A STEP BY STEP GUIDE:
Oyster Gardening Can Help Virginia's Coast
Successes in Restoration Efforts
How to Start and Maintain an Oyster Garden
Animals of the Oyster Garden
Stories from Oyster Gardeners
Oyster Gardening Websites and Contacts

Start growing your oysters today for a healthier tomorrow!
This 2nd edition of the Virginia Oyster Gardening Guide was produced by the Virginia Coastal Zone Management (CZM) Program in partnership with the Virginia Marine Resources Commission, Virginia Institute of Marine Science, Tidewater Oyster Gardeners Association, Oyster Reef Keepers, Chesapeake Bay Foundation and Virginia Department of Health.

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Cover photo by Laura McKay. Photo above courtesy of TOGA. Photo upper right courtesy of TOGA. Photos bottom right top to bottom - oyster seed and oyster float, courtesy of TOGA; mud crab by K. Hill, Smithsonian Marine Station at Fort Pierce, FL; oysters on the half shell, courtesy of CBF. Back cover photo by Tom Zolper/CBF.
Welcome to Oyster Gardening!

Thank you for starting your own oyster garden!

We hope this oyster gardening guide will help you learn how to grow oysters in the most efficient way possible while gaining an understanding of the value oyster gardening brings to improving habitat, water quality and the overall vitality of our coastal waters.

The information is as up to date as possible, but as new information becomes available, please check the Web sites listed at the end of the guide for the most current information.

We hope that through oyster gardening you will become a proponent for restoration efforts to help increase oyster populations and improve Virginia's coastal waters. We also hope that you will encourage others to take up this hobby. Remember even if you don't own waterfront property, your friends, neighbors, employers, schools, local parks and businesses might - and you could be the one to get them hooked on oyster gardening.

Have Fun!

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Oyster Gardening Can Help Virginia's Coast!

Whether you are planning to grow oysters for your own consumption, for donation to sanctuary oyster reefs or for some other reason, your efforts can help improve water quality and biodiversity along Virginia’s coast.

Virginia's coastal population has increased 41% from 3 million in 1986 to 5 million in 2010. We are the 8th fastest growing state in the country. As Virginia’s population continues to increase, it becomes more and more difficult to reduce the increasing amounts of fertilizer (from lawns and farms), stormwater runoff and other pollutants associated with human activities that contribute huge quantities of nitrogen to coastal waters. Too much nitrogen causes algae blooms, turning the water a greenish hue and preventing sunlight from reaching underwater grass (SAV or Submerged Aquatic Vegetation) beds that provide critical habitat for finfish and other shellfish.

When the algae die, decomposing microorganisms proliferate. Decomposers consume dissolved oxygen and their sudden increase in numbers remove large amounts of oxygen from the water, creating a condition known as anoxia, or absence of oxygen. Anoxia can kill shellfish and finfish - especially species that cannot swim away from the anoxic area. The end result of excessive nutrients like nitrogen and phosphorus in coastal waters is dead finfish and shellfish and many other animals, as well as the loss of a critical part of the Bay and coastal ecosystem. Many nutrient reduction efforts focus on land-based solutions. Growing oysters can potentially contribute to nutrient reduction.

Clear water is needed in order for sunlight to reach underwater grasses rooted to the bottom. SAV beds are essential habitat for other finfish and shellfish. Eelgrass is ideal nursery habitat for the bay scallop, which as juveniles attach themselves to eelgrass blades to stay out of reach of predators. Photo courtesy of VIMS.

In addition to helping to clear the water by filtering out algae and sediment, natural oyster reefs provide habitat to a tremendous number and variety of other finfish and shellfish. See the Oyster Toadfish hiding among the oysters? Photo courtesy of CBF.

Virginia’s native oyster, Crassostrea virginica, can help to improve water quality because it feeds on algae. An adult oyster can filter up to 50 gallons of water per day when water temperatures are above 50 degrees Fahrenheit. Oysters are one of nature’s water filters. They remove particulate algae and sediment from the water by beating the cilia on their gills and drawing water in at a rate of 2-3 gallons per hour. The food particles, caught in mucous strings on their gills, are passed around the gills to the palps where some of the food is ingested. The remainder is released as “pseudofeces”, which effectively packages and removes sediment from the water column and places it on the bottom.

Virginia’s native oyster, Crassostrea virginica. Drawing and information sources - www.infovisual.info and Maryland Sea Grant.
Oyster Biology, Lifecycle and Interesting Facts

Oysters are scientifically classified as molluscs, a word from the Latin meaning soft.

The ancient Romans served large quantities of oysters at their banquets, learned to cultivate them, and even made a monetary unit, the denarius, equal in value to one oyster.

The native eastern oyster, *Crassostrea virginica*, usually lives in water depths of between 3 and 25 feet and naturally forms three-dimensional reefs.

An oyster orients itself with the flared edge of its shell tilted upward. The left valve is cupped, while the right valve is flat. The oyster uses its adductor muscle to open its shell to feed on plankton.

While the power of the adductor muscle varies with the size and condition of the oyster, it takes a pull of over 20 lb to open the shell of a 3 to 4-inch Eastern oyster in good condition.

Oysters usually mature in one year. There is no way of telling male oysters from females by simply looking at them. While oysters have separate sexes, they may change sex one or more times during their life span. They are protandric, which means that in the first year they spawn as males, but as they grow larger and develop more energy reserves in the next two to three years, they spawn as females.

An increase in water temperature triggers male oysters to release sperm and females to release eggs into the water. This begins a chain reaction of spawning which clouds the water with millions of eggs and sperm. A single female oyster produces 10 to 100 million eggs annually.

When water temperatures fall over the winter, oysters cease to feed. The oysters stop filtering and seldom open their shells. However, unlike hibernating bears and other animals which live on stored fat, they show very little weight loss after the winter’s sleep.

Across the world, almost two billion pounds of oysters are eaten each year. Oysters are high in calcium, iron and protein and contain numerous vitamins including C, D, B₁, B₂ and B₃. Four or five medium size oysters supply the recommended daily allowance of iron, copper, iodine, magnesium, calcium, zinc, manganese and phosphorus.

It is possible for edible oysters from the family *Ostreidae* (such as *Crassostrea virginica*) to produce pearls. However, it is the oysters from the family *Pteriidae* that produce the pearls used in jewelry.

Sperm fertilize eggs in the water column. Fertilized eggs develop and progress through a series of free-swimming larval stages (Stage 4) over a period of 14 to 20 days, depending on water temperature. These stages are referred to as the trochophore, veliger and pediveliger. The trochophore larvae feed on very small algae as they move through the water column. Trochophore larvae quickly develop into more motile veliger larvae (Stage 5). Toward the end of the larval cycle, pediveligers (Stage 6) develop a foot that helps them find a suitable hard substrate on which to attach (set) and transform into small oysters. This stage is also called an "eyed larvae" because of the development of a pigmented eye spot.

Pediveliger, See Stage 6 - top graphic. Pictomicrograph of eyed larvae with pseudopod extended. Photo by Michael Congrove, VIMS.

Eyed pediveligers settle out of the water column when they are approximately 300 micrometers (μm) and may be stimulated to settle by the presence of adult oysters. Finding a clean, hard substrate (culch) is essential to their survival. The eyed larvae can move only very small distances, once they settle, in order to find a suitable spot. Once settled, they attach and transform into small oysters called spat. Spat soon begin feeding on algae by filtering water through their gills and a special structure (labial palps) located just in front of the mouth.
Successes in Restoration Efforts

Why are so few wild oysters left?

Based on historical accounts, three-dimensional oyster reefs were once a prominent feature of Virginia’s coast. Captain John Smith reported in the early 1600’s that a person could practically walk across the James River on the tops of the oyster reefs. During the Civil War, oyster reefs were still so large that they were a danger to navigation in the Chesapeake Bay. In the early 1900’s, Diamond Jim Brady was said to have eaten over 100 oysters in one sitting. And in some years past, Virginia used to produce 7-8 million bushels of oysters per year with approximately 20 million bushels harvested Bay-wide. Overharvesting caused a precipitous decline between 1907 and the 1930s.

After a slight recovery in the 1940s and 50s, oyster harvests declined again drastically in the mid-1950’s, reaching their lowest points in the 1990’s. This decline in oyster populations was due to over-harvesting, habitat loss, poor water quality, and two diseases, MSX and Dermo (see page 6). Due to all of these problems, only a small percentage of the oyster population now exists. Over the last decade, the status of wild oyster populations has improved and the oyster aquaculture industry has grown, however there is still a long way to go.

Oyster gardening can help increase native oyster populations if diploid (fertile) animals are grown and allowed to reproduce. The cumulative impact of thousands of people growing fertile oysters could be quite significant.

Increasing our native oyster population.

Commercial oyster aquaculture may take some harvesting pressure off the wild population as retailers, restaurants and consumers demand consistently sized and shaped oysters. Private oyster gardening also can help increase the native oyster population if gardeners place their reproductive oysters on sanctuary reefs. New techniques to grow oysters both in cages and as spat on shell, improvements in the genetics of the native oyster to impart traits for disease tolerance and faster growth, the availability of sterile, triploid oysters for good year round meat quality, and expanding private hatchery capacity have all spurred rapid growth of oyster aquaculture production in Virginia (see figure on page 5 - private bushels).

There also are improvements in Virginia's wild oyster harvest (see figure below). In 1999 the Virginia CZM Program initiated the Virginia Oyster Heritage Program (VOHP) investing significant coordinative effort and over $1.5 million to increase Virginia’s wild oyster population through the restoration of natural 3-dimensional reef habitat. This public-private partnership brought together state, federal, non-governmental, and private oyster industry partners, including the Virginia Marine Resources Commission, Virginia Institute of Marine Science, National Oceanic and Atmospheric Administration, Army Corps of Engineers, and the commercial oyster industry. That year, Virginia’s harvest had been the lowest ever recorded. The VOHP partnership leveraged additional funds and led to the construction of more than 80 sanctuary reefs and 1000 acres of harvest area in Virginia's coastal waters. In 2007, as pressure mounted to open oyster sanctuary areas to harvest, the Virginia CZM Program reconvened the VOHP partners. Together the partners created an innovative Oyster Management Plan for the Lower Rappahannock River that combines a 3 year rotational harvest protocol, using six

Graphs courtesy of Virginia Marine Resources Commission and Virginia CZM Program.
geographic areas in the lower section of the river, and a buy-back program for large oysters that helps preserve brood-stock on the sanctuary reefs.

The three-year rotational harvest protocol allows the maximum amount of harvest before oysters succumb to disease, and then allows each area time to "rest", giving oysters time to reproduce and replenish the harvest area. Oyster harvests have increased significantly with this harvest strategy, and the populations of oysters on both sanctuary and harvest areas remain stable. This model has now expanded to the Tangier-Pocomoke Sound Area and the York River.

The payoff for this investment over the past 10 years has been substantial. Oyster harvests have increased 10-fold over the past decade, from an annual harvest of less than 23,000 bushels to a harvest of more than 250,000 bushels and a dockside value now of over $9 million (2012 VMRC data). Planting shells on public harvest areas has provided a positive return on the financial investment.

Over the last 5 years, researchers, commercial fishermen and aquaculturalists on the Seaside of the Virginia’s Eastern Shore have all observed very high oyster recruitment on restored reefs and noticeable increases in oyster densities. In 2008, an inventory estimated the number of oysters to be 3.1 million. Today, the number of oysters would be exponentially higher!

In 2013, the Governor and General Assembly appropriated $2 million for oyster restoration, which is the largest state investment that has ever been made in oyster restoration.
Dealing with Disease

Oyster diseases

MSX and Dermo are not caused by viruses or bacteria, but rather by single-celled protozoans. Neither parasite is harmful to humans. In the Chesapeake Bay, oysters become infected with MSX from mid-May through October. Infections develop rapidly in susceptible oysters, and result in mortalities from April through October. Oysters that survive their first season may still harbor the parasite over the winter and succumb to the disease the following spring or early summer. Temperature and salinity regulate MSX. Both parasite and host are inactive at temperatures <5°C (41°F). At 5-20°C (41-68°F), the parasite proliferates more rapidly than the host can control it. Above 20°C (68°F), resistant oysters can overcome the parasite while susceptible oysters are killed. A salinity below 10 parts per thousand (ppt) results in expulsion of the parasite at temperatures above 20°C. A salinity of 15 ppt is required for infection; 20 ppt is required for rapid and high mortality. Fortunately, wild oysters are increasingly tolerant to MSX and this tolerance is heritable. For several decades hatchery-based breeding programs have made use of this heritability to selectively breed strains of oysters that are highly tolerant to MSX. If you are growing oysters in waters where the salinity regularly exceeds 10 ppt, you should be sure to use one of these lines of oysters. See VIMS’ Aquaculture Genetics and Breeding Technology Center (ABC) website, www.vims.edu/abc, for more information about lines breeding. A variety of selectively bred lines may be available from commercial seed sellers – just ask!

Dermo infections occur throughout the warm months, May through October, with maximum mortalities observed in September and October. Low numbers of parasites remain over the winter, and these parasites proliferate once temperatures increase in late spring. Infective stages of the parasite are released from infected and dying oysters, so it is imperative to avoid moving infected oysters into an area containing uninfected oysters. Temperature and salinity greatly influence Dermo. The parasite proliferates and infections intensify above a threshold of 20°C (68°F). At temperatures above 25°C (77°F), the parasite rapidly multiplies, spreads, and kills oysters. Infections decline at temperatures below 15°C (59°F). Prevalence and infection intensities of Dermo increase with increasing salinity. High intensity infections and high mortalities often occur in areas with salinities above 12-15 ppt. Infection intensities remain low in areas with salinity consistently below 9 ppt. While selective breeding has yet to produce a strain of oysters that is totally resistant to Dermo, different strains do have varying degrees of tolerance to the parasite. For example, some lines bred at VIMS, using naturally Dermo resistant oysters from the Gulf coast hybridized with Virginia oysters, display improved tolerance to Dermo. Oysters also have been bred for faster growth so that they reach market size before they succumb to Dermo. When growing oysters at sites with salinities above 9 ppt, it is important to use one of the selected strains that have been demonstrated to have some Dermo tolerance.

The timing of planting your oyster seed can also affect their exposure to Dermo. Growing oysters rapidly and harvesting prior to a second summer of exposure to the disease can reduce mortality.

Healthy oyster gut epithelium on the right side of the photo and a region damaged by Dermo on the left side of the photo. Photo by Ryan Carnegie, VIMS.

Oyster Aquaculture Links

Aquaculture Genetics & Breeding Technology at VIMS-
www.vims.edu/abc
VIMS Marine Advisory Services Aquaculture-
www.vims.edu/map/aquaculture
Aquaculture Program at VA Tech VA Seafood Agricultural Research Center-www.arec.vaes.vt.edu/virginia-seafood/
VMRC Shellfish Aquaculture, Farming and Gardening-
www.mrc.virginia.gov/Shellfish_Aquaculture.shtm
Virginia Aquaculture Oyster Growers-virginiaoysters.org
Creating a better oyster for cultivation

Disease resistant oyster lines are now a reality for aquaculture. However, wild stocks of oysters are also showing some effect of natural selection with increased tolerance to MSX and, to a lesser extent, Dermo. Selective breeding for aquaculture has produced lines of oysters that live longer and grow faster. And genetic improvement has led to another beneficial farm characteristic - sterility. Sterile oysters have three sets of chromosomes (triploid) instead of two, like a normal fertile (diploid) oyster. At first, making oysters sterile might seem counterproductive. Triploids, however, are used exclusively on oyster farms to enhance product quality because triploids do not become spent, watery and of poor quality for consumption after spawning, like their normal reproducing cousins. There are other advantages to triploids on commercial farms, including faster growth (even faster than an oyster selectively bred for faster growth) and higher survival in the face of disease (even higher than those selectively bred for survival). Selective breeding is an ongoing process and as one generation of oysters has been distributed to hatcheries, another generation is being developed and tested. Selective breeding programs might someday deliver the “perfect oyster” and diseases could become a distant memory to aquaculturists. Diseases will likely always be an issue in the wild.

For more about these diseases, visit the VIMS MSX and Dermo Fact Sheet at www.vims.edu/_docs/oysters/oyster-diseases-CB.pdf.