Oyster Gardening Manual

An environmental demonstration project for North Carolina

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Funding provided by: APNEP- Neuse and Tar-Pamlico River Councils
Lead Project Investigator: Carteret Community College, Aquaculture Tech Program
Project Partners: Shellfish Gardeners of NC, NC Coastal Federation, The Nature Conservancy, NC National Estuarine Research Reserve, NC Sea Grant, NCDENR

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Acknowledgements

I would like to thank APNEP and the Neuse and Tar-Pamlico River Councils for funding this project. I hope your expectations for a good project have been born out in the enthusiasm that it has generated among the participating citizens for good water quality and increasing oysters in the state. It has catalyzed citizens' involvement in developing new ideas for oyster gardening.

Many people at Carteret Community College helped in carrying out and completing the project. My first oyster hatchery operator, and first aquaculture graduate, Lewis Shields, went the extra mile operating the prototype oyster hatchery and helped me prove that it could be done. Trent Boyette operated the hatchery at the "lab on the slab" during the time when we were on the lawn without a roof over our heads. Jessica Luker continued the excellent tradition of CCC Aquaculture students by helping with the hatchery and growing algae cultures. My right hand helper, Matt Penny, filled in for me many times when I was busy being a college professor and was always willing and eager to help out. Most importantly he kept the pumps running and the seawater flowing so the hatchery could go on. I thank all of my students who have helped with parts of the project including the education, training and hatchery operations. Morgan Smith and Deby Willis of the CCC Public Relations Department got us some great publicity, skillfully promoted the program and filmed workshops and hatchery activities.

A special note of thanks goes to the Shellfish Gardeners of NC for the aggressive way they have promoted oyster gardening. John Alison, Oriental Chapter, became the driving force behind the effort to form the non-profit organization. Other original members who have worked to keep that group expanding and growing are from Bogue Banks, John U. Davis, Richard Seale, and John Zimmerman; from Oriental, Earl Evens, Gary Wiard and Gary Williams; from the Outer Banks, Mike Halminski and Harry Schiffman; from Hampstead area, Bill Mothorpe, Jack Spruill and Tom Beckingham. Thanks to Tom, Mike, Jack, Earl, and Aaron for the many pictures of their gardening experiences which provided feedback and guided the direction of the project. Thanks to the many other gardeners who quickly picked up on the ideas presented here and started their oyster gardens along the North Carolina coast; some developed new ideas for future gardeners.

Amy Saul of the North Carolina National Estuarine Research Reserve was a wonderful help with producing and presenting the training workshops. Aaron McCall and Patrick Ertel, of The Nature Conservancy, collected broodstock oysters for our hatchery so we would have spawning stock; they set the larvae on marl and contributed them to the award winning Festival Park oyster restoration in Manteo. Jim and Bonnie Swartzenberg donated huge oyster broodstock from Stump Sound which were the champion spawners. Sarah King and Sarah Phillips, North Carolina Coastal Federation, and summer interns delivered hundreds of oyster shell bags for setting the larvae and then planted the seeded cultch in the NCCF oyster sanctuary.

Without the help of all our partners and contributors this project would never have succeeded. I would like to acknowledge the existing resources that are included in the manual; sources are credited in context. To everyone who gave time and effort to the project, thank you all very much.

Skip Kemp

Introduction to Oyster Gardening for North Carolina

Oysters are an important species in the estuary that filter water, provide food and produce their own critical habitat. No other estuarine organisms produce the hard substrate habitat required by oysters. During the last century oyster populations plummeted 97% to 3% of those historic numbers. Mechanical harvesting and overfishing contributed to the habitat loss which reduced oyster populations. As a result remaining oysters are suffering a lack of reproduction and recruitment especially in the Tar-Pamlico and Neuse River basins.

A little known fact is that oysters are nature's water filters. In the process of feeding and respiration oysters can filter 10-30 gallons of water per day. Oyster filtration has a positive effect and without the presence of oysters water quality in the estuary continues to decline. Oysters provide other benefits to the long-term health of North Carolina waters and marine resources. Oyster beds also serve as fishery nursery areas and promote the growth of myriad other marine species including shrimp, crabs, fish and invertebrates.

Because oysters are in such decline some citizens' groups have begun using aquaculture methods and gardening programs to restore populations of native oysters their habitat and their ecological functions to estuaries where these critical habitats have disappeared. Aquaculture can provide a sustainable oyster production. And it can bring back the water filtration and fishery habitat that is desperately needed to keep estuaries healthy.

Oyster gardening can be as simple as planting hard substrate, called cultch, in estuaries to encourage oyster growth. It can also involve programs of training and hands-on learning experiences to teach residents how to grow oysters and about the interrelationships between oysters, estuaries and water quality. This manual provides an introduction to on-bottom oyster gardening and additional information on estuaries, oyster biology, hatcheries and testing water quality that could be useful to schools and other groups.

Oyster survival and growth is much greater when they are grown in off-bottom cages or other containers. A new permit allows this type of gardening under some docks in North Carolina waters. Contact the Shellfish Gardeners of NC, Inc. or the NC Division of Marine Fisheries (see Appendix) for information and assistance with the UDOC permit.

This is an environmental demonstration project funded by the Neuse and Tar-Pamlico River Councils of the Albemarle-Pamlico National Estuary Program (APNEP). The Aquaculture Technology Department of Carteret Community College in Morehead City, NC conducted the project. Project partners were the Shellfish Gardeners of North Carolina and the North Carolina Coastal Federation, NC National Estuarine Research Reserve Program and The Nature Conservancy.

Concurrent with using this manual please browse the website:
http://www.carteret.edu/aqu/cogp or **http://www.oysters-cleanwater.info**

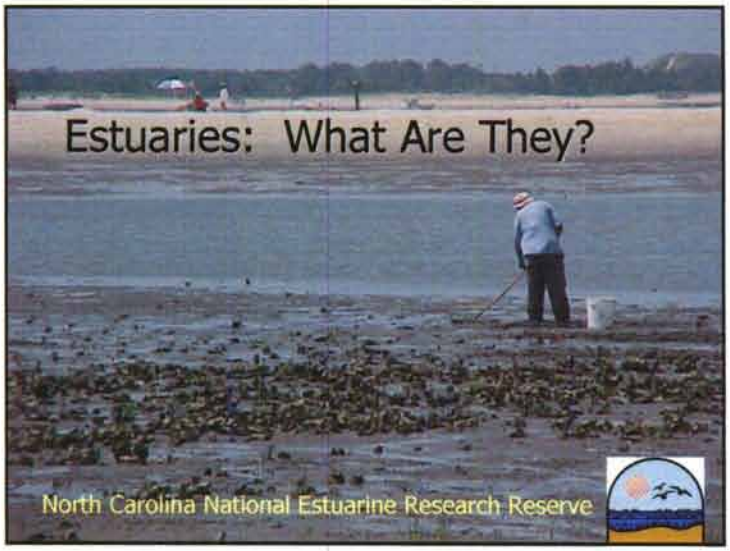
How and where you can become involved in oyster gardening

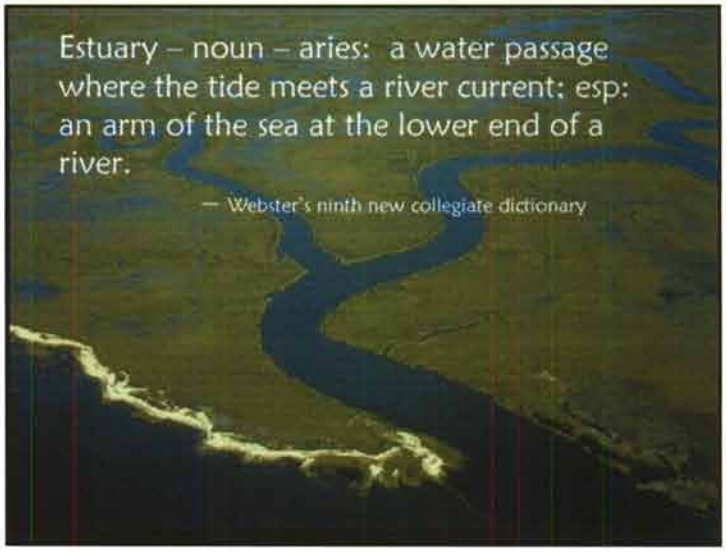
The Citizens' Oyster Gardening Project has already spun off into various chapters of the Shellfish Gardeners of North Carolina, Inc.-SGNC, which is working to develop OFF-bottom oyster gardening for the UDOC-Under Dock Oyster Culture permit. Other partners such as The NC Coastal Federation and The Nature Conservancy also have oyster restoration activities and may have some projects in your area for which you can volunteer to participate. Carteret Community College, NCNERR and NC Sea Grant can provide information and assistance (see appendix contact listings).

To begin your oyster garden you can simply follow the methods and materials outlined in this manual or you can begin a community effort with friends in your area. For the latter, typically you would hold an informational meeting combined with a training workshop along the lines of the following outline. This outline and manual were developed from the material presented at the APNEP workshops and help from project partners.

Typical community oyster gardening training workshop:

- Welcome and Introductions (oyster filtration demonstration)
    - Set up an aquarium with oysters in it and watch the water clear up
    - How to become involved and who to contact
- The Estuary: What it is and what are its characteristics?
- Oyster Biology and Ecology- (hands-on) investigate oyster rocks
    - Look at clusters of oysters and discuss their ecology
- What is Oyster Gardening and how to get started growing oysters
    - Shellfish 4 Us
    - Backyard oyster gardening
    - Spat collection and obtaining seed oysters
    - Hands-on: make cages and spat collectors
- Oyster hatchery and aquaculture.
    - How oysters are cultured in the hatchery and commercially.
    - Backyard remote setting of eyed-larvae oysters
- Water Quality/ Estuaries: Rainfall, runoff, salinity, nutrients, plankton, bacteria
    - Primer on chemistry, properties and qualities of water
- Learn how to test water quality (hands-on): Use water quality testing equipment for: testing temperature, rainfall, salinity, dissolved oxygen, secchi visibility; make secchi disks.
- Review the NC Rules and Regulations dealing with oysters.
    - Know the laws that affect oyster gardening.
- Where to go from here and how to network with others.





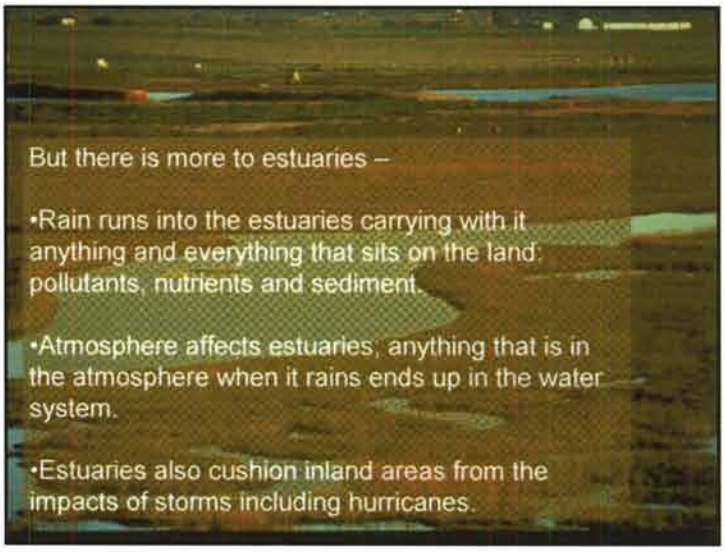
So? What does that mean?

That means that the sounds, the salt marshes, the tidal creeks, the sand flats, mud flats, are all considered estuarine – parts of an estuary.

What does it mean to you and me?

NC has over 2 million acres of estuary. 95% of all the seafood we eat spends part of its life in an estuary.

Do you like crab, shrimp, flounder, clams, red drum, scallops, oysters?? They all depend on estuaries –a place also known as a nursery area – since these things often spend time growing in the shallow protected waters of an estuary.



Estuarine Water Levels

- Water levels in the estuary vary:
  - **Tides**
  - Weather conditions (rainfall, streamflow, and stormwater runoff)
- Physical, chemical, and biological conditions within the estuary vary with water level
- Increased water levels affect the concentration of dissolved and suspended materials
- Stormwater runoff increases suspended sediments and may increase bacterial levels
- Turbidity may increase during periods of low water volume because of the action of wind and waves on muddy bottom sediments

Source of information: Estuary-Net curriculum www.ncnerr.org

Chemical Properties: Water Temperature

- Critical factor in determining where marine organisms live and how well they thrive
  - Phytoplankton has an optimal temperature for survival
  - Shifts in temperature cause variations in phytoplankton abundance and species composition
  - Growth rates of estuarine plants and cold-blooded animals generally increase with temperature
- **Dissolved oxygen** is a function of temperature, as water temperature increases, the solubility of oxygen decreases.
  - Fresh sterile water at 0°C (32°F) can contain up to 14.6 mg of oxygen per liter of water
  - At 20°C (68°F) it can hold a maximum of only 9.2 mg of oxygen per liter. [One milligram (mg) of a substance is equal to one-one thousandth of a gram. There are about 28 grams in an ounce.]

Source of information: Estuary-Net curriculum www.ncnerr.org

Chemical Properties: Salinity

- The total amount of dissolved solids in a volume of water
- About 35 parts per thousand (ppt) in the open ocean
- Estuarine salinity varies according to:
  - Location
  - Tidal fluctuations
  - The volume of freshwater runoff
- Variations in salinity produce changes in species composition, distribution, and abundance in an estuary
- Salinity also important affects chemical conditions within the estuary, particularly dissolved oxygen levels.
  - **Dissolved oxygen** (solubility) decreases with increasing salinity
  - The solubility of oxygen in seawater is about 20% less than in freshwater of the same temperature

Source of information: Estuary-Net curriculum www.nenerr.org

Chemical Properties: pH or Alkalinity

- pH is a measure of a solution's acidity
- pH is defined as the negative logarithm of the hydrogen ion concentration in solution
- the pH scale ranges from 0 to 14
  - Distilled water has a pH of 7 (neutral)
  - Solutions with a pH less than 7 are acidic
  - Solutions with pH greater than 7 are basic (alkaline)
- The pH in an estuary will remain fairly constant because the chemical components of seawater resist large changes in pH
- Biological activity, however, may significantly alter pH levels in an estuary

Source of information: Estuary-Net curriculum www.nenerr.org

Chemical Properties: Dissolved Oxygen (DO)

- Aerobic aquatic organisms such as zooplankton, invertebrates, and fish require sufficient levels of DO to survive
- Oxygen enters water by:
  - Diffusion of atmospheric oxygen into the water (mixing caused by wind and waves increases the rate)
  - Photosynthesis by phytoplankton and aquatic macrophytes (seaweeds and seagrasses),
- DO levels are influenced by temperature and salinity
- Increased temperature and salinity decreases the solubility of oxygen (lower Oxygen)
- DO varies seasonally, with the lowest levels occurring during the late summer months
- Oxygen is removed from the water by aerobic respiration and bacterial decomposition

Source of information: Estuary-Net curriculum www.nenerr.org

Chemical Properties: Dissolved Oxygen (DO) continued

- Oxygen depletion may occur when
  - Many plants die and decompose
  - Runoff or poorly treated wastewater containing large amounts of organic matter enters the estuary
- Large nutrient inputs (ex. from sewage inputs) stimulate phytoplankton blooms
  - When these organisms die they begin to decompose
  - The decomposition process depletes the surrounding water of oxygen
  - May lead to anoxic (very low oxygen) conditions that kill bottom-dwelling organisms.
- Shallow, well-mixed estuaries are less susceptible to this phenomenon

Turbidity

- The ability for light to transmit through the water column
- Aquatic plants and phytoplankton and the organisms that feed on them are affected:
  1. Limiting photosynthetic processes, increasing respiration and oxygen use;
  2. Clogging of fish gills and feeding apparatus of bottom dwelling animals by suspended particles;
  3. Obscuring vision of fish as they hunt food; and/or
  4. Smothering bottom-dwelling animals.
- Suspended solids include:
  - Particles of algae
  - Sediment
  - Detritus
  - Solid waste

Source of information: Estuary-Net curriculum www.nenerr.org

Osmoconformers: These species, such as an oyster, adjust the body fluids to match those of the surrounding liquids.
Osmoregulators: These species, such as a marine crab, maintain or regulate osmotic concentration in spite of external concentration changes.

Source of information: Estuary-Net curriculum www.nenerr.org

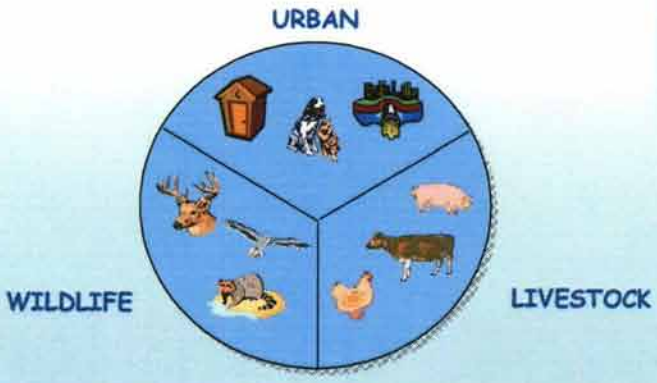
Microbes & Water Quality

- Some microbes are pathogenic, or disease-causing
- Pathogenic microbes include:
  - Viruses: enteroviruses, Hepatitis A, Norwalk-like viruses
  - Bacteria: Salmonella, Campylobacter, Yersina, Shigella
  - Parasites: Giardia and Cryptosporidum

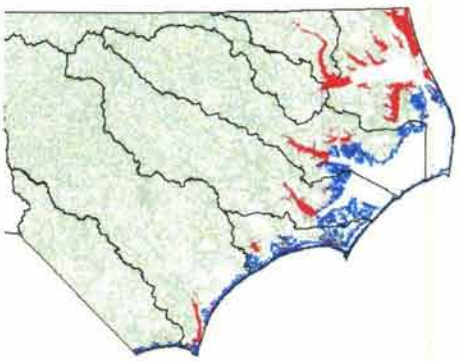
Impacts of Microbes on Estuaries

- Mainly deposited into surfaces waters through stormwater runoff
- Have the potential to cause closure of shellfish harvesting areas and posting of swimming advisories
- Can contaminate drinking water
- Can cause intestinal and stomach problems

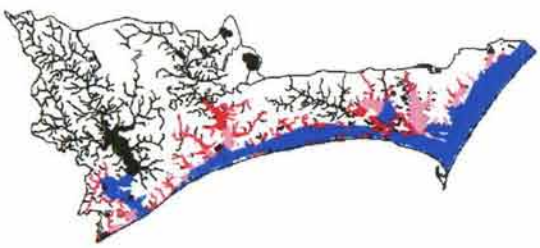
Major Sources of Microbial Contamination



DWQ Class SA Waters
Commercial Shellfish Harvesting



White Oak River Basin



North Carolina National Estuarine Research Reserve
www.ncnerr.org

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Southern
Regional
Aquaculture
Center

August 2001
Revision

Cultivating the Eastern Oyster, *Crassostrea virginica*

Richard K. Wallace*

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

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

Oyster biology

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

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

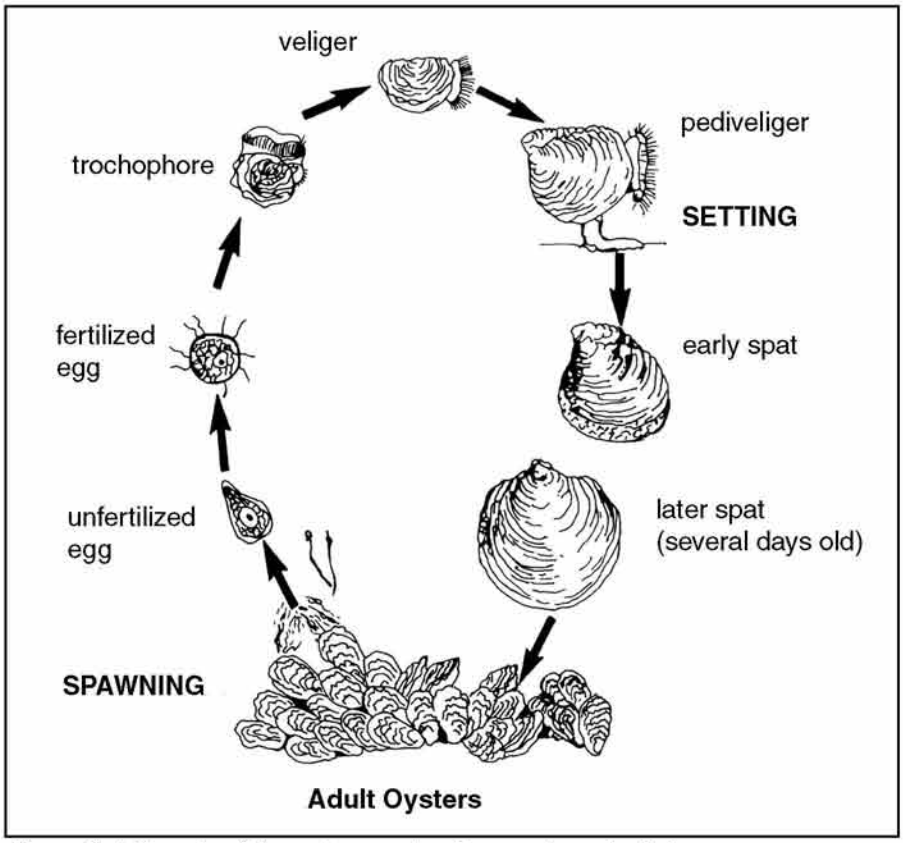

Figure 1. Life cycle of the eastern oyster, Crassostrea virginica.

*Auburn University, Marine Extension and Research Center

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

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

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

Oyster culture

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

After oysters are harvested, additional cultch is planted to provide substrate where more oyster larvae can set.

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

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

Oysters set on shells

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

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

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

Single oysters

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

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

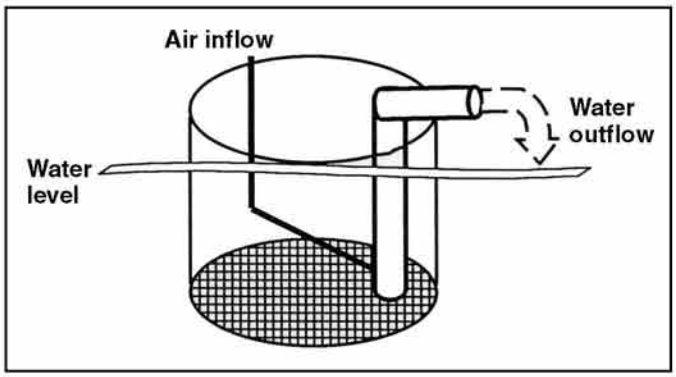

Figure 2. Airlift upweller.

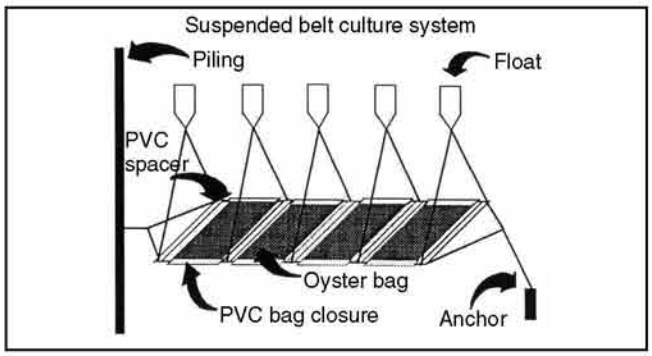

Figure 3. Example of a flexible belt system with flotation. (Illustrated by F. Scott Rikard)

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

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

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

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

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

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

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

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

Site selection

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

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

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

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

Marketing

Oyster production in the U.S. has declined from 40 years ago, while inflation-adjusted prices have remained flat or increased only slightly. This indicates that consumer demand has decreased over time, possibly because of concerns about the safety of eating raw oysters and general changes in people's eating habits. Oysters can be sold to existing markets at prevailing prices. Some producers have been able to market their oysters under brand names or regional names and obtain a premium in specific markets. A number of post-harvesting techniques that reduce human health concerns are being tried, and these may help rebuild markets. However, markets should be realistically assessed before resources are committed to oyster cultivation.

Significance

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

SRAC fact sheets are reviewed annually by the Publications, Videos and Computer Software Steering Committee. Fact sheets are revised as new knowledge becomes available. Fact sheets that have not been revised are considered to reflect the current state of knowledge.

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Shellfish 4 Us:
Backyard Shellfish Gardening

Philip S. Kemp Jr.
Cartenet Community College

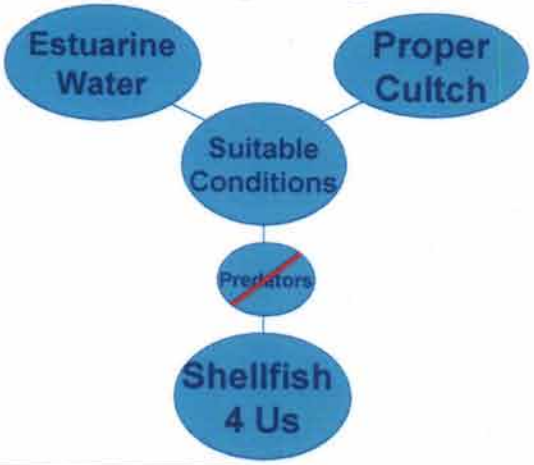
Shellfish are good for:

- Food
- Filtering water
- Fishery habitat

What's the Caveat?

If you grow it, I can harvest it !

Gardening Requirements

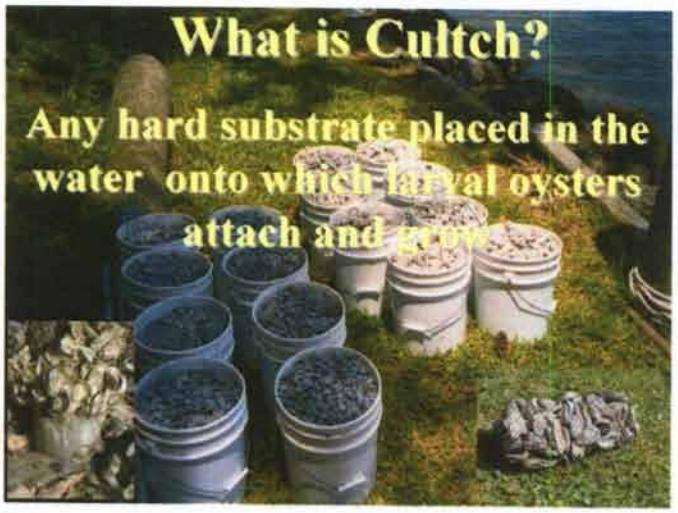


What about Water?

- Clams
  - salinity > 20 ppt
- Oysters
  - salinity >12 ppt
- If it's a North Carolina estuary, it will grow shellfish

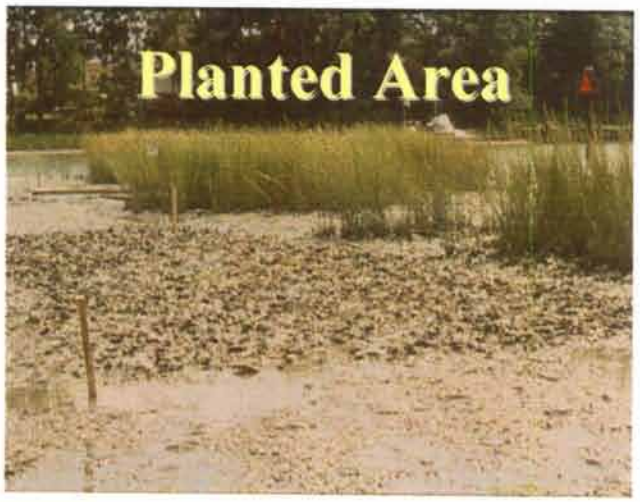
What is Cultch?

Any hard substrate placed in the water onto which larval oysters attach and grow



Planting Cultch

- Use shells, marl rock or natural material
- Portland cement and lime coating enhances oyster spat set
- Large cultch pieces attract oysters
- Small cultch pieces enhance clams
- **Plant cultch during summer**



Planting Seed

- Purchase seed from North Carolina suppliers
- DMF requires importation permit for out-of-state seed
- Keep receipt
- Plant seed in during spring or fall when water is cold and predators are inactive
- Plant cultch to protect seed

Predators

Blue crabs

Oyster drills

Mud crabs

Harvesting

- Must be approved shellfish waters
- NC DMF regulates shellfish harvest
- 3-inch minimum oyster length, open season only
- 1-inch minimum clam thickness, 100 per day

UNC-SG-BP-02-01

Sea Grant North Carolina

BLUEPRINTS

NORTH CAROLINA SEA GRANT NC STATE UNIVERSITY BOX 8605 RALEIGH, NC 27695-8605
www.ncseagrant.org

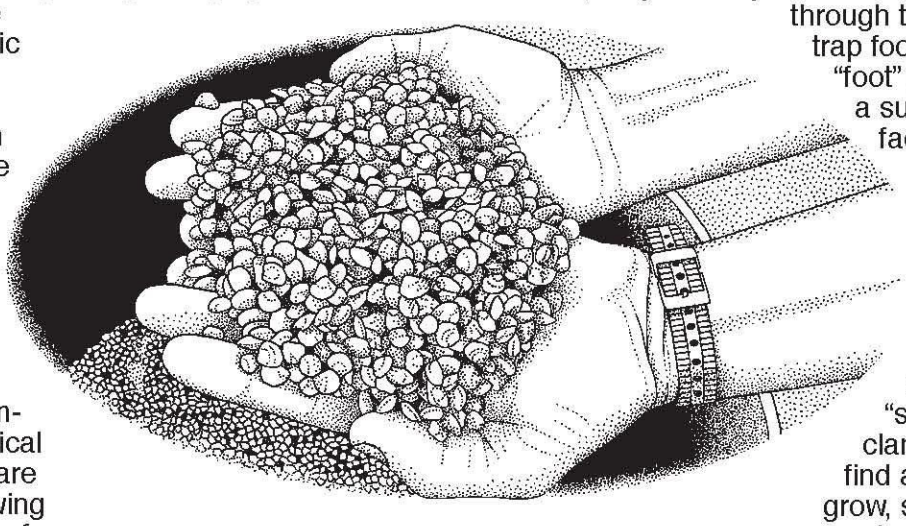
Shellfish 4 Us: Backyard Shellfish Gardening

Citizens of North Carolina who own or live along estuarine shoreline property — or have access to it — have an extraordinary backyard gardening option. They may grow shellfish for personal consumption or for environmental enhancement without special licenses or permits.

Getting started in backyard shellfish gardening is not too difficult, requiring a minimum amount of material. In the long run, growing oysters and clams can provide personal and public rewards.

Harvesting succulent shellfish for the dinner table is an obvious payback.

The public also benefits from the improved water quality. Shellfish are important members of the ecological community. They are filter feeders, drawing in food and oxygen from surrounding enriched waters and leaving unconsumed algae pellets as food for other marine organisms.



Large oysters, for example, can filter up to 50 gallons of water a day through their gills. For this reason they are important to the health of our estuaries.

In addition, myriad organisms attach and grow on oyster shells, creating habitat for mini ecological communities. Fish, shrimp and crabs of all descriptions live around these oyster shell communities.

Shellfish biology

Oysters and clams have interesting life cycles. They have similar larval stages. Both adult clams and oysters spawn in the spring when the water begins to warm. They spawn throughout the summer and again in early fall. Eggs are fertilized in the open water and develop into microscopic free-swimming shellfish larvae with tiny, glass-like shells.

Larvae develop through several stages over a period of 10 to14 days, with water temperature and food availability controlling growth time. During this time, they use tiny hair-like cilia to swim freely through the water and to trap food, and grow a "foot" to crawl around on a suitable hard surfaces.

Then, clam and oyster larvae take separate paths to becoming juveniles — a metamorphosis commonly called "setting." Setting clams crawl around to find a suitable place to grow, such as on shells or rocks known as "cultch."

Clams attach themselves to cultch with a byssal thread. Set clams, or "seed," detach from the cultch and settle into the bottom when they are large enough to survive in the bottom.

Oysters attach permanently by gluing themselves in place to cultch. They prefer shells, but will attach to almost anything with a smooth, hard surface. Set oysters are called "spat."

Getting Started

Planting cultch for larval settlement is essential for establishing a clam or oyster bed.

Oyster, clam and scallop shells make the best cultch. Save shells from oyster roasts and clam bakes to start a shellfish bed. Or, purchase large

Planting cultch is essential to establishing a shellfish bed.

quantities from commercial processing plants.

Or, use marl rock, an aggregate of fossilized shells that contains calcium carbonate that attracts shellfish larvae. Marl can be purchased from local quarries or aggregate suppliers. However, the N.C. Division of Coastal Management regulations prohibit placing such a large quantity of marl that it constitutes "filling." If your plan involves a substantial amont of marl, or if you are unsure whether your plan constitutes filling, contact DCM before starting.

Oyster spat also will settle on other natural material, such as pine boughs, tree branches and myrtle bushes.

Planting the Cultch

To start the shellfish bed, plant cultch by spreading a 2- to 3-inch layer of cultch material on the estuarine bottom. Start near the shore and expand beds outward. Be certain the cultch will remain above the bottom sediments. A thin layer of cultch will sink into the sediment, become covered with mud, and prevent attachment by larvae.

Plant cultch during the summer months when shellfish larvae are in the water and are ready to settle. Cultch planted in winter or spring will not be productive for oysters because the cultch material will become covered with sediments and fouling organisms before the following summer, leaving no space for oyster spat to attach.

Oyster spat prefer to settle on large, whole shells. Or, plant large pieces of marl (2-inch diameter) in a 3-inch thick layer to attract oyster spat.

Clam larvae prefer to settle in small shells or crushed shell, but will settle in large shell cultch. Plant a 2-inch thick layer of crushed shells or small pea gravel-sized marl rocks to encourage clam settlement.

Planting Shellfish Seed

In addition to attracting natural larvae to cultch, you may buy seed shellfish from a North Carolina hatchery to plant in your prepared shellfish bed.

Be sure to keep your sales receipt as the "proof of purchase" document needed to possess these small cultured clams and oysters. The seed must be tagged as aquaculture product. Keep the documentation with you until you have planted the seed. Once planted, the shellfish revert to the public, and you have no further ownership of them. (See Public Trust Waters, below.)

For best results, purchase large seed clams, a minimum of 12 to 18 millimeters long, and broadcast them into the cultch you have prepared. The cultch helps protect the seed clams from predators and improves survival.

Unlike cultch, plant clam seed during colder weather when preadators are not active and seed can acclimate to the bottom conditions before the next spring when preadators become active.

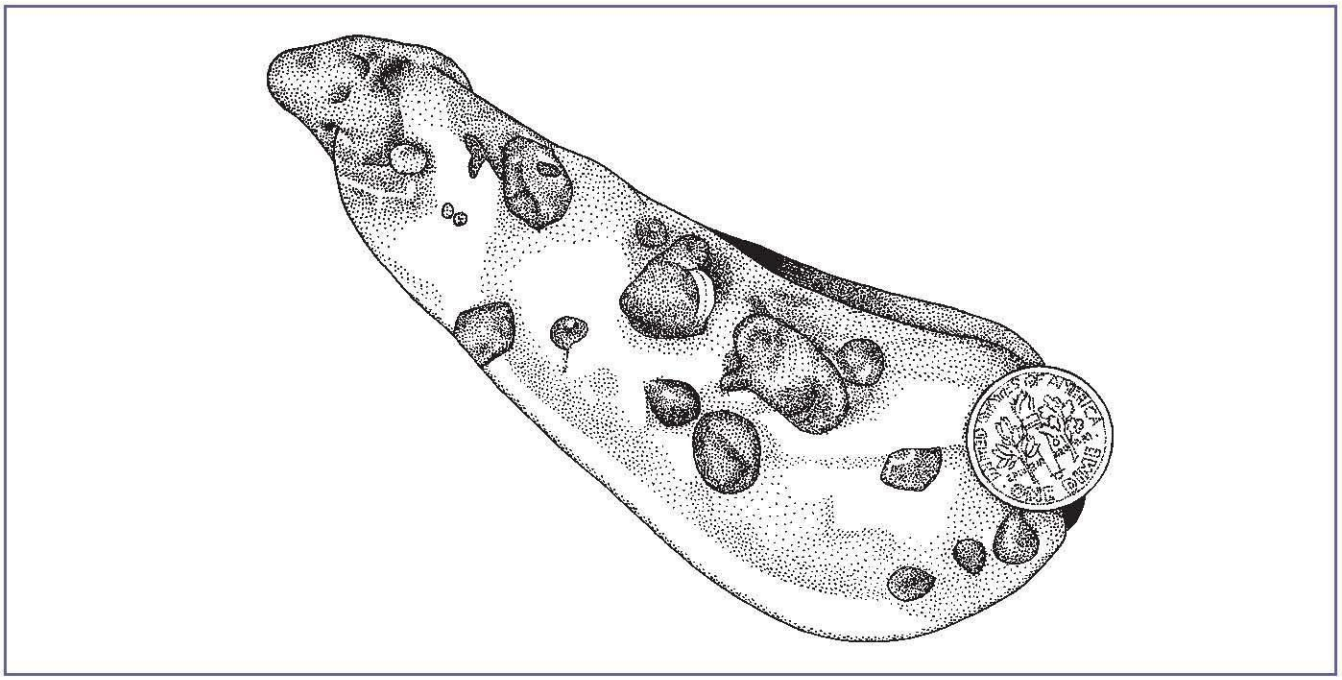
Husbandry

Once you have planted the cultch for either a clam or oyster bed, watch its progress. If cultch becomes covered with sediment, rake cultch into a pile or shallow layer during the summer to remove sediment and improve settlement.

Observe the cultch for signs of spat setting. Oyster spat appear as tiny flat circles on the shell or marl. Oyster spat also develops a small white or black streak on the shell. Distinguish spat from barnacles by gently rubbing your finger over them. Barnacles are rough on top and look like tiny volcanoes, while oysters are smooth on top.

Predators

Predators are the major threat to the sur-



After a larval period of about 3 weeks, juvenile oysters attach to hard surfaces, such as shells, and are known as 'spat.'

vival of clams and oysters.

Crabs are the most common predators of clams. However, if clams are buried down in a bed of shells or crushed shell material, it is more difficult for crabs to get to them.

Other preadators of clams include snapping shrimp, whelks, moon snails, and finfish such as drum and singrays. Even birds such as seagulls and oystercatchers can be a threat to clam survival. The larger the clam grows, the better it can survive attacks from preadators.

In the absence of preadators, clams usually survive well in good quality waer. Historically, they do not suffer from any serious clam diseases.

Many species of crabs also prey on small oysters. Size is the most important factor of survival. When oysters are attached to another shell or hard substrate, they are more difficult for crab predators to manipulate and eat.

Other oyster predators include the oyster drill snail, oyster leech, finfish such as drum, and birds such as the oystercatcher.

Oysters sometimes become sick with oyster diseases that can weaken or kill them. The most common oyster disease is Perkinsus marinus, or "Dermo," which does not affect humans.

Harvesting

Shellfish require two to three years of growth to reach harvest size. You may harvest oysters or clams during the regular open seasons, from open areas, and according to the legal size and possession limits.

Oyster havsting is allowed during the season specified by the DMF, usually from Oct. 15 through May 15. This can change by DMF proclamation. Oysters must be at least 3 inches from hinge to lip. There is a one-bushel-per-day havest limit per person.

Clam harvesting is allowed year-round in open bodies of water. This can change by DMF proclamation.

Generally, clams must be 1-inch thick, measured side-to-side across the hinge. There is a 100-clams-per-day harvest limit per person.

Harvesting oysters and clams for consumption is allowed in many areas . However, due to water pollution, some bodies of water are closed to shellfish harvest because of public health concerns.

The Shellfish Sanitation Section of the N.C. Department of Environmental Health tests shellfish waters for bacterial contamination. That agency closes and posts bodies of water that don't meet stringent standards.

Closures may be temporary due to isolated factors such as a wastewater spill or stormwater runoff.

Contact the N.C. Division of Marine Fisheries at 252/726-7021, or on the Internet at www.ncfisheries.net for all information on shellfish regulations, including harvest seasons and size and quantity limits.

For information about bodies of water open to shellfish harvesting, contact the Shellfish Sanitation Section of the N.C. Department of Environmental Health at 252/726-6827.

Public Trust Waters

Once shellfish are planted onto the estuarine bottom, they become part of the public domain and you lose ownership of them. Waters and bottomlands of the state are held in trust for public use. Therefore, you may not prohibit others from harvesting shellfish in the beds you have created.

However, to retain ownership, shellfish leasing is allowed by North Carolina statute for the commercial production of shellfhish. Contact Craig Hardy of the Division of Marine Fisheries, or Skip Kemp of North Carolina Sea Grant for detailed information on shellfish leasing and mariculture.

— Philip "Skip" Kemp
North Carolina Sea Grant
Mariculture and Marketing Specialist

For More Information...

About Shellfish Culture:
Philip S. Kemp Jr.
North Carolina Sea Grant
303 College Circle, Morehead City, NC 28557
252/222-6314; skip_kemp@ncsu.edu
www.ncsu.edu/seagrant

About Regulations:
N.C. Division of Marine Fisheries, 800/682-2632
www.ncfisheries.net/
N.C. Division of Environmental Health, Shellfish Sanitation Section, 252/726-6827
www.deh.enr.state.nc.us/shellfish/index.html
N.C. Division of Coastal Management, 252/808-2808
http://dcm2.enr.state.nc.us/

About Shellfish Gardening:

Maryland Oyster Gardening Program
www.mdsg.umd.edu/oysters/garden/
VIMS Oyster Gardening Webpage
www.vims.edu/abc/green/ogp.htm
Oyster Habitat Restoration and Enhancement
water.dnr.state.sc.us/marine/mrri/shellfish/restore1.htm
Oyster Gardening
www.hrgardening.com/edibles/99aug-1.htm
Tidewater Oyster Gardeners Association
www.oystergardener.org/

How to make and use a spat collector

When oyster larvae stop swimming and metamorphose into the sessile stage they are termed "spat". Oyster spat attach to most any type of hard substrate, called cultch, during the summer when eyed-larvae are abundant. Oyster gardeners provide cultch for oyster larvae to attach by spreading oyster shells and other material such as marl rock on the estuary bottom. In order to determine the number of spat in any given body of water, spat collectors are deployed. Spat collectors simply provide a surface for oyster larvae to attach that can easily be examined by the gardener. A 6-in x 6-in brick "quarry tile" makes a good spat collector.

To make a simple spat collector from a 6-inch quarry tile, tie a piece of string around the tile just as you would tie the ribbon around a birthday present. Lay the string across one flat side of the tile, turn the tile over on the string and bring the string ends up crossing in the middle of the tile. Turn the strings 90-degrees and continue wrapping the strings back around to the first side of the tile. Use any secure knot to tie the string ends together snugly in the center of the tile so that the tile can be suspended horizontally in the water.

Deploy a single tile spat collector on the first day of June, July, August and September. Count the number of spat oysters that appear on each tile and record in your data log sheet. How do you know whether oysters are returning to your area? As oyster populations in your area increase you will see higher numbers of spat on your collectors.

Below is a picture of a spat collector with a large number of oyster spat:

Collecting Oysters to Grow

The previously mentioned tile spat collector is used for monitoring and gathering data. If you want to actually collect spat or seed oysters to grow you can place cultch in the estuary during the summer and oyster spat should attach to it. This works best in areas where oysters are more plentiful such as in the southern areas of North Carolina. If you don't live in an area where oysters are plentiful you could connect with another oyster gardening group or a friend who lives in such an area. You could put out collectors in their area and bring back to your area after spat have settled on the collectors.

Some gardeners place oyster shells in plastic mesh bags and hang from the dock. Others use a slurry mixture of Portland cement and water to coat various materials and then place those materials out to collect the oysters. The following objects can be coated with cement to collect oyster spat: 1/8-inch diameter wire, PVC pipe, wooden dowels or sticks, tree limbs, almost anything that the cement will adhere to will collect oyster spat. Biodegradable materials are best because they will decompose in the environment leaving the attached oysters to begin an oyster bed. Push cement-coated wooden sticks about 6-inches into the bottom. Place them 6-inches apart over sections of bottom to attract oyster spat for starting a new oyster bed.

Other gardeners use rope to hang oyster shells or seeded cultch from the dock. There are two ways to attach the shells: 1) drill holes in cultch shells and string them onto the rope using a small section of PVC pipe as a spacer between shells, place the smooth side of the shell facing downward for best results, 2) untwist the rope every 4-inches down its length and insert a shell between the warps of the rope, the rope twists back around the shell holding it securely in place.


Cement-coated wire with spat


Oyster shell-string spat collector


Oysters-on-a-rope


Spat on cement-coated sticks

Oyster Hatchery:
North Carolina Style

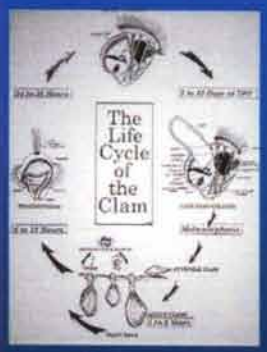
Philip S. Kemp Jr.
Carteret Community College
Aquaculture Technology Department

Hatchery Goals

- Mass produce eyed-larvae oysters
- Seasonal production
- Simple operations
- Minimum equipment
- Ship to remote users or
- Set on cultch and distribute to on-bottom oyster gardeners for oyster restoration

Shellfish Life Cycle

- Condition broodstock
- Temperature trigger
- Separate sexes spawn
- In-water fertilization
- Swimming larvae
- 10-days to pediveliger
- 3-day metamorphosis
- Sedentary juvenile



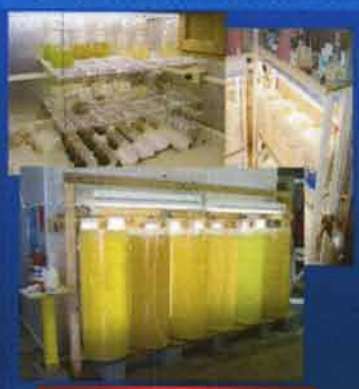
Hatchery Systems

- Water supply
- Water filtration
- Aeration
- Larvae tanks
- Algae culture
- Holding system
- Support laboratory

Water Supply

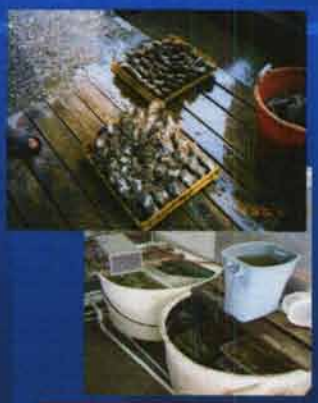
- Centrifugal pump
- Sand filters
- 5-micron bag filter
- Chlorination for algae water
- Water heaters

Culturing Algae



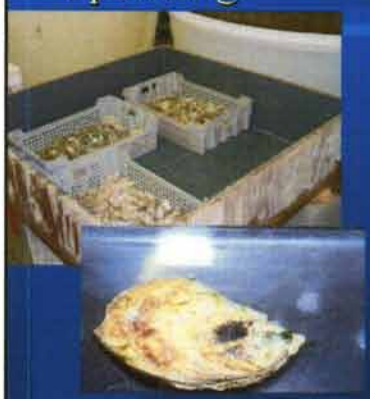
- Use sterile water
- Maintain clean inoculant cultures
- Transfer to clean culture vessels
- Add nutrients, silica, and CO-2 to aeration
- 4-5 day growth
- Harvest frequently

Broodstock



- Select from:
- Ripe wild stocks
- Delay spawning by chilled holding or
- Condition with feeding in chilled holding system:
- Chiller
- Biofilter
- Recirculation
- Feeding algae

Spawning



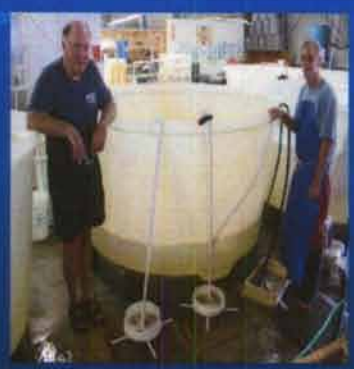
- Batch spawning of ripe or conditioned broodstock
- Change temperature to initiate spawning
- Separate spawners to buckets
- Mix gametes together to fertilize

Hatching and Larvae Production

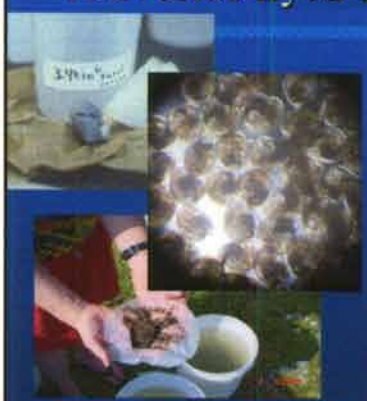
- Four larvae tanks
- 1000 gallons each
- 8 ft diameter
- 20 million eggs
- 5 million spat

Larval Culture

- 2-day drain down
- Clean larvae tanks
- Clean water refill
- Microscopic exam
- Sieve, size and count larvae
- Replace larvae and feed them



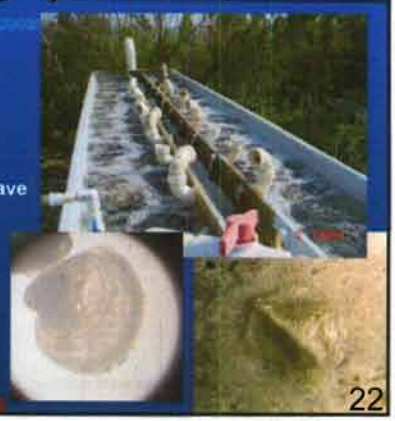
Harvested Eyed-larvae



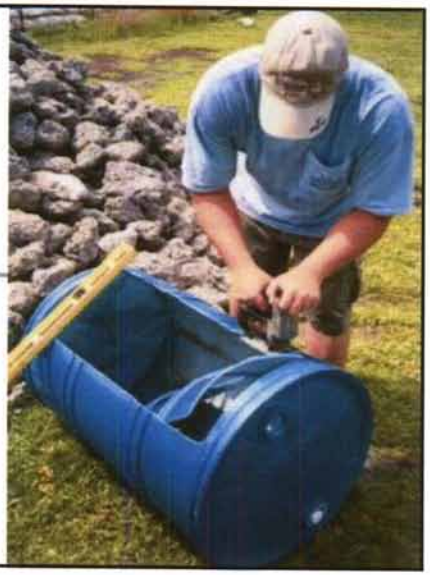
- 21-day product
- 250-micron harvest sieve
- 20-ml per million
- Keep moist and refrigerate up to one week
- Set on cultch

Remote Setting Eyed-larvae

- 4-day setting period
- Setting containers:
  - 55-gallon drum
  - 32-gallon trash can
  - Any large tank you may have
- Requires aeration



How to build a backyard remote setting system:



Step 1) Cut the side out of a 55-gallon plastic barrel

- Step 2) Wash dirt and organic matter off the cultch

- Step 3) Place airstones evenly spaced in the bottom of the barrel

- Step 4) Fill barrel with washed cultch

- Step 5) Fill barrel with seawater from the estuary and turn on air pump
- (Drain and fill barrel at least once prior to stocking larvae)

- Step 6) Stock 25,000 eyed-larvae oysters from the hatchery into the tank

- Step 7) Cover and leave running for 4 days

- Step 8) After 4 days remove seeded cultch and spread it on the bottom of your gardening area
- Step 9) After several weeks the seeded cultch will have small oysters growing on it as shown in the picture.

North Carolina Rules and Regulations for Recreational Harvesting and Possession of Oysters

NCDMF Rules Summary

- Oyster harvesting open season: October 15th through May 15
- Minimum size limit: 3-inches long (7.62 cm)
- Recreational possession limit without license: one bushel of oysters per day
- Harvest allowed during daylight hours only
- Harvest allowed only in areas certified "OPEN" by Shellfish Sanitation Section, not in "CLOSED" (Polluted) waters or during temporary rainfall-related closures by proclamation.

Check Polluted Area Proclamations for openings/closings during the oyster season at NCDMF website: http://www.ncfisheries.net/paprocs/index.html

Note: DMF considers holding oysters in mesh containers to be your "Possession"

Rules and Regulations are subject to change. For timely information on local regulations please contact NC Division of Marine Fisheries. Also with recent legislation allowing OFF-bottom culture of oysters, the DMF has the new UDOC permit:

UDOC- Under Dock Oyster Culture permit

Contact: Shellfish Gardeners of North Carolina
Visit: NCDMF website at
http://www.ncfisheries.net/shellfish/UDOC1.htm
Or
Contact:
Craig Hardy
Chief, Resource Enhancement Section
NC Division of Marine Fisheries
769 Arendell St.
Morehead City, NC 28557
800-682-2632
252-726-7021
craig.hardy@ncfisheries.net

About Polluted Areas and Proclamations:

As described in the presentation on Estuaries there are many types of microbes on land and in the water. Most are species are benign bacteria and do good things, but some are pathogenic and can cause disease or illness in humans. Most of the pathogenic bacteria are associated with human waste and are indicated by the presence of *Escherichia coli* a species of bacteria that is endemic to the intestines of all warm-blooded animals.

After large rains the rainwater runs off into streams, which carry *E. coli* and other bacteria with it and eventually finds its way to the estuary. If this runoff contains waste from warm-blooded animals it will also contain *E. coli* and that area of water is closed to the harvest of oysters and clams because of their filter-feeding habits. These areas are called "polluted" areas, "closed" areas and "contaminated" areas. The term "closed" refers to the fact that molluscan shellfish cannot be harvested there. Some areas may normally be "open" to shellfish harvesting but they may close after large rains. Then when the bacteria count lowers to the legal threshold the area is reopened to harvest (presuming it is during the open season for oysters).

Without complicating matters too much, keep in mind that there is an additional open/closed season for harvesting oysters. Clam season is open year-round; however oyster season is only open from October 15th to May 15th. For more details you should contact the NC Division of Marine Fisheries at 252-726-7021 or 800-682-2632 or through their website at www.ncfisheries.net

If areas are normally closed to harvest, they will be designated as such with signs posted by the Division of Marine Fisheries. However, such signs may be too far apart to see or they may have been knocked down by a storm. So before harvesting shellfish in unfamiliar areas it is wise to check with DMF first to determine whether the area is open or closed.

Conversely, areas that are normally open may close after heavy rains. NCDMF has a system in place to announce closures of this type. It is called the Polluted Area Proclamation. A proclamation may be released closing an area after heavy rains. The first paragraph of such a proclamation contains the wording, "**will take effect immediately**:" The proclamation goes on to specifically identify the affected area. When the bacteria count in the water lowers, another proclamation is issued re-opening the affected area. The first paragraph of these proclamations contains the wording, "**will take effect at sunrise**"

You can view past proclamations on the DMF website at:
http://www.ncfisheries.net/paprocs/index.html
You may also sign up to receive proclamations through email at:
http://www.ncfisheries.net/meetings/mail_lists.asp

Example of Proclamation Closure

PA-6-2005

PROCLAMATION

RE: SHELLFISH POLLUTED AREA

Preston P. Pate, Jr., Director, Division of Marine Fisheries, upon the recommendation of Leah Devlin, D.D.S., M.P.H., State Health Director, Department of Health and Human Services, hereby announces that the following shellfish area temporary closures **will take effect immediately**.

No person shall take or attempt to take any oysters, clams or mussels or possess, sell or offer for sale any oysters, clams or mussels taken from the following polluted areas:

CARTERET / ONSLOW / PENDER AND BRUNSWICK COUNTIES

Sleepy Creek - All those waters in Sleepy Creek upstream of a straight line across the mouth.

Whitehurst Creek - All those waters in Whitehurst Creek upstream of a straight line across the mouth.

North River - All those waters in North River upstream of a straight line beginning at a point at the permanent closure line near Channel Marker #56B to the mainland side of the Harkers Island Bridge at The Straits.

Newport River - All those waters in Newport River upstream of the Highway 70 High Rise Bridge and Morehead-Beaufort Causeway, to include all tributaries and Core Creek.

All those waters between the North Topsail High Rise Bridge and the Surf City Bridge.

Lockwoods Folly River: All those waters north of a line beginning on the west shore at a point 33°55.7954'N - 78°13.3096' W approximately midway between Genoes Point and Spring Creek; running southeasterly to a point 33°55.2284'N - 78°12.7791' W near the northwest point of Horse Island, to include the open portion of the Atlantic Intracoastal Water Way north of Horse Island. (Map Attached)

Shallotte River - All those waters in Shallotte River upstream of a straight line from Bowen Point to Long Point.

GENERAL INFORMATION:

A. This proclamation is issued under the authority of G.S. 113-170.4; 113-170.5; 113-182; 113-221(e); 143B-289.52 and N.C. Marine Fisheries Rules 15A NCAC 3H .0103 and 3K .0101.

B. It is unlawful to violate the provisions of any proclamation issued by the Fisheries Director under his delegated authority per 15A NCAC 3H .0103.

C. These temporary closures are due to heavy rainfall and resultant runoff.

February 28, 2005
10:50 a.m.
PA-6-2005
/ph

Example of Proclamation Opening

PA-6-2005

PROCLAMATION

Preston P. Pate, Jr., Director, Division of Marine Fisheries, upon the recommendation of Leah Devlin, D.D.S., M.P.H., State Health Director, Department of Health and Human Services, hereby announces that the following changes in shellfish harvesting areas **will take effect at sunrise, Friday, March 4, 2005.**

All those waters in **Brunswick, Pender, Onslow and Carteret Counties** will return to the status in existence immediately prior to the February 28, 2005 temporary closures with the following **exceptions which will remain closed:**

No person shall take or attempt to take any oysters, clams or mussels or possess, sell or offer for sale any oysters, clams or mussels taken from the following polluted areas:

CARTERET COUNTY

Wards Creek - All those waters in Wards Creek east of a line beginning on the south shore on the impoundment bulkhead at 34° 45' 27.1" N – 76° 35' 10.6" W, running 342° 15' 08" TRUE to a point on the north shore at 34° 46' 16.0" N – 76° 35' 29.6" W.

Newport River - All those waters in Newport River upstream of the Telephone Cable Crossing.

GENERAL INFORMATION:

A. This proclamation is issued under the authority of G.S. 113-170.4; 113-170.5; 113-182; 113-221.1(b); 143B-289.52 and N.C. Marine Fisheries Rules 15A NCAC 3H .0103 and 3K .0101.

B. It is unlawful to violate the provisions of any proclamation issued by the Fisheries Director under his delegated authority per N.C. Marine Fisheries Rule 15A NCAC 3H .0103.

C. This proclamation returns the following areas to normal closure boundaries: Shallotte River, Lockwoods Folly River, the waters between the North Topsail High Rise Bridge and the Surf City Bridge, Sleepy Creek, Whitehurst Creek and a portion of Newport River.

D. These reopenings are due to satisfactory bacteriological sampling results.

March 3, 2005
11:20 a.m.
PA-8-2005
/sab

Oyster Gardening Quiz

1) Water is formed by the combination of hydrogen and oxygen, which forms a polar molecule. This polar quality is important because it allows water to dissolve many compounds such as salt and oxygen and is the reason water is also described as:
    a. Spring water
    b. Hard water
    c. Universal solvent
    d. Salt water
    e. All of the above
2) Estuaries are water passages where saltwater meets freshwater. Although the salinity of estuaries varies they are home to marine organisms called:
    a. Osmoregulators
    b. Osmoconformers
    c. Fish, shrimp and crabs
    d. Oysters
    e. All of the above
3) When using water quality measuring instruments to evaluate your water it is important to periodically _____ them to insure the accuracy of your data.
    a. Clean
    b. Calibrate
    c. Circulate
    d. Correlate
4) What temperature (degrees C) should you look for southern oysters to begin spawning?
    a. 10
    b. 15
    c. 20
    d. 25
5) Broodstock oysters spawn when the water warms in springtime. Most female oysters can produce up to how many eggs?
    a. 10
    b. 100
    c. 1000
    d. 1,000,000 or more
6) Microscopic larval oysters swim in the water column for 15-21 days feeding on phytoplankton until they are ready to settle or “set”. What is the term for the ready-to-settle stage of larval oysters?
    a. Eyed-larvae
    b. Trochophore
    c. Veliger
    d. Zygote
7) The setting larval oysters go through metamorphosis changing from swimming to sessile organisms and they attach to hard substrate called cultch. Which of the following is a suitable substrate for attaching larval oysters?
    a. Oyster shells
    b. Clam shells
    c. Marl rocks
    d. All of the above

8) The oyster hatchery's goal is to produce oyster larvae and ship them to oyster farms, restoration projects and oyster gardeners. Using a 2-day tank drain down cycle and daily feeding of cultured algae, oyster larvae can be produced in about 15-12 days. The larvae are harvested with a 250-micron sieve and are counted volumetrically. What is the volume of one million eyed-larvae oysters?
    a. 20 milliliters
    b. 100 liters
    c. 1 bushel
    d. 1 gallon
9) The open season for harvesting oysters is normally set for
    a. Only months with the letter "R" in them
    b. October 15th through May 15 of each year
    c. Winter months only
    d. Summer months only
10) Polluted areas can be used for on-bottom oyster gardens but harvesting is never allowed from those areas. What situation is most likely to cause an area currently open for harvesting oysters to close temporarily?
    a. Boat wreck
    b. Oyster spawning season
    c. Heavy rainfall runoff
    d. Phytoplankton bloom
11) Oyster gardeners have private ownership rights to the oysters that they grow.
    a. True
    b. False
12) A 55-gallon plastic drum can be modified for use as a backyard remote setting system for oyster larvae by cutting out the side, placing air stones in the bottom, supplying air and filling the drum with cultch and seawater. What is the recommended number of oyster larvae to stock into this 55-gallon system?
    a. 250
    b. 2,500
    c. 25,000
    d. 2,500,000
13) What are some common predators of juvenile oysters?
    a. Snails
    b. Fish
    c. Birds
    d. Crabs
    e. All of the above
14) Oysters filter water!
    a. True!
    b. False
15) Oysters provide fishery habitat!
    a. True!
    b. False
16) Oyster gardening can be a benefit to the environment!
    a. True!
    b. False

Appendix I.

Some Basic Chemistry and Properties of Water

A water molecule consists of three atoms; an oxygen atom which is covalently bound to two hydrogen atoms. Hydrogen has an atomic mass of 1 g/ mol and oxygen has an atomic mass of 16 g/mol. This means that the mass of a water molecule is 18 g/ mol.

Water exists in three states: solid, liquid and gaseous. At normal temperatures it is liquid, but below 0-deg C it will freeze and turn to ice. Water is found in the gaseous state above 100-deg C, the boiling point of water, at which point water starts to evaporate.

Water is a "polar" molecule, meaning that there is an uneven distribution of electron density. Water has a partial negative charge (-) near the oxygen atom due the unshared pairs of electrons, and partial positive charges (+) near the hydrogen atoms. It is the polar property of water, which allows it to be termed the “universal solvent.”

An electrostatic attraction between the partial positive charge near the hydrogen atoms and the partial negative charge near the oxygen results in the formation of a hydrogen bond. Hydrogen bonds form in solutions to dissolve other compounds and they form when water freezes. The latter gives ice a lattice-type structure, which is less dense than the liquid form. That is why ice floats on water.

As rain falls from the clouds, carbon dioxide dissolves in it forming a weak solution of carbonic acid. Generally speaking, rainwater has a pH about 5.5, rather acidic (because carbon dioxide dissolves from the atmosphere and produces weak carbonic acid). Acid rain has a much lower pH of about 4.3.

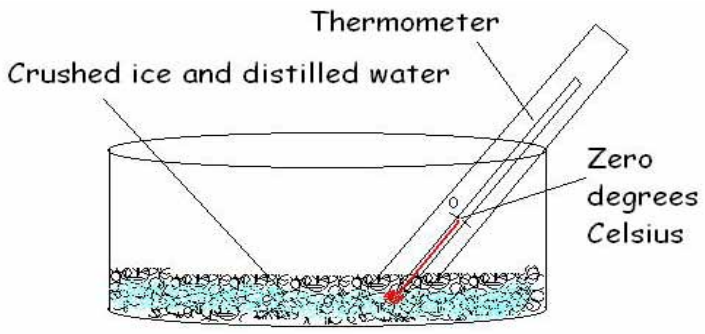
Other unique physical properties, including a high heat of vaporization, strong surface tension, high specific heat, and nearly universal solvent properties of water are also due to hydrogen bonding. The hydrophobic effect, or the exclusion of compounds containing carbon and hydrogen (non-polar compounds like oil), is another unique property of water caused by the hydrogen bonds.

Density is the mass per unit volume. The density of water is usually taken as 1.0 g/mL. At 4°C pure water has a specific gravity of 1. The specific gravity increases as salt is dissolved into freshwater.

Sources:
Univ. Arizona, The Biology Project, Biochemistry: Chemistry Tutorial
http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page3.html
Lenntech. Water Chemistry FAQ.
http://www.lenntech.com/water-chemistry-FAQ.htm

Thermometer Calibration

Thermometers range from the cheap garden type models to accurate and expensive laboratory models. With inexpensive types it is important to be sure your thermometer is giving accurate readings. Thermometer calibration simply involves immersion of the thermometer in ice water for obtaining a zero reading. Use crushed ice for quickest cooling and distilled water for most accurate calibration. If your thermometer is not accurate, simply note the difference with permanent marker on the device. If your thermometer is reading 2 degrees low write +2 on it so you will remember to add 2 degrees to your reading.



Thermometer calibration

Temperature Conversion Chart

Celsius	Fahrenheit	Celsius	Fahrenheit	Celsius	Fahrenheit
0 C	32.0 F	11 C	51.8 F	21 C	69.8 F
1 C	33.8 F	12 C	53.6 F	22 C	71.6 F
2 C	35.6 F	13 C	55.4 F	23 C	73.4 F
3 C	37.4 F	14 C	57.2 F	24 C	75.2 F
4 C	39.2 F	15 C	59.0 F	25 C	77.0 F
5 C	41.0 F	16 C	60.8 F	26 C	78.8 F
6 C	42.8 F	17 C	62.6 F	27 C	80.6 F
7 C	44.6 F	18 C	64.4 F	28 C	82.4 F
8 C	46.4 F	19 C	66.2 F	29 C	84.2 F
9 C	48.2 F	20 C	68.0 F	30 C	86.0 F
10 C	50.0 F				

The equation for converting Fahrenheit to Celsius is:

((Deg. F) - 32) x (5/9) = Deg. C

The equation for converting Celsius to Fahrenheit is:

(Deg.C x 1.8) + 32 = Deg

Hydrometer

Hydrometer is a device for measuring the specific gravity of water. This reading can be converted to salinity once the temperature is known.

Plastic pointer-type hydrometer:

- Fill hydrometer to indicated level and read specific gravity from imprinted scale; sometimes the scale is also pre-calibrated with an estimated salinity reading.
- **Important**: hydrometer pointer should be free of bubbles; tap to release bubbles!

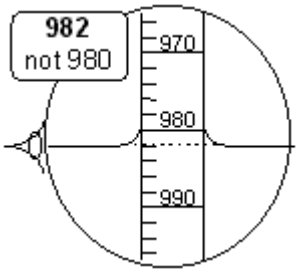
Glass tubular hydrometer

Before using the hydrometer

- Pour water carefully into the hydrometer jar to avoid the formation of air bubbles. Do this by pouring it slowly down the side of the jar.

Taking a Reading

- Carefully insert the hydrometer into the water, holding it at the top of the stem, and release it when it is approximately at its position of equilibrium.
- Note the reading approximately, and then push the hydrometer gently into the liquid a few millimeters beyond its equilibrium position.
- Release the hydrometer; it should rise steadily and after a few oscillations settle down to its position of equilibrium.
- The correct scale reading is that corresponding to the plane of intersection of the horizontal liquid surface and the stem. This is not the point where the surface of the liquid actually touches the hydrometer stem. Take the reading by viewing the scale through the liquid, and adjusting your line of sight until it is in the plane of the horizontal liquid surface. Do not take a reading if the hydrometer is touching the side of the hydrometer jar.



Taking the Temperature

- Using a suitable thermometer, take the temperature of the liquid immediately after taking the hydrometer reading.
- If there is any chance of a change in the temperature of the liquid it is safer to take the temperature both before and after the hydrometer reading. A difference of more than 1°C means that the temperature is not stable, and the liquid should be left to reach room temperature.

Handling the Hydrometer

- The hydrometer should never be held by the stem, except when it is being held vertically for placing into the sample jar.

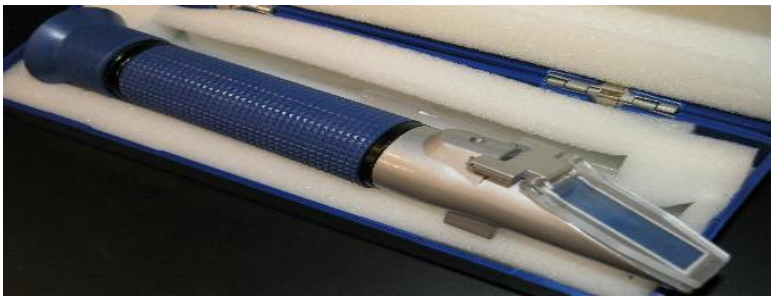
Always handle with care!

Information source: Stevenson-Reeves LTD
http://www.stevenson-reeves.co.uk/howto.htm

Refractometers

What is a refractometer?

A salinity refractometer is a device designed for testing the concentration of saltwater brine. This device provides a direct reading of the specific gravity and salt concentration in parts per thousand (ppt). The reading is caused by the differential refraction of light through the water and prism. Looking through the eyepiece of the refractometer you will see a circular field with graduations down the center. The scale on the left is specific gravity and the scale on the right is parts per thousand salinity (ppt). With a water sample in place you will see an upper blue field and a lower white field. The line between the two fields is called the boundary. Note the value where the boundary crosses the graduated scale, which will give you the salinity. Most refractometers are temperature-compensated; however if you are using a non-compensated model use the conversion tables in the appendix to convert to salinity as with the hydrometers.



How to use a refractometer

Procedure:

1. Calibrate first with fresh water. Open the daylight plate and place 1-2 drops of distilled water on the prism.
2. Close the daylight plate so that the water spreads across the entire surface of the prism. Make sure there are no air bubbles or dry spots visible on the prism.
3. Point the refractometer toward a light source and view through the eyepiece.
4. Turn the calibration screw (located on top of the refractometer in front of the daylight plate) until the boundary between the upper blue field and the lower white field meet exactly on the zero scale. This concludes the calibration process.
5. Clean and dry the prism.
6. Place 1-2 drops of sample to be tested onto the prism.
7. Close the daylight plate, look into the eyepiece and check the reading. Take the reading where the boundary line of the blue and white fields meet across the graduated salinity scale.
8. Read the salinity in parts per thousand to the closest mark.

Results:

Fresh water is generally less than 1 ppt
Brackish water is highly variable and may range from 2-20 ppt
Salt water ranges from 20-35 ppt
Full strength ocean seawater is 35 ppt

Appendix I.

What is a Secchi Disk?

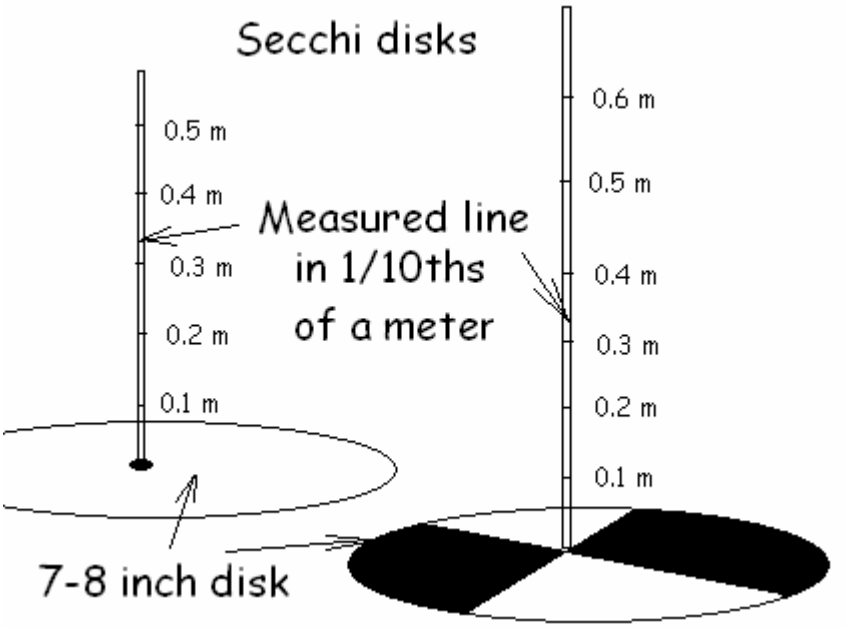
A Secchi disk is a round white or black and white weighted disk approximately 8 inches in diameter attached to a length of rope marked in increments of 0.1 meters. Secchi disks are white or black and white so that they are easily visible under the water. They are used to measure the turbidity, or "visibility", of water. Turbidity can be affected by a variety of factors such as rainwater runoff with suspended sediments, plankton and algae blooms. The Secchi visibility gives an indication of the algae in the water, which is a source of food for oysters.

How do you use a Secchi Disk?

Allow the disk to sink down through the water column until it reaches the point of "zero visibility". Slowly retrieve the disk until it becomes visible once again. This depth is known as the "Secchi visibility depth". Make a note of your measurement.

What do my results tell me?

Less than 1 meter = Eutrophic status (very murky and high in nutrients)
From 1-8 meters = Mesotrophic
Greater than 8 meters = Oligotrophic (very clear, few nutrients)



How-to Build and Use a Secchi Disk

Turbidity can be caused by several factors but is primarily caused by phytoplankton, silt and suspended solids. Secchi disks are used to measure turbidity of water and the measurement is called the secchi disk visibility. Professional secchi disks are very durable but expensive with some models selling for $20 or more. A very inexpensive secchi disk was developed for the citizens' oyster gardening program. It requires a white plastic paint can lid or a Cool Whip-type container lid, a 6-ounce pyramid fishing sinker and a 12-foot length of white string.

How do I make my own Secchi Disk?

1. Obtain a plastic lid approximately 8-inches in diameter. Paint can lids or Miracle Whip lids are about the right size. If it is not already white in color paint it white.
2. Cut or drill a small hole in the center of the lid.
3. Obtain a 6 oz. pyramid fishing weight and push the eye (wire loop) of the weight through the hole in the disk from the bottom side.
4. Tie a 2-3 meter (6-10 ft) length of heavy white cord securely to the wire loop of the weight. Tie a very big knot so the cord will not pull back through the lid.
5. Using a black permanent marker and a metric measuring stick mark the cord in increments of $1/10^{ths}$ of a meter. Use a different color marker to mark the half, one- and two-meter marks.

How to use a Secchi disk

To determine the secchi disk visibility of your water first remove your sunglasses. Lower the secchi disk into the water until you can no longer see it. Raise it up until you can barely see it then lower it again until it just barely disappears from view. Then slowly raise the secchi disk counting the number of black 1/10th meter marks on the string until the disk reaches the surface. The resulting number is the secchi disk visibility and is reported in meters and tenths of meters.

For example:
A typical secchi disk reading might be 0.8 meters or 1.1 meters visibility.
Record the information in your oyster gardening data sheet.

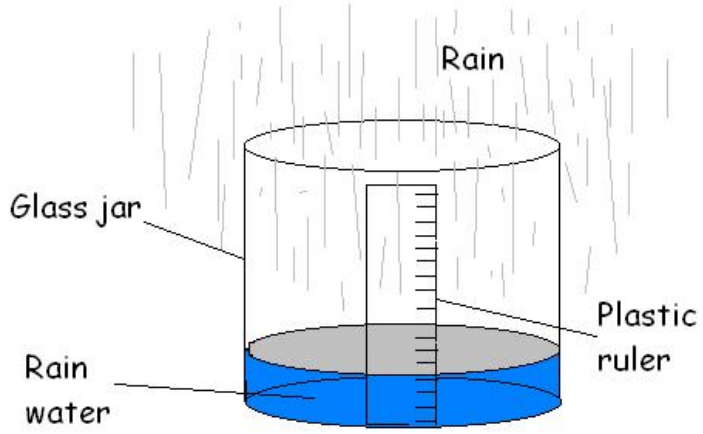
Other water quality parameters

Water quality test kits are available for testing many water quality parameters including:

Rainfall
Dissolved Oxygen
pH
Hardness
Alkalinity
Ammonia
Nitrite
Nitrate
Carbon dioxide
Coliform bacteria

Rain Gauge

The rain gauge is a device used to measure precipitation such as rainfall and snow. The most important factor of the rain gage is its location, which needs to be free of natural and man-made obstructions. Exposure to the elements is essential to accurately determine the amount of precipitation. Rain gages can be bought cheaply or you can make one yourself from a straight-sided jar and ruler. Below is a simple diagram of a homemade rain gauge made from a jar with a ruler that can be attached with hot glue. Simply put it outside and wait for rain and when its finished measure the amount of rainfall left in the bottom. Be careful though; sometimes weather like erratic winds can affect results. A narrow-mouth jar will give false readings.



Homemade Rain Gauge

APNEP Citizen's Oyster Gardening Project

Water Quality Records and Data Sheet

Location: ____

		Temperature						
Date	**Time**	**Air**	**Water**	**Salinity**	**Rainfall**	**Secchi**	**Spat**	**Comments**
.								

Appendix III.

Hydrometer conversion table

Table gives salinity in parts per thousand for temperatures **9-18 °C .** Use hydrometer reading for specific gravity and water temperature to determine salinity in ppt.

S.G.	Temperature °C									
	9	10	11	12	13	14	15	16	17	18
1.002	1.6	1.8	1.9	2	2.1	2.3	2.4	2.5	2.8	2.9
1.003	2.9	3.1	3.2	3.3	3.4	3.6	3.7	3.8	4.1	4.2
1.004	4.2	4.4	4.5	4.6	4.8	4.9	5	5.1	5.4	5.5
1.005	5.5	5.5	5.7	5.8	5.9	6.2	6.3	6.6	6.7	7
1.006	6.8	6.8	7	7.1	7.2	7.5	7.6	7.9	8	8.3
1.007	8.1	8.1	8.3	8.4	8.5	8.8	8.9	9.2	9.3	9.6
1.008	9.3	9.4	9.6	9.7	9.8	10	10.2	10.5	10.6	10.9
1.009	10.6	10.7	10.9	11	11.1	11.3	11.5	11.8	11.9	12.2
1.010	11.9	12	12.2	12.3	12.4	12.6	12.8	13.1	13.2	13.5
1.011	13.2	13.4	13.5	13.6	13.7	13.9	14.1	14.4	14.5	14.8
1.012	14.5	14.7	14.8	14.9	15	15.2	15.4	15.7	15.8	16.1
1.013	15.8	15.8	16	16.2	16.3	16.5	16.7	17	17.1	17.4
1.014	17	17.1	17.3	17.5	17.7	17.8	18	18.3	18.6	18.7
1.015	18.3	18.4	18.6	18.8	19	19.1	19.3	19.6	19.9	20
1.016	19.6	19.7	19.9	20.1	20.3	20.4	20.6	20.9	21.2	21.3
1.017	20.9	21	21.2	21.3	21.6	21.7	22	22.2	22.5	22.7
1.018	22.2	22.3	22.5	22.6	22.9	23	23.3	23.5	23.8	24
1.019	23.5	23.6	23.8	23.9	24.2	24.3	24.6	24.8	25.1	25.3
1.020	24.7	24.8	25.1	25.2	25.5	25.6	25.9	26.1	26.4	26.6
1.021	26	26.1	26.4	26.5	26.8	26.9	27.2	27.4	27.7	27.9
1.022	27.3	27.4	27.7	27.8	28.1	28.2	28.5	28.7	29	29.2
1.023	28.6	28.7	28.9	29.1	29.4	29.5	29.8	30	30.3	30.6
1.024	29.9	30	30.2	30.4	30.6	30.8	31.1	31.3	31.6	31.9
1.025	31.1	31.3	31.5	31.7	31.9	32.1	32.4	32.6	32.9	33.2
1.026	32.4	32.6	32.8	33	33.2	33.4	33.7	33.9	34.2	34.5
1.027	33.7	33.9	34.1	34.3	34.5	34.7	35	35.2	35.5	35.8

Source: Aquatext- Free on-line aquaculture dictionary
http://www.aquatext.com/tables/hyd18-23.htm

Hydrometer conversion to salinity

Table gives salinity in parts per thousand for temperatures **18.5-23 °C .** Use hydrometer reading for specific gravity and water temperature to determine salinity in ppt.

S.G.	Temperature °C									
	18.5	19	19.5	20	20.5	21	21.5	22	22.5	23
1.000	0.5	0.6	0.7	0.8	1	1.1	1.2	1.4	1.5	1.6
1.001	1.8	1.9	2	2.1	2.3	2.4	2.5	2.5	2.7	2.8
1.002	3.1	3.2	3.3	3.4	3.6	3.7	3.8	4	4.1	4.2
1.003	4.4	4.5	4.6	4.8	4.9	5	5.1	5.3	5.4	5.5
1.004	5.7	5.8	5.9	6.1	6.2	6.3	6.4	6.6	6.7	7
1.005	7.1	7.1	7.2	7.4	7.5	7.6	7.7	7.9	8.1	8.3
1.006	8.4	8.5	8.7	8.8	8.9	9.1	9.2	9.3	9.4	9.6
1.007	9.7	9.8	10	10.1	10.2	10.4	10.5	10.6	10.7	10.9
1.008	11	11.1	11.3	11.4	11.5	11.7	11.8	11.9	12	12.2
1.009	12.3	12.4	12.6	12.7	12.8	13	13.1	13.2	13.4	13.6
1.010	13.6	13.7	13.9	14	14.1	14.3	14.4	14.5	14.8	14.9
1.011	14.9	15	15.2	15.3	15.4	15.6	15.7	16	16.1	16.2
1.012	16.2	16.3	16.5	16.6	16.7	17	17.1	17.3	17.4	17.5
1.013	17.5	17.7	17.8	17.9	18	18.3	18.4	18.6	18.7	18.8
1.014	18.8	19	19.1	19.3	19.5	19.6	19.7	19.9	20	20.1
1.015	20.1	20.4	20.5	20.6	20.8	20.9	21	21.2	21.3	21.6
1.016	21.4	21.7	21.8	22	22.1	22.2	22.3	22.5	22.7	22.9
1.017	22.9	23	23.1	23.3	23.4	23.5	23.6	23.8	24	24.2
1.018	24.2	24.3	24.4	24.6	24.7	24.8	24.9	25.2	25.3	25.5
1.019	25.5	25.6	25.7	25.9	26	26.1	26.4	26.5	26.6	26.8
1.020	26.8	26.9	27	27.2	27.3	27.4	27.7	27.8	27.9	28.2
1.021	28.1	28.2	28.3	28.5	28.6	28.9	29	29.1	29.2	29.5
1.022	29.4	29.5	29.6	29.8	30	30.2	30.3	30.4	30.7	30.8
1.023	30.7	30.8	30.9	31.2	31.3	31.5	31.6	31.7	32	32.1
1.024	32	32.1	32.2	32.5	32.6	32.8	32.9	33.2	33.3	33.4
1.025	33.3	33.4	33.7	33.8	33.9	34.1	34.2	34.5	34.6	34.7
1.026	34.6	34.7	35	35.1	35.2	35.4	35.6	35.8	35.9	36
1.027	35.9	36.2	36.3	36.4	36.5	36.7	36.9	37.1	37.2	37.5

Source: Aquatext- Free on-line aquaculture dictionary
http://www.aquatext.com/tables/hyd18-23.htm

Hydrometer conversion table

Table gives salinity in parts per thousand for temperatures **23.5-28 °C .** Use hydrometer reading for specific gravity and water temperature to determine salinity in ppt.

S.G.	Temperature °C									
	23.5	24	24.5	25	25.5	26	26.5	27	27.5	28
0.998	0.1	0.2	0.3	0.6						
0.999	0.5	0.6	0.7	0.8	1	1.2	1.4	1.5	1.8	1.9
1.000	1.8	1.9	2	2.1	2.4	2.5	2.7	2.9	3.1	3.2
1.001	2.9	3.1	3.2	3.4	3.6	3.8	4	4.2	4.4	4.5
1.002	4.4	4.6	4.8	4.9	5	5.1	5.4	5.5	5.7	5.9
1.003	5.8	5.9	6.1	6.2	6.3	6.6	6.7	6.8	7.1	7.2
1.004	7.1	7.2	7.4	7.5	7.7	7.9	8	8.3	8.4	8.5
1.005	8.4	8.5	8.7	8.9	9.1	9.2	9.3	9.6	9.7	10
1.006	9.7	9.8	10.1	10.2	10.4	10.5	10.7	10.9	11	11.3
1.007	11	11.3	11.4	11.5	11.7	11.9	12	12.2	12.4	12.6
1.008	12.4	12.6	12.7	12.8	13	13.2	13.4	13.6	13.7	13.9
1.009	13.7	13.9	14	14.1	14.4	14.5	14.7	14.9	15	15.3
1.010	15	15.2	15.3	15.6	15.7	15.8	16.1	16.2	16.5	16.6
1.011	16.3	16.5	16.7	16.9	17	17.3	17.4	17.5	17.8	17.9
1.012	17.7	17.9	18	18.2	18.3	18.6	18.7	19	19.1	19.3
1.013	19.1	19.2	19.3	19.5	19.7	19.9	20	20.3	20.4	20.6
1.014	20.4	20.5	20.6	20.9	21	21.2	21.4	21.6	21.8	22
1.015	21.7	21.8	22	22.2	22.3	22.5	22.7	22.9	23.1	23.3
1.016	23	23.3	23.4	23.5	23.6	23.9	24	24.3	24.4	24.7
1.017	24.3	24.6	24.7	24.8	25.1	25.2	25.3	25.6	25.7	26
1.018	25.6	25.9	26	26.1	26.4	26.5	26.8	26.9	27.2	27.3
1.019	27	27.2	27.3	27.6	27.7	27.8	28.1	28.2	28.5	28.6
1.020	28.3	28.5	28.6	28.9	29	29.2	29.4	29.6	29.8	30
1.021	29.6	29.8	30	30.2	30.3	30.6	30.7	30.9	31.1	31.3
1.022	30.9	31.2	31.3	31.5	31.7	31.9	32	32.2	32.5	32.6
1.023	32.2	32.5	32.6	32.8	33	33.2	33.4	33.5	33.8	33.9
1.024	33.7	33.8	33.9	34.2	34.3	34.5	34.7	35	35.1	35.4
1.025	35	35.1	35.2	35.5	35.6	35.9	36	36.3	36.4	36.7

Source: Aquatext- Free on-line aquaculture dictionary
http://www.aquatext.com/tables/hyd18-23.htm

Hydrometer conversion table

Table gives salinity in parts per thousand for temperatures **28.5-33 °C .** Use hydrometer reading for specific gravity and water temperature to determine salinity in ppt.

S.G.	Temperature °C									
	28.5	29	29.5	30	30.5	31	31.5	32	32.5	33
0.998	0.7	0.8	1.1	1.2	1.5	1.6	1.9	2	2.3	2.4
0.999	2	2.3	2.4	2.5	2.8	2.9	3.2	3.4	3.6	3.8
1.000	3.4	3.6	3.7	4	4.1	4.4	4.5	4.8	4.9	5.1
1.001	4.8	4.9	5.1	5.1	5.4	5.5	5.8	5.9	6.2	6.4
1.002	6.1	6.3	6.4	6.6	6.8	7	7.2	7.5	7.6	7.9
1.003	7.4	7.6	7.7	8	8.1	8.4	8.5	8.8	9.1	9.2
1.004	8.8	8.9	9.2	9.3	9.6	9.7	10	10.1	10.4	10.5
1.005	10.1	10.2	10.5	10.6	10.9	11	11.3	11.5	11.7	11.9
1.006	11.4	11.7	11.8	12	12.2	12.4	12.6	12.8	13.1	13.2
1.007	12.8	13	13.1	13.4	13.6	13.7	14	14.1	14.4	14.7
1.008	14.1	14.3	14.5	14.7	14.9	15.2	15.3	15.6	15.7	16
1.009	15.4	15.7	15.8	16.1	16.2	16.5	16.6	16.9	17.1	17.3
1.010	16.7	17	17.1	17.4	17.5	17.8	18	18.2	18.4	18.7
1.011	18.2	18.3	18.6	18.7	19	19.1	19.3	19.6	19.7	20
1.012	19.5	19.6	19.9	20.1	20.3	20.5	20.6	20.9	21.2	21.3
1.013	20.8	21	21.2	21.4	21.6	21.8	22.1	22.2	22.5	22.7
1.014	22.2	22.3	22.6	22.7	23	23.1	23.4	23.6	23.8	24
1.015	23.5	23.6	23.9	24	24.3	24.6	24.7	24.9	25.2	25.3
1.016	24.8	25.1	25.2	25.5	25.6	25.9	26.1	26.3	26.5	26.8
1.017	26.1	26.4	26.5	26.8	27	27.2	27.4	27.7	27.8	28.1
1.018	27.6	27.7	27.9	28.1	28.3	28.5	28.7	29	29.2	29.4
1.019	28.9	29	29.2	29.5	29.6	29.9	30	30.3	30.6	30.8
1.020	30.2	30.4	30.6	30.8	30.9	31.2	31.5	31.6	31.9	32.1
1.021	31.5	31.7	32	32.1	32.4	32.5	32.8	33	33.3	33.4
1.022	32.9	33	33.3	33.4	33.7	33.9	34.1	34.3	34.6	34.8
1.023	34.2	34.5	34.6	34.8	35	35.2	35.5	35.6	35.9	36.2
1.024	35.5	35.8	35.9	36.2	36.4	36.5	36.8	37.1	37.2	37.5
1.025	36.8	37.1	37.2	37.5	37.7	37.8	38.1	38.4	38.6	38.8
1.026	38.2	38.4	38.6	38.8	39	39.3	39.4	39.7	39.9	40.2
1.027	39.5	39.8	39.9	40.2	40.3	40.6	40.8	41	41.2	41.5

Source: Aquatext- Free on-line aquaculture dictionary
http://www.aquatext.com/tables/hyd18-23.htm

Answer Key: Oyster Gardening Quiz

1) Water is formed by the combination of hydrogen and oxygen, which forms a polar molecule. This polar quality is important because it allows water to dissolve many compounds such as salt and oxygen and is the reason water is also described as:
    a. Spring water- this is not caused by polarity of water molecules
    b. Hard water- this is not caused by polarity of water molecules
    c. Universal solvent- polarity allows many compounds to dissolve in water thus the term "solvent"
    d. Salt water- this is not caused by polarity of water molecules
    e. All of the above- only the term universal solvent is directly related to the polarity of the water molecule
2) Estuaries are water passages where saltwater meets freshwater. Although the salinity of estuaries varies they are home to marine organisms called:
    a. Osmoregulators- organisms maintain salt content in their bodies different from the water
    b. Osmoconformers- organisms adjust salt content of their body to match the environment
    c. Fish, shrimp and crabs- seafood platter
    d. Oysters- a keystone species for estuaries
    e. All of the above
3) When using water quality measuring instruments to evaluate your water it is important to periodically _____ them to insure the accuracy of your data.
    a. Clean- instruments should be cleaned but it doesn't insure accuracy
    b. Calibrate- instruments should be calibrated to give accurate readings such as temperature, salinity and dissolved oxygen
    c. Circulate- not applicable to water testing
    d. Correlate- another unrelated term

4) What temperature (degrees C) should you look for southern oysters to begin spawning?
    a. 10
    b. 15
    c. 20
    d. 25
5) Broodstock oysters spawn when the water warms. Female oysters can produce how many eggs?
    a. 10
    b. 100
    c. 1000
    d. 1,000,000 or more- large female oysters can produce up to 10 million or more eggs each
6) Microscopic oysters swim in the water column for 15-21 days feeding on phytoplankton until they are ready to settle or "set". What is the term for the ready-to-settle stage of larval oysters?
    a. Eyed-larvae- larvae develop a microscopic eyespot about three days before they metamorphosis, thus giving them the name eyed-larvae
    b. Trochophore
    c. Veliger
    d. Zygote
7) The setting larval oysters go through metamorphosis changing from swimming to sessile organisms and they attach to hard substrate called cultch. Which of the following is a suitable substrate for attaching larval oysters?
    a. Oyster shells- these are the best cultch for larval oyster settlement
    b. Clam shells- suitable substrate but not as good as oyster shells
    c. Marl rocks- suitable substrate but not as good as oyster shells
    d. All of the above

8) The oyster hatchery's goal is to produce oyster larvae and ship to oyster farms, restoration projects and oyster gardeners. Using a 2-day tank drain down cycle and daily feeding of cultured algae, oyster larvae can be produced in about 15-12 days. The larvae are harvested with a 250-micron sieve and are counted volumetrically. What is the volume of one million eyed-larvae oysters?
    - **a. 20 milliliters- each oyster eyed-larvae captured on a 250-micron sieve is only about 1/3-millimeter in length**
    - b. 100 liters- this volume would yield about 5.0 billion oyster larvae
    - c. 1 bushel- this volume would yield about 1.76 billion oyster larvae
    - d. 1 gallon- this volume would yield about 189 million oyster larvae
9) The open season for harvesting oysters is normally set for
    - a. Only "R" months- myth originated because oysters spawn during summer
    - **b. October 15th through May 15 of each year**
    - c. Winter months only- oyster season contains fall, winter and spring months
    - d. Summer months only- oysters spawn in summer and harvest is closed
10) Polluted areas can be used for on-bottom oyster gardens but harvesting is never allowed from those areas. What situation is most likely to cause an area currently open for harvesting oysters to close temporarily?
    - a. Boat wreck- not related to pollution, which closes oyster harvest areas
    - b. Oyster spawning season- not related to pollution, which closes oyster harvest areas
    - **c. Heavy rainfall and resulting runoff**
    - d. Phytoplankton bloom- not related to pollution, which closes oyster harvest areas
11) Oyster gardeners have private ownership rights to the oysters that they grow.
    - a. True- no, currently oyster gardeners do not own the oysters in their gardens
    - **b. False- oyster gardeners do not own the oysters in their gardens, however a new permit passed by the NC General Assembly authorizes the NC Division of Marine Fisheries to issue a permit for private oyster gardening; but only in open areas not in polluted areas**
12) A 55-gallon plastic drum can be modified as a backyard remote setting system for oyster larvae by cutting out the side, placing air stones in the bottom, supplying air and filling the drum with cultch and seawater. What is the recommended number of oyster larvae to stock into this system?
    - a. 250
    - b. 2,500
    - **c. 25,000- only about 25% of oyster larvae survive metamorphosis, a barrel can contain 100 large marl rocks, when marl is placed on the bottom half of the young oysters die from the bottom silt, subsequent survival to adulthood varies from 10-50%. The calculation thus becomes 25,000 x .25 x .50 x .50 / 100 = 15 juvenile oysters per marl rock an adequate number to restore oyster beds.**
    - d. 2,500,000
13) What are some common predators of juvenile oysters?
    - a. Snails- yes, oyster drills and moon snails
    - b. Fish- yes, sheepshead and cow-nosed stingrays (but not oystertoad fish which eat crabs
    - c. Birds- yes, seagulls and oyster catchers
    - d. Crabs- yes, these are the most serious predators of juvenile oysters
    - **e. All of the above**
14) Oysters filter water!
    - **a. True! Mature oysters filter 30-50 gallons of water daily**
    - b. False
15) Oysters provide fishery habitat!
    - **a. True! Oyster beds function as a marine ecosystem and provide nursery areas for juvenile fish, shrimp and crabs**
    - b. False
16) Oyster gardening can be a benefit to the environment!
    - **a. True! Mature oysters in gardens spawn yearly producing millions of spat that settle on other areas. Their shells remain in the water providing substrate for additional oysters to attach each year thus beginning the long process of restoring oyster beds.**
    - b. False

Contact Information

Citizens' Oyster Gardening Project

Project Funding:
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Fax: 919-715-3060
http://www.apnep.org/

Project Coordinator:
Carteret Community College
Aquaculture Technology Program
3505 Arendell Street
Morehead City, NC 28557
Tel: 252-222-6114
Fax: 252-222-6311
http://main2.carteret.edu/~kemps/

Project Partners:

North Carolina Coastal Federation
3609 Highway 24 (Ocean)
Newport, NC 28570
Tel: 252-393-8185
Fax: 252-393-7508
Toll-Free: 800-232-6210
http://www.nccoast.org/

The Nature Conservancy
Nags Head Woods Ecological Preserve
701 West Ocean Acres Drive
Kill Devil Hills, NC 27948
Tel: (252) 441-2525
Fax: (252) 441-1271
http://nature.org/wherewework/northamerica/states/northcarolina/contact/

Shellfish Gardeners of North Carolina
http://www.oysters-cleanwater.info/
(See page 46 for more information)

NC National Estuarine Research Reserve
135 Duke Marine Lab Rd.
Beaufort, NC 28516
Tel: 252-728-2170
Fax: 252-728-6273
http://www.ncnerr.org/

North Carolina Sea Grant
NC State University
Campus Box 8605
Raleigh, NC 27695-8605
Phone: 919/515-2454
Fax: 919/515-7095
http://www.ncseagrant.org/

NC Division of Marine Fisheries
3441 Arendell Street
Morehead City, NC 28557
Tel: 252-726-7021
Or 800-682-2632
http://www.ncdmf.net/

Shellfish Gardeners of North Carolina, Inc.

To learn about Oyster Gardeners and what we do, go to:
http://www.oysters-cleanwater.info/

PERMIT
This COGP training manual describes ways to grow oysters without a permit, however the Under Dock Oyster Culture (UDOC) requires a PERMIT. The permit requirements and application and manual are available from the NC Division of Marine Fisheries website at: http://www.ncfisheries.net/shellfish/UDOC1.htm The Shellfish Gardeners of North Carolina can help you with the permit application process.

JOIN
We welcome you to join our group. Membership is not required for permitting. It is however, a good way to get

- current information
- oyster growing supplies
- larvae and spat
- training and advice

SEND an E-mail to ohara32@pamlico.net
Ask for the membership form.

We meet locally to inform and assist each other as we work to restore oyster habitat. We cooperate in the provision of oyster larvae, spat and supplies. We help train new members so they can become under-dock oyster gardeners.

We think it is important to restore oyster habitat because oysters clean water, provide habitat for the young of many species and could again be a major moneymaker for commercial oyster gatherers. Our selective harvesting can also improve the oyster gene pool. We work to inform fishermen, community members and officials of the special properties and needs of North Carolina Shellfish,

Contact Area:

Bogue Banks (Emerald Isle)	Pamlico County (Oriental)	Hatteras and (OBX areas)	Wilmington (Hampstead)
John Zimmerman	John Alison	Mike Halminski	Jack Spruill
252-393-6514	252-745-7038	252-987-2401	812-483-0762
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Additional Resources

Network With Other Gardeners

Email Discussion Group

- Shellfish_Gardening is a listserv group administered through NC State University for discussion and information dissemination regarding the development of shellfish gardening in North Carolina.
- You can subscribe at the following Web site: http://lists.ncsu.edu/ Click on the Subscriber interface button and type shellfish_gardening in the box.
- You can also subscribe by sending an email to: mj2@lists.ncsu.edu with the words subscribe shellfish_gardening in the body of the email.
- Send email messages to the group at this email address: shellfish_gardening@lists.ncsu.edu
- If you have trouble subscribing or sending messages please contact the "list-owner", Sara Mirabilio saram@csi.northcarolina.edu

Other States Oyster Gardening Programs:

- **VIMS-Virginia Institute of Marine Sciences: Oyster Gardening** http://www.vims.edu/abc/green/ogp.html
- **The Tidewater Oyster Gardeners Association (Virginia)** http://www.oystergardener.org/
- **New York-New Jersey Baykeeper** http://www.nynjbaykeeper.org/programs/42
- **Maryland Oyster Gardening Program for Restoration and Education** http://www.mdsg.umd.edu/oysters/garden/
- **The Southold Project in Aquaculture Training- SPAT (New York)** http://www.cce.cornell.edu/suffolk/spat/index.html
- **South Carolina Oyster Restoration and Enhancement (SCORE)** http://www3.csc.noaa.gov/scoysters/
- **Mobile Bay National Estuary Program**
    - http://www.mobilebaynep.com/oystergardening/Oyster%20Gardening.htm

Government / Regulations

North Carolina Division of Marine Fisheries (DMF)

The NCDMF Web site <http://www.ncdmf.net/> contains information about regulations, area closures, and laws concerning oyster gardening and other topics. This is where you can view polluted areas and proclamations as well as sign up to receive them via email.

Planting an oyster garden

Citizens' Oyster Gardening Program

Oysters Filter Water!