A Century of Gardens by the Sea:
Water Quality and Environmental Education Program at Airlie Gardens

Airlie Gardens is a place defined by water. The Garden property is adjacent to the Bradley Creek salt marsh and shares a shoreline of roughly 2,600 linear feet with that tidal wetland. Bradley Creek receives runoff from over 4,600 acres and is the second largest, and one of the most polluted, of New Hanover County's tidal creeks. Over the last century as Airlie remained preserved in a garden state, the land surrounding Airlie within the Bradley creek watershed experienced tremendous growth in population density and impervious surface. In 1999, the decision was made by New Hanover County Government to buy the Airlie tract, in large part because it was the last undeveloped tract along Bradley Creek. As a relatively undeveloped piece of land, the water quality benefits the garden provides are considered significant in this now impaired watershed. The NC Cleanwater Management Trust Fund granted New Hanover County $2.5 million to help acquire Airlie Gardens with stipulations that included conservation easements along the Bradley Creek shoreline for water quality benefits and making water quality a core component of Airlie's environmental education mission.

Within the heart of the garden is a 10-acre freshwater pond system called Airlie Lake. Prior to the 1900s, this body of water was no lake at all. It was actually called Church Creek and connected directly to Bradley Creek. Church Creek was so named because it was the waterway parishioners used to access the Mount Lebanon Chapel. This chapel was built by Dr. Thomas Henry Wright so that churchgoers living near the beach or Wrightsville Sound would not have to trek to downtown Wilmington for Sunday worship.

Through the process of turning Airlie into a garden, Sarah Jones decided to close off Church Creek from Bradley Creek and create a freshwater reservoir fed by stormwater runoff and not by the tides of the salt marsh. A levee was installed to close the mouth of Church Creek in 1902. Now a freshwater body of water, the former Church Creek became an effective reflecting pool for Sarah Jones' azaleas which line the entire shoreline of Airlie Lake. Overflow freshwater runoff flows out of the Airlie Lake and into Bradley Creek through a piped culvert running under the levee.

This is a map of Wilmington's watersheds. The Airlie Lake is encircled within the Bradley Creek watershed.

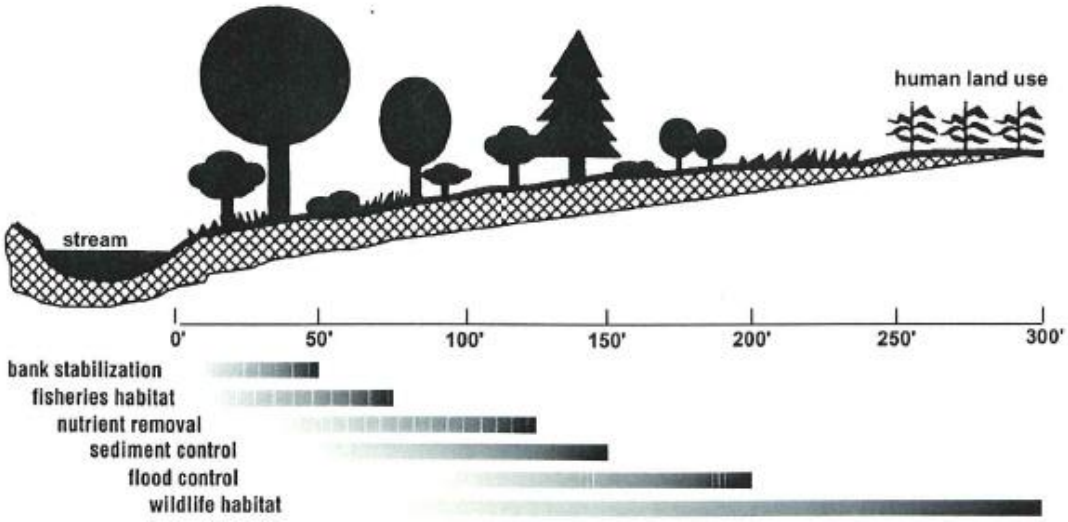
When Sarah Jones altered the hydrology of Church Creek to create Airlie Lake, the local ecosystem was able to adapt to the change. However, as more people have moved into the area over time, the environment has become increasingly altered and it has become more difficult for the ecology to adjust to these changes to local hydrology. Tributaries of rivers and streams have been piped underground, tuned into stormwater discharge pipes and the original flow of water through our landscape has been permanently changed, often in ways that negatively affect water quality.

Today, Airlie receives stormwater runoff from a large area outside of the garden, and much of this runoff contains pollution. Neighborhoods, roadways and shopping centers produce stormwater runoff that heads to Airlie's lake system. In order to address the water quality issues of Bradley Creek and New Hanover County, Airlie Gardens has implemented several stormwater best management practices.

BMPs: Best Management Practices

Best Management Practices, or BMPs for short, are conservation tools that help humans lessen their negative impacts on the environment. BMPs can either be behavioral or engineered solutions to improving environmental quality. Behavioral BMPs are practices that individual users must remember to implement, for example, remembering to turn of the light when leaving the room, thus saving energy and reducing air emissions. A structural BMP for saving electricity could be to use motion sensor lighting that turns lights off automatically when there is no activity in a space. Airlie uses a variety of BMPs but is best known for its Stormwater Best Management Practices. Stormwater BMPs are demonstrated throughout the garden. Some of these BMPs are described below.

Riparian Buffers: Riparian means relating to the banks of streams, rivers, lakes, estuaries and other waters. A riparian buffer is simply a strip of forested or vegetated land bordering a body of water. Generally, the wider a buffer strip is the more effective it is at slowing and filtering pollutants from stormwater runoff and groundwater. The roots of these buffer plants and microbes living within the soil near the rootzone are largely responsible for the filtration process. Many types of plants can be used in a buffer, but it's best to use deep-rooted, **native** plants for removing nutrients and stabilizing streambanks. Further from the waterway, plants that slow and spread the flow of runoff are used. This slowing of stormwater enables the runoff to infiltrate into the soil and recharge the groundwater supply. By soaking up rainwater like a sponge and releasing it slowly, buffers hold stormwater and minimize flooding downstream while maintaining stream flow even during the driest times. Buffers have additional purposes like timber harvest, agriculture, boating access, fish and wildlife habitat, moderating water temperature, lowering turbidity, protecting property from erosion and providing a backbone for greenways and path networks. As a property owner with riparian shoreline, it is wise to avoid maintaining lawns or fields near the edges of a waterway, limit tree-cutting in buffer zones, leave stumps of fallen or previously cut trees, avoid application of fertilizer and pesticide and keep all hard surfaces (roads and buildings) out of the buffer. Economic, environmental and social benefits for people are provided by buffers. By implementing more buffers now, which are simple and effective, we can avoid the expensive and complex costs of restoring our polluted waters tomorrow. Airlie has a 300' conservation easement setback along the shore of Bradley Creek in which development is limited in order to provide the best water quality benefit.



Constructed Wetland: The purpose of a constructed wetland is to filter out pollutants and sediment from stormwater runoff. Constructed wetlands use the concept of bioretention, which is a practice in which plants and soil remove pollutants from stormwater. At Airlie Gardens, we have created a constructed wetland that is filtering the runoff from the housing development across the street and nearby shopping centers. When the water enters the wetland, it is slowed by a grassy buffer, which helps to filter sediment. The water then washes through a wall of rock, which also performs the same function. The wetland is designed to be meandering; this helps slow down the water as it washes through. Throughout the wetland there are low-lying areas referred to as littoral shelves. These are the areas where native plants are established. These plants have a special purpose in the wetland as well. When the water level rises over these low areas, the plants help to filter out pollutants naturally. Native plants are used because they are easier to take care of, need less watering, and are plants that would naturally grow in a wetland area.

Rain Garden: Rain gardens use some of the same methods as constructed wetlands to help clean stormwater run-off. Rain gardens are easy to create. They consist of a shallow depression in the ground with newly mulched soil planted with native plants that can handle being underwater for short periods of time and also handle drought conditions. When it rains, water collects in this depression. The soils and plants help to filter out the pollutants and excess nutrients as the water slowly seeps into the ground. Rain gardens are not made to hold water, but allow rain water to slowly seep into the ground and follow the natural cleansing process. Rain gardens can also serve as habitat gardens. Designed to intercept runoff from impervious surfaces, rain gardens are installed downstream of the impervious surface and upstream from the body of water. Airlie's rain garden is located in the Water-Wise Garden.

Oyster Shell Recycling: Oysters are a vital part of the salt marsh ecosystem and the health of the oyster population is a great indicator for the general health of the marsh ecosystem. Oysters are unique in that they are considered both living animals and a habitat type. As a keystone species, oysters provide significant ecological benefits, such as the Three F's:

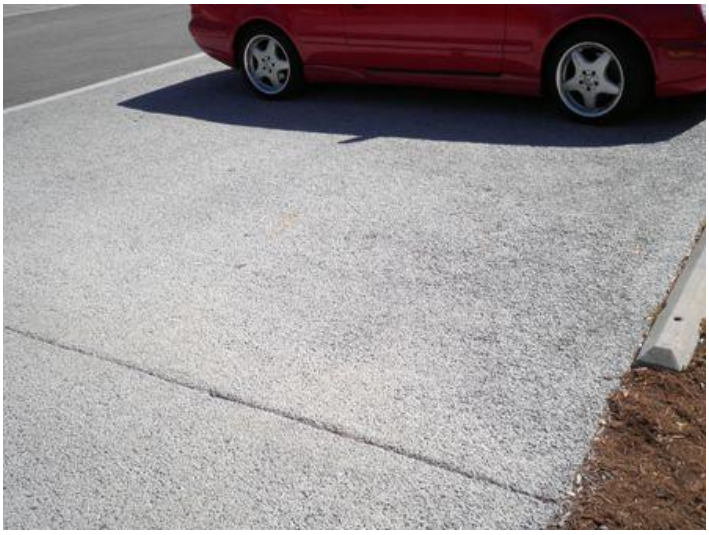
- Food—Oysters provide lots of food to an array of animals, not just humans.
- Filtration—Oysters are filter feeders, meaning they filter out sediment, nutrients and plankton from the water in the estuaries, thereby improving water quality. One adult oyster can filter between 30-50 gallons of water per day. More oysters mean cleaner water
- Fish Habitat—Oyster reefs provide critical habitat for a diverse collection of aquatic animals, including many important commercial and recreational fish species. One healthy oyster reef can be home to over 300 different organisms, such as adult and juvenile fishes, shrimp, clams, and crabs.

Airlie Gardens, in partnership with the North Carolina Coastal Federation, has embraced the oyster as the most important organism to support for local marshland restoration. Airlie has constructed a 400-foot artificial reef out of recycled oyster shells to encourage the growth of new oysters. Baby oysters, or spat, will only attach to hard surfaces, and oyster shell is their preferred substrate material. By providing that substrate, oysters will grow and thus improve water quality. A single three-inch oyster can support 30 other oysters growing on that one shell. Oyster reefs can also be used for shoreline erosion protection by breaking up waves approaching the shore.

The North Carolina oyster population has declined by 90 percent since the year 1900. Much of this decline is attributed to over-harvesting, poor water quality, oyster disease, and a lack of oyster shell recycling. Traditionally oyster shell has been discarded or used in landscaping after the meat has been consumed, but now it is against the law to send oyster shell to the landfill. The NC Division of Marine Fisheries has established an oyster shell recycling program in order to provide shells to oyster reef restoration efforts. Recycled oyster shell provides calcium to the living oysters as they grow. There are at least a dozen oyster shell drop-off recycling locations in New Hanover County, one of which can be found by Airlie Gardens' front entrance. Shell collected by the program is cured, transported, and put back into tidal creeks to help establish oyster habitat.

Rain Barrels and Cisterns: Airlie has installed two rain barrels and is in the process of installing a 2,500 gallon cistern that collects stormwater runoff from the roof of the Garden Services Center. This water will be used for irrigation purposes and reduces the amount of groundwater or municipal water used. Rainwater can be used for any purpose in which water is used, but make sure to filter the rainwater if it is to be used as a potable water source. Rainwater harvesting has been used throughout history around the world as an effective method of storing water for future use in times of water scarcity.

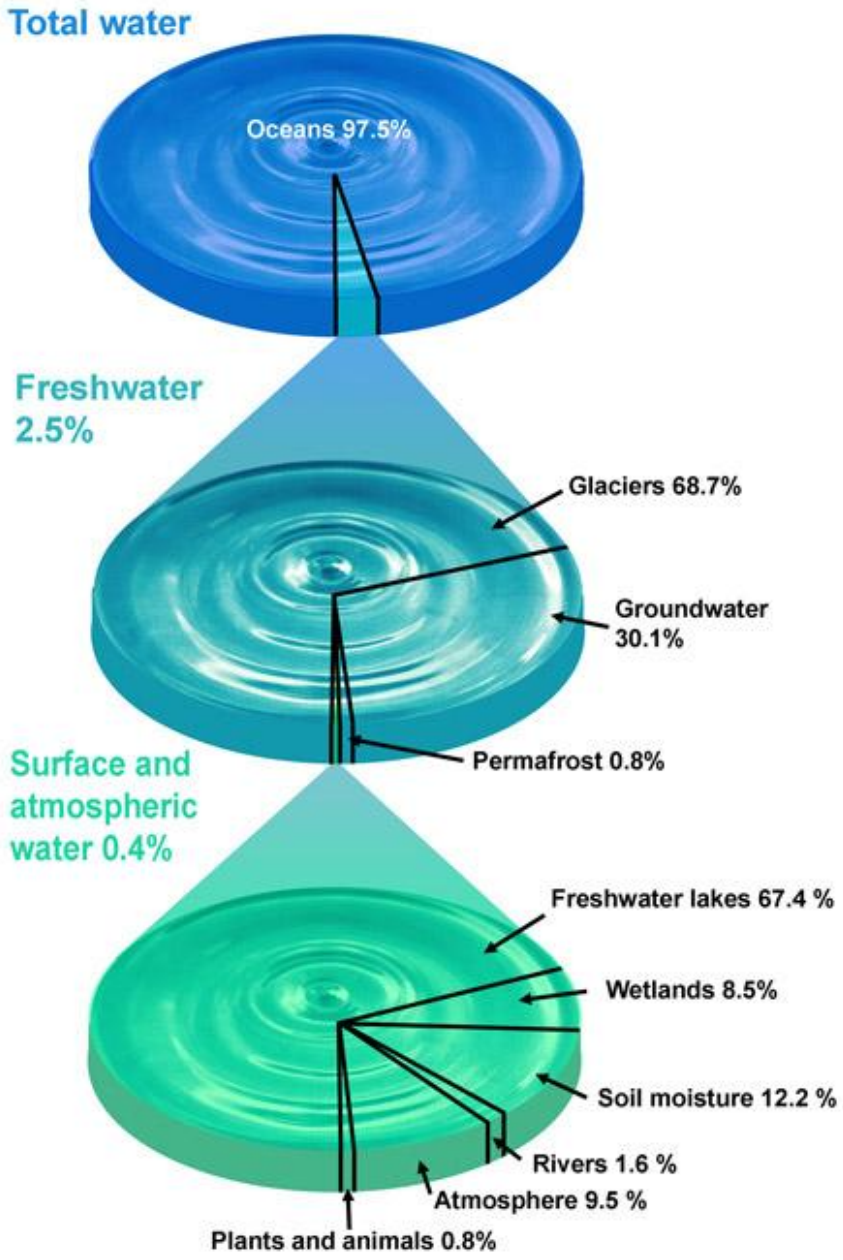
Pervious Concrete: Pervious concrete is a unique type of concrete that is highly porous. When rainwater contacts the surface of pervious concrete, the water is able to flow through and infiltrate into the ground instead of running off. Pervious concrete helps to recharge groundwater and to redirect stormwater runoff into the soil where the water can be filtered. Pervious concrete is used in light traffic areas, like Airlie's parking lot. Over time this material may fill in with sediment which can be cleaned out by vacuum.



Swales: Vegetated swales are long, narrow channels that are used to filter and infiltrate stormwater runoff from pockets of impervious development such as parking lots, sidewalks, streets or buildings. Airlie has a grassy swale connected to a smaller vegetated swale surrounding the Garden Services Center Building. The swales are designed to capture runoff from Airlie's impervious surfaces.

Freshwater Availability

Referred to by some as the 'Blue Planet', Earth is covered mostly by water which accounts for about 70.8% of planet's surface. This amount of water is deceiving because most of this water is in a form that cannot be easily accessed by people. In fact, water scarcity is a reality in many parts of the world. North Carolina, for example, often experiences water shortages and drought.



About 97.5 % of the Earth's water is salty, and salty water is unavailable for human consumption, agriculture, and most industry. The 2.5% of the Earth's water that is fresh is mostly trapped in glaciers, permafrost, living organisms, the soil, vapors in the atmosphere and groundwater aquifers. Very little freshwater is available in surface waters like lakes, rivers and streams. Due to salinity, location, and form of freshwater, only about 1 % of the Earth's water is available for human use. Unfortunately, much of this very limited freshwater is now unusable due to pollution by human activities. Toxic chemicals like mercury, volatile organic compounds (VOCs which are found in petroleum fuels), lead, pesticides, and an assortment of other poisonous chemicals can render large amounts of freshwater unusable even with the slightest contamination. As the world population grows, water scarcity and privatization are growing problems.

Environmental Quality of Water and Sources of Pollution

To determine if a body of water is "clean" or not, several qualities of the water need to be considered. With the 8th graders who visit Airlie for water quality field trips, the students learn how to measure the chemical, physical and biological quality of the water. Determining those qualities can then illustrate what pollutants are affecting Airlie's water and what the overall quality of the water is.

Pollutants include any substance or mixture of substances from unnatural sources or natural substances introduced into the environment in quantities or concentrations that harm the resource. For example, soil normally flows into rivers and streams. However, soil is a pollutant when it is deposited in streams at excessive levels caused by humanity's land-disturbing activities.

Point-source pollution and Non-point source pollution:

As water moves through the hydrologic cycle there are many ways that water picks up pollutants. In the atmosphere water vapor may form around particulate matter from factory smokestacks, car exhaust, smoke and other sources. As water runs over land it picks up pollutants from farms, streets, lawns and other sources. As water moves through the ground it may come in contact with pollutants that have leaked from

landfills, illegal dumps or chemical spills. Spills of oil and chemicals into surface waters and legal and illegal discharges of wastewater are another way water becomes polluted.

Point-source pollution comes from a pipe, such as a factory discharge pipe, and is easy to recognize along streams. **Non-point source pollution**, or runoff pollution caused when rainwater carries pollutants into nearby surface and ground waters, is now the major source of pollution harming America's surface waters. Nonpoint source pollution does not come from specific pipes but occurs through land runoff when it rains. Sources of nonpoint source pollution include farms, cattle feedlots, lawns, paved urban areas, construction sites, timber harvesting sites, landfills and home septic systems. These sources contribute pesticides, fertilizers, metals, manure, road salt and other pollutants. Another name for nonpoint source pollution could be "people pollution" because the way we use our land directly affects the amount of nonpoint source pollution in our surface waters. For example, land left as forest contributes very little pollution to surface waters, while land paved over for parking lots and highways contributes a great deal of nonpoint source pollution such as oil, grease, road salt and antifreeze.

Impervious surfaces: Instead of seeping into the ground or slowly traveling downhill through leaf litter and vegetation, stormwater now increasingly rushes over hard, human-made surfaces such as roads, rooftops, parking lots and storm drains that carry pollutants directly to larger bodies of water. This high volume of runoff reaching the streams also causes bank-scouring and erosion of the streambed. Excessive impervious surface damages stream habitat and wildlife.

Chemical Measurements

Water chemistry in a stream is affected by the land use, soils, surrounding geology and precipitation in the watershed. Chemical water quality is measured by a few basic parameters. When testing water for use as a drinking source, much more stringent standards are used. For example, drinking-water cannot have volatile organics, radioactive materials, heavy metals or toxic chemicals. Volatile organics are organic chemicals that are unstable or combustible. Toxic substances are poisonous to life.

The amount of a specific contaminant, chemical element or compound is expressed as a concentration – the specific weight of a contaminant in a specific volume of water. Milligrams per liter (mg/l) are roughly equivalent to parts per million (ppm). "Ppm" means one part contaminant for every million parts of water. This measure serves as a ratio.

Dissolved Oxygen (DO): Dissolved oxygen (DO) is simply the amount of oxygen available in the water (dissolved). The presence of oxygen in the water is a positive sign and the absence of oxygen is a sign of severe pollution. DO content in water is influenced by several factors, including water temperature, salinity, time of day, atmospheric pressure (or altitude) and the amount of oxygen-demanding waste in the water. Bacteria living in the water use up available oxygen by breaking down organic wastes such as manure, leaf litter, woody debris, dying algal blooms and organic materials in wastewater.

Much of the dissolved oxygen in the water comes from algae and other aquatic plants that deliver oxygen to the water through photosynthesis. Atmospheric oxygen can also mix with water when waves break or water flows quickly over rocks. Cold water can hold more DO than warm water. Also, the faster the water moves, the more surface area there is where the oxygen mixes with the water. DO levels change from day to night. This is because plants do not photosynthesize at night and aquatic animals continue to breathe, therefore, DO levels tend to drop during non-daylight hours.

Humans can also have an impact on DO levels. A build-up of organic wastes from either humans or their pets can cause DO levels to drop dramatically. A large part of urban runoff is fertilizer and manures that can stimulate the growth of algae and other aquatic plants. This sudden increase in the amount of plants can create extremely low DO level at night and can cause large fish kills. The amount of oxygen required by living organisms varies according to the species and stage of life. DO levels of 3-4 ppm are stressful to most

aquatic organisms. DO levels below 2 or 1 ppm will not support fish. Levels of 5 to 6 ppm are usually required for growth and activity.

Biological Oxygen Demand (BOD): BOD occurs when bacteria in the water use up available oxygen as they decompose organic matter or nutrients in the stream into simpler elements. This process of organic breakdown which utilizes oxygen is known as aerobic decomposition. If too much decomposition occurs due to the presence of excessive nutrients, oxygen levels in the stream may drop making the stream oxygen poor. This process is also known as **eutrophication**. A high degree of decomposition gives a stream a high BOD because it needs a lot of oxygen to break down organic nutrients.

Chemical Oxygen Demand (COD): COD refers to the oxygen depleted by oxygen-using chemicals in the water. These chemicals bind with oxygen molecules, making them unavailable for aquatic life. Discharges from industry may have high COD.

pH: Water contains hydrogen ions and hydroxyl ions. The pH test measures the hydrogen ion concentration of liquids and other substances. pH means (p)otential (H)ydrogen ion activity. The pH scale is used to define levels of acidity in substances like water and soil. The pH scale ranges from 0 (most acidic) to 14 (most alkaline, or basic). Pure water has a pH of 7, which is considered neutral.

A very important factor of the pH scale is that one number change on the scale is actually a 10-fold change in the acidity/alkalinity of a substance. For example, a change of six to five on the pH scale means that the substance is 10 times more acidic; from six to four means it is 100 times more acidic. The pH scale is not linear, it is logarithmic.

Most lakes and streams have a pH value between 6.5 to 8.5. The pH of a body of water has a very large impact on what can survive there. Most amphibians, fish and insects are not present in water with a pH below 4. The largest human impact on pH values comes from automobiles and coal-fired power plant emissions. The emissions from cars and power plants contain sulfur dioxide, nitrogen oxide and carbon dioxide. When these chemicals mix with moisture in the air, it then falls back to the earth as acid rain.

Alkalinity: Alkalinity of water is its acid-neutralizing capacity. Acid can enter a stream through rain or snow, and sometimes through soil. Alkalinity is created when water dissolves rock that contains calcium carbonate, such as limestone and calcite. Alkalinity is different from pH. Alkalinity is a measure of how much acid can be added to a substance without causing a great change in pH. Low levels of alkalinity make a body of water more vulnerable to acid rain and snowmelt. The higher the alkalinity of the water sample, the more acid can be added to it without a significant drop in pH. An alkalinity test measures the level of bicarbonates, carbonates, and hydroxides in water and test results are generally expressed as "ppm of calcium carbonate ($CaCO3$). The Environmental Protection Agency has suggested a minimum of 20mg/L of $CaCO3$ for freshwater aquatic life except where natural concentrations are less.

Hardness: Hardness measures the concentration of calcium and magnesium ions in the water, usually expressed as ppm of calcium carbonate equivalent. Calcium and magnesium enter surface waters through the breaking down of rocks known as weathering. When total hardness exceeds total alkalinity, chloride and sulfide ions are present. These metals can harm aquatic life.

Nitrate: Nitrogen is needed by all living organisms to survive and build cells like protein. Nitrogen exists in waterways in many different forms. The form of nitrogen most tied to water quality is nitrate. The nitrate

form of nitrogen comes naturally from the atmosphere through rain, snow, fog, and from the decay of organic materials in the soil. The nitrate molecule has one atom of nitrogen and three atoms of oxygen.

Humans also have a large impact on nitrate levels. Sewage and fertilizers are large contributors to increased nitrate levels in a body of water. Small levels of nitrate can be a good thing to have in the water, but too much of it can cause *eutrophication*. This is when a body of water becomes so enriched with nitrates that it sparks a growth of aquatic plants and algae. This enriching of the water can result in taste and odor problems in lakes used for drinking-water, and can also negatively affect fish and other aquatic organisms.

Unpolluted waters usually have a nitrate level below 4 parts per million (ppm). Nitrate levels above 40 ppm are considered unsafe for drinking-water. The number one source of aquatic pollution in New Hanover County is excess nitrates from pet waste (which also contains fecal coliform pathogens).

Phosphates: Phosphates are another plant nutrient like nitrates that can enter water in excessive amounts due to runoff from fertilizers spread on farm fields or lawns. Some household detergents also contain phosphates. Excess phosphate bonds to soil particles, and thus a large amount of phosphate can be stored in sediment captured by riparian buffers.

Physical Measurements

Temperature: The temperature of water directly affects its chemical concentrations, fish diversity, rate of photosynthesis in algae or aquatic plants, metabolic rates of aquatic organisms and sensitivity of organisms to toxic wastes, parasites and disease. Water has a high heat capacity, which makes it resistant to changes in temperature. In the winter, water temperatures are often warmer than air temperatures. Temperature requirements vary among fish species. Trout need cooler water than carp, for example. Rapid changes in temperature (more than 1 to 2 degrees Celsius in 24 hours) can cause thermal stress to fish and other aquatic life.

Increased temperatures can decrease water's ability to hold dissolved oxygen and can impair feeding, growth and reproduction of fish. Temperature increase may ultimately result in the death of aquatic life. Water temperature is largely determined by the amount of solar energy, or sunlight, absorbed by the water. Thermal pollution occurs when temperature increases exceed normal levels for the stream. Thermal pollution can be cause by upstream damns, removing streambank shade trees, heated discharges from industries or power plants and inflow of stormwater runoff from urban streets.

Salinity is the measure of salt in water. It is measured in parts per thousand (ppt). The ocean averages 35 ppt. What this actually means is that if one thousand cups of ocean water were gathered and then the salt separated out, 35 cups out of the thousand would be filled with salt, and the rest would be filled with water. Brackish water is a mixture of fresh and salt water. Brackish refers to anything between 6 and 34 ppt. The salinity averages 18-20 ppt for brackish water. Fresh water measures 0-5 ppt. In salt marshes, the salinity can vary greatly; high tides bring in more salty water and low tides flush these areas with fresh water runoff.

Turbidity: Turbidity, or cloudiness of the water, is caused by the number of suspended solids in the water. Although natural water systems have a certain amount of materials suspended in the water from decayed organic matter, sediment, minerals and other particulate matter, the concentration of these solids must not exceed the normal amount for the stream. Too many solids in the water can block light to underwater plants and clog fish gills, suffocating the fish. Fish and insect spawning beds are buried as solids settle to the stream bottom. Suspended solids are also a problem because the may contain nutrients, pesticides and toxins. Total suspended solids (TSS) is a measure of the total amount of solids in a liter of water. Simple tests for turbidity in streams are conducted with portable turbidimeters. Secchi disks are used to measure turbidity in lakes or standing water.

Sedimentation: Sedimentation is the tendency for particles in suspension to settle out of the water column, and come to rest against a barrier. As sediment accumulates along a streambed it smothers the eggs of fish

and insects. In the salt marsh, sediment covers the shells of oysters which hurts the oysters underneath and prevent future oysters from attaching to the shell below. A dime's width of sediment covering an oyster reef is thick enough to smother new oyster larvae trying to settle onto that reef. The number one source of aquatic pollution in the state of North Carolina is sediment caused by accelerated soil erosion from farming and development practices.

Water Flow: The volume of water flow in a stream or river is critical to the types of aquatic life that can survive there. A typical water flow measure is cubic feet per second. The presence of pools, riffles and meanders in the stream also affect water quality and habitat values. The amount of sediment covering rocks in a stream and the degree to which the rocks are cemented together is known as embeddedness. The greater the degree of embeddedness, the poorer the habitat for aquatic critters.

Biological Measurements

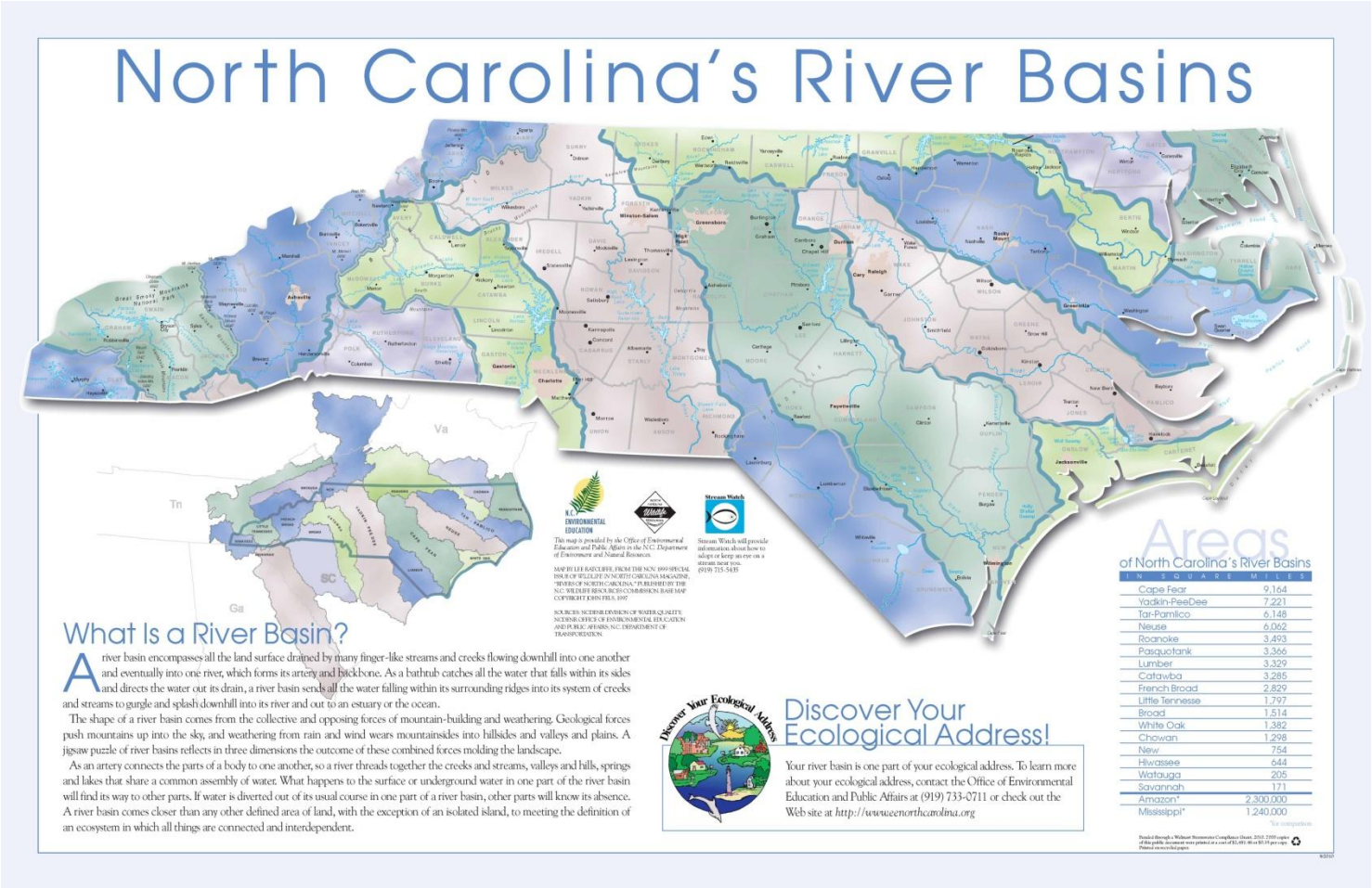
Pathogens: Another important indicator of water quality is the presence or absence of pathogens, which are disease-causing organisms. Pathogens can be enteric, which means they are found in the intestine of warm-blooded animals, including people. Fecal coliform bacteria are found in the lower intestine of humans. Fecal coliform are not a pollutant, but they can indicate the presence of contamination by human waste from failing septic systems or wastewater treatment plants. Fecal coliform is measured as the number of colony forming units (CFUs) per 100 ml of water. Drinking-water should have no fecal coliform.

Biological Monitoring and Benthic Macroinvertebrates: Stream biology is important to observe because the aquatic life present in a stream indicates if the stream is healthy. Benthic means 'bottom dwelling' and macroinvertebrates refer to invertebrates (animals without backbones) that can be seen with the unaided eye. Most benthic macroinvertebrates in moving water are insects, both in adult and larval stages. Some examples of macroinvertebrate indicators are stonefly nymphs, dragonfly nymphs, midge larvae, clams, and worms. Macroinvertebrates are good indicator species because: many are sensitive to chemical and physical changes in the water; many live in the water for long periods of time; it is more difficult for them to escape pollution than it is a faster moving animal, such as a fish; and they are easy to collect from streams and rivers.

Every species can only live in a certain range of chemical and physical conditions. Scientists have spent time studying benthic macroinvertebrates to understand which species can tolerate high pollution levels, and which cannot. By sampling an area to discover what species are present, it will indicate what the water quality is like. Recording fish populations and algal species can also be monitored to determine water quality.

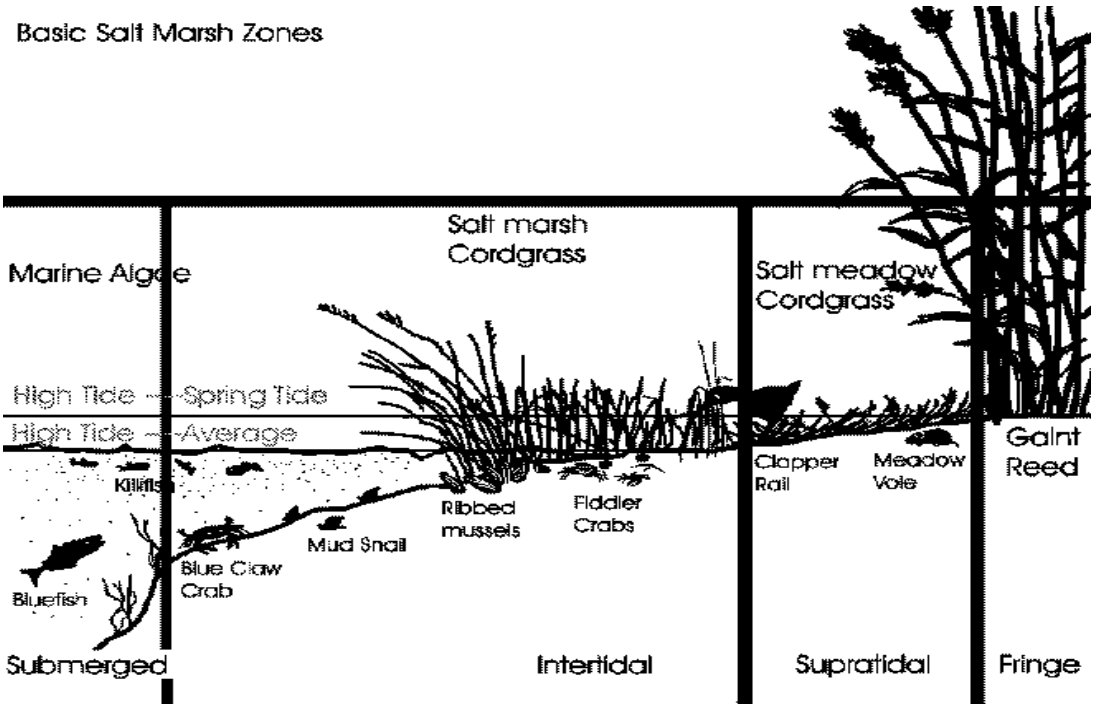
Aquatic Terminology and Lifeforms

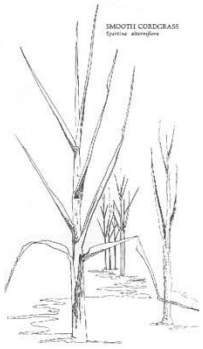
Watersheds and River Basins: A watershed is the land area that drains water to a particular stream, lake, river or other body of water. The area of land that drains to an area is determined by gravity and topography, known as the 'lay of the land'. For instance, if you live in the Bradley Creek watershed, runoff from your property will flow into the Intracoastal Waterway and then to the Atlantic Ocean. If you live in the Smith Creek watershed, runoff from your property will end up in the Cape Fear River which eventually ends up flowing to the Atlantic Ocean. Many watersheds together can form larger drainage basins or river basins that may span several states. The largest river basin in North Carolina is the Cape Fear River Basin, which drains an area of over 9,000 square miles and is the only river in NC to directly empty into the Atlantic Ocean.



Salt Marsh: Salt marshes are areas where freshwater and saltwater meet. They occupy the intertidal zone of estuaries where salinity varies from near ocean strength to upriver freshwater. Marshes play a wide variety of roles in an estuarine system. Marsh plants, bacteria and algae help export organic matter that forms the basis of the food web vital to fish and shellfish populations. The marsh offers protection from many predators, wave and storm action and other dangers. This makes for a great nursery habitat for fish. Salt marshes are one of the most productive ecosystems in the world. Close to95% of the commercial seafood that we eat spend part of their life cycle in this estuarine system.

Native Marsh Plants: The plants of North Carolina's estuarine areas are vital to the health and survival of the tidal creeks. Not only do they contribute to the cleansing properties of the marsh by absorbing excess nutrients and some pollutants, but they also buffer wave action from the shore and contribute to the estuarine food web.





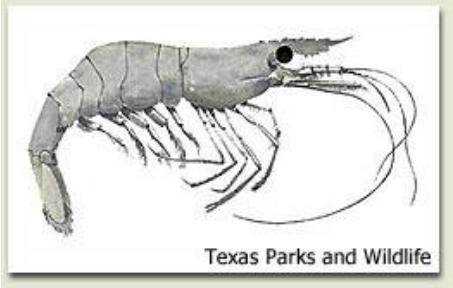
Spartina alterniflora, or **Saltmarsh Cordgrass**, is the dominant species in salt marshes along the Atlantic coast. Spartina is one of the only species of terrestrial plants that can survive being submerged in salt water for hours at a time. Spartina can take in the saltwater and excrete the salt out. If you run your fingers over a blade of Spartina, you will notice salt crystals.

Borrichia frutescens, or **Sea Oxeye Daisy**, is a low shrub found along the high marsh line. The plant has thick green leaves and yellow, daisy-like flowers in the summer.

Juncus roemerianus, or **Black Needle Rush**, is also another common marsh plant. Like the Sea Oxeye Daisy, it also grows along the high marsh line. It is characterized by having a hard, sharp point on the tip of the leaves. A person leaning over in the marsh could easily have an eye punctured, so please be careful!

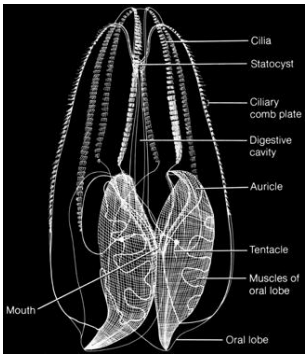
Fiddler Crabs: There are numerous species of fiddler crabs that live at the edges of marshes and rivers. Males have one large claw and one small claw. They wave around the large claw to attract a mate and defend territory. They use the smaller to eat. Females have two small claws, which they use for eating. Their activity rate changes with the tides. Activity peaks at low tide as hundreds of fiddler crabs gather at the water's edge to feed on detritus (small pieces of dead plants and animals).

Sea Squirts: Grape-shaped animal that squirts water when disturbed. They are actually considered vertebrates because they have a notochord (beginnings of a spinal cord). They are filter feeders; water is pumped in one siphon, passes through the body, is used for breathing and eating, and then is expelled through the other siphon.



Grass Shrimp: Small, transparent shrimp most commonly found in marsh habitats. Grass shrimp hide among the Spartina at high tide. Because they are transparent, these shrimp blend right in. Grass shrimp are scavengers. They help break down

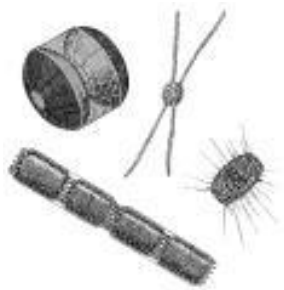
detritus into even smaller bits, which more animals can eat. Grass shrimp are not edible.



Comb Jellies: Planktonic blobs of solid, clear jelly that cannot sting; they are not jellyfish. They have eight rows of ciliated combs on the outer surface for movement. These combs become luminous at night. You can see this luminescence if you hold them up to the light. They feed on larval fish, minnows and small crustaceans. Comb jellies swim forward, eating everything in their way.

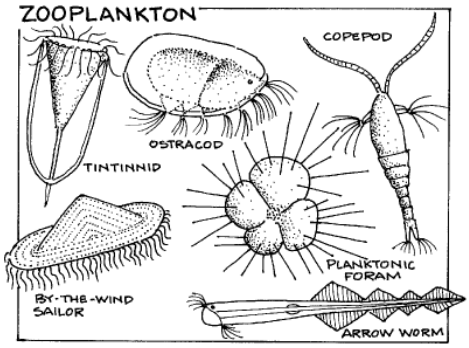
These are just some of the more common species you can find.

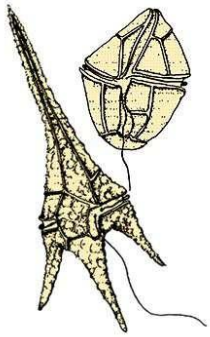
Plankton: Plankton are small floating or weak swimming plants and animals in the water. All plankton is at the mercy of the waves, tides, and currents for transportation. Either directly or indirectly, almost all other marine life depends upon plankton as a source of food. There are two main types of plankton: phytoplankton and zooplankton.



Phytoplankton: Phytoplankton are plant plankton. They are important producers and are the foundation of the marine food web. Much of the oxygen we breathe, an estimated 80%, is produced by phytoplankton. Diatoms are the most abundant form of phytoplankton. They must stay near the top of the water so they can absorb sunlight for photosynthesis. They have developed ways to float: some attach to air bubbles; some join together and others actually produce oils that help them float.

Zooplankton: Zooplankton is animal plankton. Within in this grouping are two distinct types: holoplankton spend their entire lives in a floating state (ex. Copepods, jellyfish) while meroplankton only spend part of their lives as plankton (ex. eggs and larvae of crabs and oysters). Some of the most common types of zooplankton are copepods, comb jellies, and barnacle larvae.





Dinoflagellates: Dinoflagellates have characteristic of both animal and plant plankton. They are able to propel themselves through the water, but they also photosynthesize. Two different types of dinoflagellates are responsible for "red tides" which is simply a large bloom of the dinoflagellates that can have a variety of toxic effects. Other types can cause bioluminescence in the water at night. If you were to run your hand through the ocean at night, you might notice little sparks of lights, which are actually dinoflagellates that glow when disturbed.