). Researchers have developed high quality oyster broodstock for producing disease-resistant oyster seed.

Oyster seed is available as diploids, containing the normal two sets of chromosomes, or as triploids, containing three sets of chromosomes. The choice of diploids or triploids depends upon your goal. If you want to produce oysters for restoration or conservation efforts, use diploid oysters, which can reproduce. If you're growing oysters to eat, you can choose either diploids or the non-reproductive triploids. However, triploid oysters tend to grow a little faster and are edible during warmer months, whereas diploid oysters spawn and atrophy during warmer months, making them less desirable for consumption.

When choosing oyster seed, select the best available broodstock. Disease-resistant seed should be chosen for oysters you plan to eat. For oysters intended for restoration or conservation purposes, consult with local resource managers as to the preferred broodstock for your area.

Whenever possible, purchase seed from local shellfish hatcheries. If there are none in your area, visit the East Coast Shellfish Growers Association website for a list of shellfish seed suppliers (under the "Resources" heading at *www.ecsga.org*). Some states restrict the entry of oyster seed from areas other than neighboring states or may have strict guidelines regarding importation, including requiring certification that the seed is disease free. Great care must be taken not to introduce diseased oyster seed into a disease-free area. Contact your state resource management agency about regulations pertaining to the importation of oyster seed into your state.

Oyster seed can be purchased in different sizes, generally based upon the length of the shell as measured from the hinge to the farthest margin of the shell edge. Most oyster gardeners prefer to purchase 1-inch-long seed because less gear will be needed during the growing season. Seed smaller than 1 inch will require smaller mesh bags to prevent seed from falling through mesh openings. With experience, the oyster gardener will know which size oyster seed is best for a particular growing site.

Purchased oyster seed is usually packaged in fine-mesh bags. These bags can be transported to the growing site in a cool container, avoiding any direct contact with ice or other coolants. Seed should not be submerged in water during transport. Once at the growing site, the seed should be permitted to acclimate to the ambient temperature, put into the appropriately sized mesh bag to prevent seed from falling through, and planted. Keeping seed in the bags used to transport them to the growing site, even for a very short period of time, is not advised. Predators can attack seed bags and damage or destroy the seed.

Containment systems

Why use containment systems?

Oyster gardeners usually use containment systems, also called growout gear, for good reason.

- Oysters grow best when they are floating within the water column or held above the sediment, and containment systems are designed to keep oysters off the bottom. The water column is ideal because oysters have better access to food and less contact with fine sediments.
- Containment systems protect small oysters from predators. Oyster gardeners usually plant cultchless oyster seed—single oysters that are not attached to a substrate. At this small size, cultchless oysters are extremely vulnerable to a variety of predators. Using a containment system will help keep predators from getting your oysters. (For more information on the production of oyster seed, cultchless and spat-on-shell, see SRAC Publication No. 4302, "Oyster Hatchery Techniques." For information on oyster predators, see Publication No. 180 from the Northeastern Regional Aquaculture Center, available at *www.nrac.umd.edu*.)
- Containment systems make handling oysters easier. Just like a vegetable garden, you have to tend

an oyster garden by removing unwanted plants and competitors. A containment system makes it easier for you to accomplish these tasks, and the more easily you can garden, the more likely your success.

Types of containment systems

Oyster garden containment systems are either floating or submerged. Neither is preferable. Here are some things to keep in mind when choosing a containment system:

- Wave action. If you're gardening in a place where waves are very strong, a submerged containment system might be easier to secure in place than a floating system.
- Firmness of the sediment. Mucky, soft mud bottoms may not support the combined weight of submerged gear, oysters, and the gardener. In this situation, floats might be best.
- A dock or other structure. Floats will need to be secured to some structure so they don't float away.
- Weather. In northern areas with cold winters, either type of containment system is fine; however, you will need to choose the system that is easiest to move or keep your oysters submerged during the winter when cold air temperatures can kill oysters. Areas that experience severe weather conditions such as hurricanes or strong northeaster storms need containment systems that can be quickly secured or removed from the water in advance of inclement weather.
- Aesthetics. Submerged systems may be preferable in shallow waters where the use of floats might be visually unacceptable to adjacent property owners.

You can purchase containment devices or construct your own. Start with a quick Internet search for "oyster gardening supplies" to find available equipment or instructions for constructing your own. The Tidewater Oyster Gardeners Association website (*www.oystergardener.org*) contains pictures and information on a variety of different containment devices, including construction directions

Floating gear. Floating oyster containment systems float either at or near the surface. These containment devices are known as Taylor floats, flip-floats, float bags, floating cages, OysterGro™, Aquapurse™, etc. All of these are designed to keep oysters within about 1 foot of the water's surface. Aquapurse™, for example, can be attached to a float or suspended from a line at the water's surface and hangs down into the water column.

Taylor floats, named after their inventor, were the first containment devices introduced to oyster gardeners (Fig. 3). Taylor floats attach a wire mesh basket to a floating PVC frame. The basket is usually constructed of plastic-coated wire mesh with 1-inch-square openings. The PVC

Figure 3. Taylor float designed to hold oysters in the upper water column.

float can be any size, but oyster gardeners usually find smaller floats are more manageable. Small oyster seed less than 1 inch long are placed in oyster growing mesh bags, which in turn are placed within the Taylor float. As the oysters grow, growers move them to larger mesh bags until the oysters are big enough to rest within the basket without falling through. Depending on the float size, 500 to 1,000 3-inch oysters can be held. Search the Internet for "oyster mesh bags" to find vendors and various mesh sizes available.

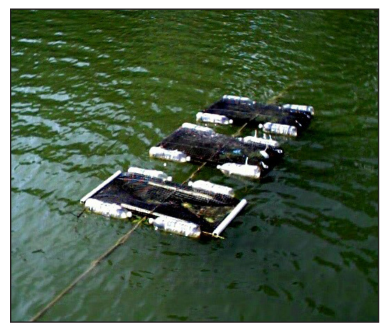

Figure 4. Plastic mesh cages with empty 2-liter soda bottle floatation.

Plastic mesh bags for growing oysters also can be attached to floatation devices such as empty soda bottles (Fig. 4), pool "noodles," or specially designed float "torpedoes" (see the Tidewater Oyster Gardeners Association website). You may need to add more or different floats to handle the increasing weight as your oysters grow or as biofouling increases. Floating mesh bags are easy to handle but do not usually hold more than 150 large oysters.

Submerged gear. As with floats, you can purchase or make your own submerged containment equipment. One type of submerged gear is called a rack-and-bag system (Fig. 5). This is the simplest of the bottom gears; in fact, commercial oyster growers use this type of gear, too. The same plastic mesh bags used in floats are secured to a steel rebar rack with legs. The legs are pushed into a firm, sandy sediment so that the bags holding oysters are completely submerged but several inches above the bottom. Rack-and-bag systems can be used at sites where low tides drop very close to the sediment and may expose oysters occasionally. This short air exposure will help control biofouling and make cleaning and handling the bags easier. As with floating plastic mesh bags, only about 150 large oysters can be held in the individual bags of a rack-and-bag system.

Bottom cages also keep oysters several inches above the bottom and are another popular containment system for gardeners and commercial oyster growers. Bottom cages can be made any size, but larger cages will require heavy lifting devices. This particular gear is best for very firm sediment or rocky bottoms. Bottom cages operate much like Taylor floats; they require plastic mesh bags until the oysters are large enough to remain within the cages.

Figure 5. Rack-and-bag culture system for growing oysters in the intertidal zone.

Maintenance

Before you plant oysters, take time to label your containment gear with your name, address and telephone number. Despite best efforts at securing your gear, accidents do happen and gear, especially floating containers, can escape. Having your contact information prominently displayed on your gear could result in the timely return of your garden should it become dislodged from your growing location.

When first purchased, put oyster seed into the largest mesh bag that will prevent them from falling through the openings but will provide the greatest flow of water. This water exchange is important for bringing in new food (phytoplankton) and removing fecal matter or other material (sediment, etc.). A standard plastic mesh bag will measure 36 inches by 18 inches by 2 inches. As many as 1,000 1-inch oyster seed can be initially stocked in a single plastic mesh bag. However, the small seed can grow quickly, overcrowding the bag. At this point the seed needs to be culled and split into additional bags to prevent stunting. It may be necessary to cull and split the oysters several times until the final growout density is achieved within the mesh bag (~150 individuals) or until time to release them into a larger containment device. You will know when to cull and split by routinely inspecting the containment systems for signs that oysters are becoming overcrowded. You should anticipate the increasing number of bags necessary to accommodate the final number of oysters you wish to grow.

Once planted, your oyster garden should be tended like any other garden. During the warmer months, gear should be tended every couple of weeks; in colder months gear may need tending every 4 to 6 weeks or less. Containment gear must be cleaned to remove fouling organisms, food competitors, and vegetation or debris that may restrict water flow. This is also the time to evaluate the need to cull and split the crop. Fouling organisms and food competitors (sea squirts, barnacles, and other filter-feeders) should be removed regularly. Soft-bodied animals can be washed off, while the more tenacious, harder ones may require brushing. Air-drying gear or dipping it in brine helps in cleaning. Some gardeners have additional, clean containment gear on hand and simply move oysters into the clean gear while the other gear is getting cleaned.

Containment gear must also be inspected for the presence of predators, especially crabs. When small crabs enter mesh bags, they may prey on small oysters and live within the bags until they are large enough to eat larger oysters. Any crab within a mesh bag should be removed.

Dead oysters and shells also can be removed. It is a good practice to keep records of oyster deaths over time so you can gauge how well your garden is growing.

Your garden is also going to attract many other animals, including small fish, shrimp, and other crustaceans. Most of these will not cause problems but are simply taking advantage of the protection provided by your gear. Observing this variety of animals can be a source of enjoyment for gardeners and provide educational opportunities as well. Just make sure you return these oyster “neighbors” to the water as soon as possible. You can avoid pulling these animals onto dry land by shaking containment gear over the water before moving the gear to a dock or onto the land.

Adverse weather can cause special maintenance needs. Hurricanes and severe weather are a fact of life in the region where Eastern oysters grow. Take special precautions when these storms are predicted. Heavy rainfall may decrease river or creek salinities to lethal levels for oysters. Tether gear to solid structures or remove and store away from the water. In either case, if you keep oysters covered and moist most will survive a couple of days out of the water. Remember, it is better to lose some oysters than to lose all your oysters and the containment gear.

The final maintenance task is harvesting. The size of the oyster at harvest will be based on your reason for oyster gardening. Oysters grown for restoration purposes may be harvested at any size, depending upon the criteria being used by the restoration agency. Most gardeners raising oysters for personal consumption prefer to let their oysters grow to almost 3 inches in shell length. Depending upon the growing conditions, oysters could reach this size in as little as 12 months after planting. The final decision is whether to eat them raw, roasted, steamed or stewed!

Oyster culture as a learning tool

Each school year, many teachers use oyster gardening to grab students' attention in the science classroom. In Virginia alone, during the last 14 years more than 81,000 students have helped raise roughly 4.4 million oysters and transplant them into local waters.

Many teachers are finding that oyster growing in the classroom can provide hands-on activities to support standards-based concepts. Evidence shows that meaningful hands-on education improves student performance. Not only do students do better on standardized tests in science, literacy, and mathematics (Stohr-Hunt, 1996; Jorgensen, 2005), but their engagement and participation, concept comprehension, classroom grades, and uniformity of achievement also improve (Tretter and Jones, 2003). Other studies show that repeated outdoor, place-based learning results in a positive behavior change towards the environment (Prather, 1989; Sobel, 2004), and that these opportunities can increase attentiveness in students with attention deficit/hyperactivity disorder (Kuo and Taylor, 2004). As most environmental educators and students can attest, there is no better route to hands-on education than getting wet and muddy.

From its role as a staple food at the Jamestown Settlement in the early 1600s to the battles it caused during the so-called Oyster Wars on the Chesapeake Bay and Potomac River in the late 1800s, the oyster's place in our country's history and literature makes it a model specimen for interdisciplinary, hands-on learning. The oyster can inspire learning activities in courses other than the sciences, including writing/language arts, social studies, math, engineering, and economics. And, or course, growing oysters is an excellent way for students to learn and practice environmental stewardship and natural resource restoration.

Key teaching points are:

- the importance of oysters to the environment (removing algae and sediment from the water, providing crucial habitat for juvenile fishes and invertebrates)
- the importance of oysters to the economy (creating jobs and income for the watermen who harvest them, processors who shuck and package them, and restaurants that serve them)

Integrating oyster gardening into the classroom is not an easy project, particularly if your school is not located near a body of salt or brackish water. But with lots of teamwork from teachers, students and parents, an oyster growout project can have many positive, long-lasting outcomes for you and your students.

Science classroom activities

There are many useful classroom resources for teachers and informal educators who are interested in teaching about oysters without using the live organism. A sampling of these activities can be found in the Additional Web Resources section. These activities demonstrate the ecological and economic importance of the Eastern oyster, *Crassostrea virginica.*

The following eight activities are for teachers who want to raise oysters with their students. They can help integrate the project into a variety of courses at most grade levels (see Table 1). These activities have been aligned to the National Science Education Standards (National Research Council, 1996; *www.nap.edu/html/nses/*) to assist with state standards alignment (see Table 2), and they have been aligned with the Ocean Literacy Essential Principles (Ocean Literacy Network, 2005; *www.coexploration.org/oceanliteracy*) as well (see Table 3).

The first three activities below were developed by Laurie Carroll Sorabella, Director of Oyster Reef Keepers of Virginia, Inc. (ORKVA). ORKVA has been facilitating classroom oyster projects since 1997 and has helped teachers and students raise millions of oysters. These oysters have been transplanted, in most cases by the students, to restoration reefs in Chesapeake Bay tributaries throughout southeastern Virginia. For more information on any of the ORKVA activities below, please contact Laurie Carroll Sorabella at *oysterreefkeeper@yahoo.com* or (757) 460-1200.

Meaningful Sampling (ORKVA)

Measuring and recording your oysters' shell lengths with a Vernier caliper or standard ruler is an important step in monitoring their growth over time. This activity guides students through two ways of sub-sampling to help them understand which is more accurate. Group N measures 50 individual oysters they have picked one by one from the growout bag. This usually results in students selecting and measuring larger oysters (Fig. 6). Group R measures the first 50 oysters they have scooped from the tray. Group N's average length will most likely be larger than Group R's average because of the selective subsample vs. the random sample. To speed the process of measuring oysters and counting the dead oysters (Fig. 7), consider sampling a subset of your population. This activity includes several discussion questions, a data sheet, a data table, and graph paper for charting the N vs. R data.

Growth & Mortality (ORKVA)

Recording the shell lengths of randomly subsampled oysters allows students to track the growth of their oyster population over the course of the school year. When average length is plotted against time and/or water quality parameters, students can draw conclusions about what may

Table 1. Correlating live oyster activities to course/topic areas.

		Course/Topic Area									
Activity	Author	Life Science	Physical Science	Oceanography	Ecology	Geometry	Algebra	Economics	Graphing	Engineering	Observation/Teamwork/ Communications
Live oyster activities											
Meaningful Sampling	ORKVA	X		X	X		X				X
Growth & Mortality	ORKVA	X		X	X		X		X		X
Common Oyster Reef Dwelling	ORKVA	X		X	X				X		X
Water Quality Monitoring	n/a		X	X					X		X
Oysters and a Clear Bay/ Filtering Demonstration	Chesapeake Bay Foundation	X		X	X				X		X
Oyster Anatomy Lab	Maryland Sea Grant	X			X						X
Oyster Genetics	n/a	X		X			X	X	X	X	X
Design a Better Oyster Trap	n/a	X				X	X	X		X	X
General oyster education resources											
Bridge DATA: Juvenile Oyster Disease	The Bridge	X			X		X		X		
Education on the Halfshell	Louisiana Sea Grant	X			X					X	X
Oyster Shell Observations	Beacon Learning Center			X							X
Tragedy of the Commons	Garrett Hardin	X		X	X				X		X
VIMS Molluscan Ecology Resources	VIMS Mulluscan Ecology Program	X		X	X		X		X		X
Living Bay Online	Living Classrooms Foundation	X		X	X		X				X
ALEARN Oyster Resources	ALEARN	X			X						

Table 2. National Science Education Standards that can be taught using live oyster activities.

National Science Education Standards		Grade Levels
Science as Inquiry	Abilities necessary to do scientific inquiry	5–8; 9–12
	Understanding about scientific inquiry	5–8; 9–12
Life Science	Structure and function in living systems	5–8
	Reproduction and heredity	5–8
	Regulation and behavior	5–8
	Populations and ecosystems	5–8
	Diversity and adaptations of organisms	5–8
	Molecular basis of heredity	9–12
Science and Technology	Abilities of technological design	5–8
Science in Personal and Social Perspectives	Populations, resources, and environments	5–8
	Natural resources	9–12

Table 3. Ocean Literacy Essential Principles and Fundamental Concepts that can be taught using live oyster activities.	
Ocean Literacy Essential Principles and Fundamental Concepts	
1. The Earth has one big ocean with many features.	e. Seawater makes up most of Earth's water and it has unique properties. h. Although the ocean is large, it is finite and resources are limited.
5. The ocean supports a great diversity of life and ecosystems.	d. Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms. e. The ocean is three-dimensional, offering vast living space and diverse habitats. f. Ocean habitats are defined by environmental factors, and their interactions with other factors. i. Estuaries provide important and productive nursery areas for many marine and aquatic species.
6. The ocean and humans are inextricably interconnected.	b. The ocean provides food and jobs and supports our nation's economy. e. Humans affect the ocean in a variety of ways.
7. The ocean is largely unexplored.	b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes. c. The use of ocean resources has increased and future sustainability of resources depends on our understanding of those resources. f. Ocean exploration is truly interdisciplinary.

Figure 6. Randomly sampled oysters (left) contain a wide range of sizes, but selectively sampled oysters (right) are more uniform in size.

Figure 7. In this picture, dead oysters are open without any soft tissues inside. Sometimes dead oysters will be found with decaying tissue still inside.

contribute to their oysters' growth rate—such as water temperature or food availability. Using a Secchi disc to measure turbidity could provide a crude estimate of food availability.

While recording oyster shell lengths, students can also record the number of dead oysters per subsample. Students can calculate the mortality rate using the following formula:

$$\left(\begin{array}{c}\text{Dead}\\\text{oysters}\end{array} \div \begin{array}{c}\text{Total number}\\\text{of oysters}\end{array}\right) \times 100 = \begin{array}{c}\text{Mortality}\\\text{rate (\%)}\end{array}$$

Mortality rate can be graphed along with water quality parameters to determine whether water quality is the cause of oyster death. Remember that some mortality is normal in any oyster population. By recording mortality each time the oysters are tended, a cumulative oyster mortality rate can be calculated for each oyster cohort raised.

Common Oyster Reef Dwelling Organisms: Dichotomous Key Activity (ORKVA)

Just as coral reefs harbor countless organisms in tropical waters, the nooks and crannies of an oyster reef or growout bag provide habitat for other ecologically and economically important species in temperate waters. Entire food webs exist in, on and around an oyster reef. In this activity, while measuring, counting and cleaning their oysters, students use a dichotomous key to identify other species. Students then record and graph the total counts of each organism present. Higher level students can use organism counts to calculate biodiversity indices (such as species richness, species evenness, and the Shannon-Weiner Index) for their oyster floats. A dichotomous key for the Virginia area is provided. If it does not apply to your location, you can work with your students to create one specific to your area.

Water Quality Monitoring

As mentioned in the oyster gardening section, monitoring the water quality at your oyster grow-out site is imperative. At the very least, measuring salinity, water temperature, and turbidity and tracking the tides may help explain the growth and mortality rates of your oysters. Measuring additional parameters such as dissolved oxygen, water current speed, and chlorophyll *a* concentration will provide more data for students to analyze. Depending on the sampling frequency, these data can be plotted, either by hand or with graphing software, across time to display daily and seasonal trends and episodic events such as coastal storms. Water quality data can also be graphed and compared to oyster length and mortality averages, which might allow students to draw conclusions about factors that contributed to oyster growth and death. These parameters can also be plotted against each other to determine relationships—e.g., dissolved oxygen vs. water temperature.

There are high- and low-tech methods for measuring all of the water quality parameters discussed above, and most equipment is available from any science supply company. If your growout site is near a NOAA- or university-sponsored coastal observation buoy, real-time and archived data are available via the Internet. Unlike data recorded by students at discrete times, buoys continuously measure water and air quality, providing more complete coverage of short-term anomalies and major storm events. To find observation buoys near you, visit *www.ndbc.noaa.gov.*

Oysters and a Clear Bay

Oysters and a Clear Bay is a product of the Chesapeake Bay Foundation (CBF; *www.cbf.org*) that integrates observation with engineering, history and graphing. This publication has classroom activities and instructions for demonstrating an oyster's filtering power, as seen in this CBF YouTube video: *www.youtube.com/user/ChesapeakeBayFound#p/u/58/VTuBbuUro4g.* Teachers can simply show this video of oysters filtering a tank of water, or create their own demonstration using oysters from the classroom project or large Eastern oysters borrowed or purchased from an oyster gardener, commercial grower, shucking house, or even grocery store.

The full version of *Oysters and a Clear Bay* is available at *www.ngsednet.org/community/resource_uploads/SW%204.2S%20_oyster.pdf.*

Oyster Anatomy Lab

Maryland Sea Grant offers the most comprehensive guide to conducting an oyster dissection available on the Internet. The online guide has high-resolution images of internal and external anatomy, Quicktime movies, a glossary, and links to additional resources; it follows the 5E Learning Cycle Model. The guide is available as a webpage and as a downloadable document at *www.mdsg.umd.edu/issues/chesapeake/oysters/education/anatlab/.*

Oyster Genetics

Scientists have engineered an oyster that has three sets of chromosomes in each cell (triploid) instead of the two sets that normal oysters have (diploid). Triploid oysters are reproductively inactive, and instead of using energy to produce eggs and sperm, the triploid oyster's energy is used solely for growing. From a commercial standpoint, these oysters are ready for market sooner than their diploid relatives, and unlike diploid oysters, the soft bodies of triploid oysters do not atrophy during the reproductive season.

To investigate diploid vs. triploid oysters further, you may be able to obtain triploid oysters from commercial growers or university oyster hatcheries. Include triploid oysters in your oyster growout system, keeping them separate from your diploid oysters, and compare growth and mortality rates as outlined above. Differences in growth and mortality rates may be harder to observe if your oysters are transplanted to a restoration reef before the spawning season.

Design a Better Oyster Trap

Built of PVC pipe and wire, the Taylor float is by far the most popular containment system for small, and even some large-scale, oyster growout operations. While the Taylor float can become heavy and awkward to handle, this design has several advantages. Taylor floats hold a large number of oysters at the surface where food is readily available and where they are easily accessible. To build engineering skills, have students design a better oyster containment device. Understanding the oyster's biology, such as dissolved oxygen and food requirements, students can research, conceptualize, design, and build a more advantageous oyster containment system. If successful, share their systems with your state's Sea Grant Aquaculture Specialist who can facilitate further research and design.

Additional Web resources

The following activities can be used to teach the importance of the Eastern oyster, either to supplement an on-going oyster growout project, or in the absence of one.

Bridge Data Analysis Teaching Activity— *Juvenile Oyster Disease: A Growing Problem*

In this activity from The Bridge, students determine if oyster size, time of planting, or water temperature are significant in relation to the onset of juvenile oyster disease using data from the University of Maine. *www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive0103.html*

Education on the Halfshell

Created by Louisiana Sea Grant and focusing on an oyster hatchery at Grand Isle, Louisiana, this activity will help students understand how an oyster hatchery is run and why it is an important resource to the economy.
lamer.lsu.edu/halfshell/culturecycle.htm

Oyster Shell Observation

Students use oyster shells to observe and identify specific attributes and communicate those in writing to other classmates. This activity helps students practice proper scientific observation and communication.
www.beaconlearningcenter.com/Lessons/790.htm

Tragedy of the Commons

This classic article written by Garrett Hardin was published in the journal *Science* in 1968. It describes the problems that arise when some limited resource is shared among multiple individuals who act independently and in their own self-interest, as was the case with oyster harvesting in early America. An Internet search will provide many different activities based on the Tragedy of the Commons concept; however, the simulation listed below is endorsed by The College Board Advanced Placement Program.
www.sciencemag.org/content/162/3859/1243.fullapcentral.collegeboard.com/apc/members/repository/ap03_apes_tragedy_stu_35071.pdf

Virginia Institute of Marine Science Molluscan Ecology Program website

The very successful Molluscan Ecology Program at the Virginia Institute of Marine Science (VIMS) has published numerous educational resources about oysters and their predators. Several resources are available as free, downloadable pdfs.
web.vims.edu/mollusc/education/meeducate.htm

Living Bay Online

From the Living Classrooms Foundation (LCF), this website includes a 10-lesson curriculum that integrates the science of oysters with language arts, social studies, math, and economics concepts. Additionally, there are ten highly interactive demonstrations, quizzes, and challenging activities that teach about oysters, algae, and the Chesapeake Bay. Activities cover topics such as breeding disease-resistant oysters, managing the oyster industry, and methods of oyster harvesting.
www.livingclassrooms.org/lbo/index.html

ALEARN Oyster Resources

The Alabama Education in Aquatic Sciences, Aquaculture, Recreational Fisheries and Natural Resources Conservation (ALEARN) cooperative effort has posted several valuable oyster resources, including a 5-minute video on using thermal shock to spawn oysters. They also provide three supplemental readings on cultivating oysters, oyster hatchery techniques, and oyster products food safety. The website includes activities about fisheries, finfish aquaculture, the water cycle, and water quality.
www.aces.edu/dept/fisheries/education/lessonplans.php

Model Oyster-in-the-Classroom Programs

- **Christchurch School, Virginia**
  Students at Christchurch School are actively involved in the school's oyster farming project on the banks of the Rappahannock River. Oysters are raised for restoration and are sold locally for consumption. Money raised by the project is invested in raising more oysters. Students work with the Chesapeake Bay Oyster Company (*www.bayoyster.com*), a local commercial oyster farm, to learn oyster biology and the importance of oysters to the Chesapeake Bay, while also learning about stewardship and sustainability.
  www.christchurchschool.org
  sites.google.com/site/antiochccs/about-me
- **Marine Academy of Technology and Environmental Science (MATES), New Jersey**
  For the past several years, students at MATES have been working with a local organization, ReClam the Bay (www.reclamthebay.org), raising oysters in the classroom. The oysters are then used for restoration. Students closely monitor water quality and test hypotheses through experimentation to find optimal growing conditions.
  www.ocvts.org/htm/mates/mates-academy.html
- **Point Option School, Virginia**
  Getting students out of the classroom and into the field, Point Option's oyster restoration program is teaching students not only about oysters and why they are important, but also about social responsibility. Students measure water quality and learn about the oyster's rich history in the Chesapeake Bay, working with the education staff at the Watermen's Museum in Yorktown, Virginia (*www.watermens.org/*), while raising oysters for restoration.
  pointoption.nn.k12.va.us/
  www.nnpstv.com/index.php?option=com_seyret&Itemid=53&task=videodirectlink&id=491
- **Urban Assembly New York Harbor School, New York**
  On Governors Island in the heart of New York Harbor, inner-city students are raising 500,000 oysters and numerous finfish species in systems they designed and built as a part of their curriculum. Students also take courses in aquaculture, marine technology, marine engineering, and

marine policy. The goal of the New York Harbor School is to instill ethics and foster stewardship in its students, while helping to restore the waters around New York City.
www.newyorkharborschool.org/

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NOAA U.S. DEPARTMENT OF COMMERCE

USDA United States Department of Agriculture — National Institute of Food and Agriculture

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