PROJECT O*CEANOLOGY*

Virtual Field Trip: Intro Ocean Physical/Chemical
Educator Guide

Overview

In this half of our multidisciplinary virtual field trip, students will investigate the **non-living** (abiotic) components of Long Island Sound!

In “The Bow” of the Enviro-Lab, your students will learn how to use a wide range of oceanographic equipment to investigate physical and chemical aspects of the water column and the bottom. You can allow students to choose their own research focus from the list provided, or assign them to ensure the class as a whole covers all the topics of interest. See the educator key (part II of this document) for information on what they will find. The data used are drawn from our flagship environmental monitoring program. Project Oceanology students have been collecting data on the living and non-living components of ecosystems in Long Island Sound and Fishers Island Sound for more than thirty years, and our data are used by scientists at the University of Connecticut and elsewhere to understand long-term environmental trends.

I. NGSS Alignment for Middle School and High School

Performance Expectations

HS-LS2-6 Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. *Students will gather empirical evidence about the environmental conditions in Long Island Sound, and identify how those conditions change along an environmental gradient (depth). Students will describe the potential for long-term and short-term environmental change, and how selected organisms are adapted for different environmental conditions.*

HS-LS4-5 Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
Students will gather empirical evidence about the physical components of the Long Island Sound estuary and generate ideas about biotic impacts.

MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
Students will gather empirical evidence about physical components of Long Island Sound, and describe how it is related to selected organisms. Students will use the information they have gathered to assess whether they think the environment is healthy.

Science and Engineering Practices

Developing and using models

Students will construct a vertical profile of the water column, showing how each variable changes with depth.

Analyze and interpret data

Students will describe their findings, and analyze the results to make an assessment of whether the ecosystem is healthy based on standard ranges for the area.

Engaging in argument from evidence

Students will gather empirical data on a physical aspect of Long Island Sound and use this evidence to make a claim which answers a research question.

Cross-Cutting Concepts

Patterns

Students will look for patterns across environmental gradients (particularly depth) in the physical data they collect.

Cause and Effect: Mechanism and Explanation

Students will collect empirical evidence showing how a physical variable may vary with depth of the water column, and then describe why this occurs.

Scale, proportion, and quantity

Students will use correct units, calculations, and conversions for data analysis and modeling.

Stability and change

Students will collect empirical data on a physical characteristic of the water column, and investigate if it remains constant with depth or changes with depth.

Disciplinary Core Ideas

LS2.A: Interdependent relationships in ecosystems. Organisms and populations are dependent on their environmental interactions both with other living things and with nonliving factors.

Students will gather empirical data on the living and non-living components of Long Island Sound, and describe how they are connected.

LS2.C: Ecosystem dynamics, functioning, and resilience. Ecosystems are dynamic in nature; their characteristics vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

Students will gather empirical data on the living and non-living components of Long Island Sound, describe how they are connected, and describe how and why they may have changed over time.

Nature of Science

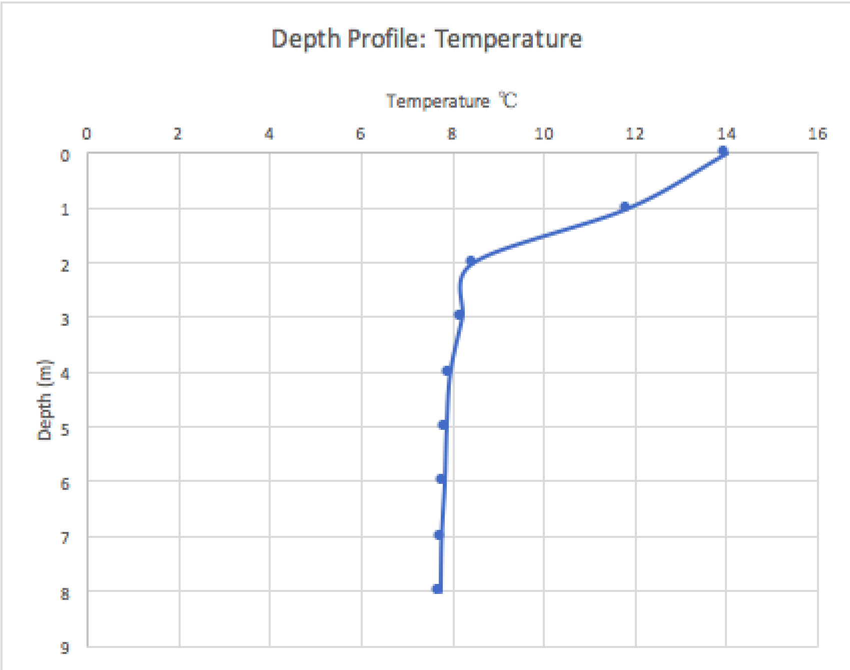
Scientific knowledge is based on empirical evidence

Students will gather empirical data on the living and non-living components of Long Island Sound, then use their information to assess the health of Long Island Sound.

II. Educator guide to graphs and their interpretation

Many of the abiotic components studied below show how the parameter changes with depth, using a model called depth profile. On a depth profile, depth is graphed on the y-axis, with the surface (depth of 0 meters) at the top of the graph. The measurement being studied is graphed along the x-axis (again along the top) from lowest to highest. Below we provide simple graphs that show the expected patterns. Your students' graphs may vary.

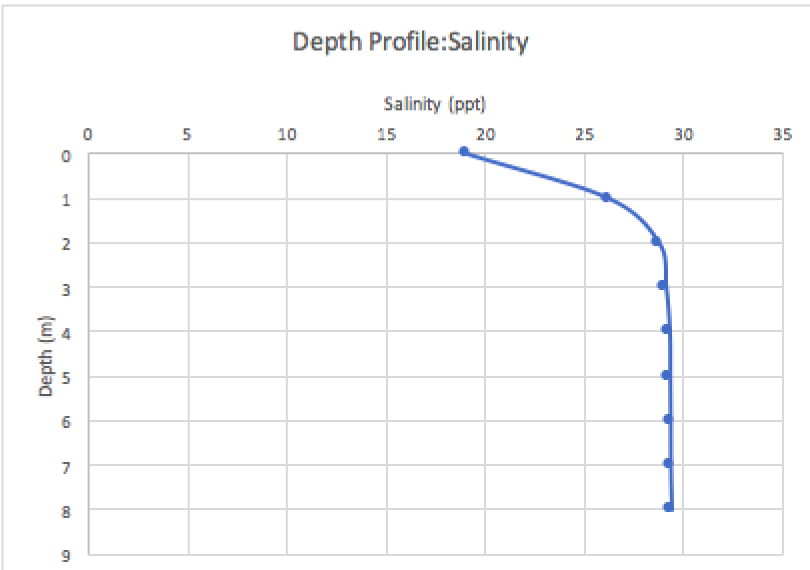
<u>Temperature</u>



Interpretation for teachers: The temperature data provided are from a typical day in the month of May, recorded in Celsius to the nearest hundredth of a degree. In spring, warming air temperatures and increasing hours of sunlight influence the surface water temperatures, but have not penetrated to all layers of the estuary. The sharp change in temperature between meter one and meter two represents a *thermocline* in the water, or a steep temperature gradient. These different temperatures change the density of the water, creating distinct layers which do not mix readily. The depth and strength of the thermocline changes seasonally, and year to year.

Extension: The rising temperatures in Long Island Sound are the result of global climate change. Because they are shallow, estuaries such as Long Island Sound are warming faster than most other marine habitats. Shorter term causes of temperature changes in estuaries include seasonal changes, annual variability (for example, El Nino vs. La Nina years), and rainfall events. Lobsters are negatively impacted by rising temperatures in Long Island Sound - because they are adapted to cold water, if the water gets to warm it can cause physiological stress. Warm water can also make lobsters more susceptible to diseases such as shell disease, and it can impact their ability to reproduce because eggs won't develop properly at the wrong temperatures. People are impacting lobster because global climate change is driven by human actions, and also as a result of overfishing. The changes in lobster populations impact people because the once-profitable lobster fishery in Long Island Sound has collapsed.

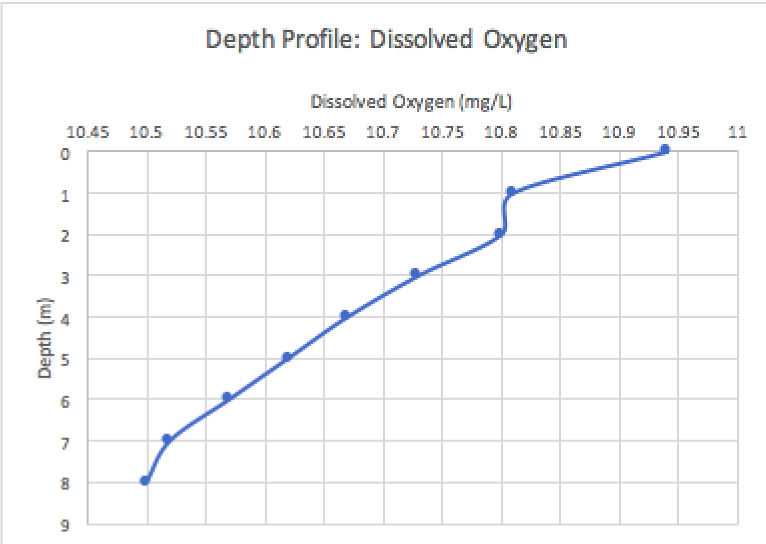
Salinity



Interpretation for teachers: The salinity data provided are from a typical day in the month of May, recorded in parts per thousand (ppt) to the nearest hundredth of a part. Salinity in the estuary is influenced primarily by two factors: wind and tides can alter the amount of salty ocean water entering and leaving the estuary; likewise rainfall and runoff within the estuary (or lack thereof) can alter the amount of freshwater entering the estuary. Saltwater and freshwater have different densities, creating layers that do not mix readily. Freshwater runoff floats above a salty layer, and minimally mixes, creating a brackish layer above a salty layer. In this data, the sharp change in salinity between the surface and meter one represents a *halocline*, or steep salinity gradient. These numbers are typical for eastern Long Island Sound.

Extension: In the long term, salinity has been increasing in Long Island Sound, perhaps related to higher evaporation rates. One organism that is impacted by changes in salinity is the Eastern Oyster. Oysters are sensitive to increases in salinity, and are often more impacted by diseases in saltier environments. Oyster reef restoration efforts are already helping to improve water quality by their filtering nature, their reefs increase habitat area for other commercially important animals, and improve resilience to other climate change effects like sea level rise. A critical loss of oysters would negatively impact the local benthic community and human economy.

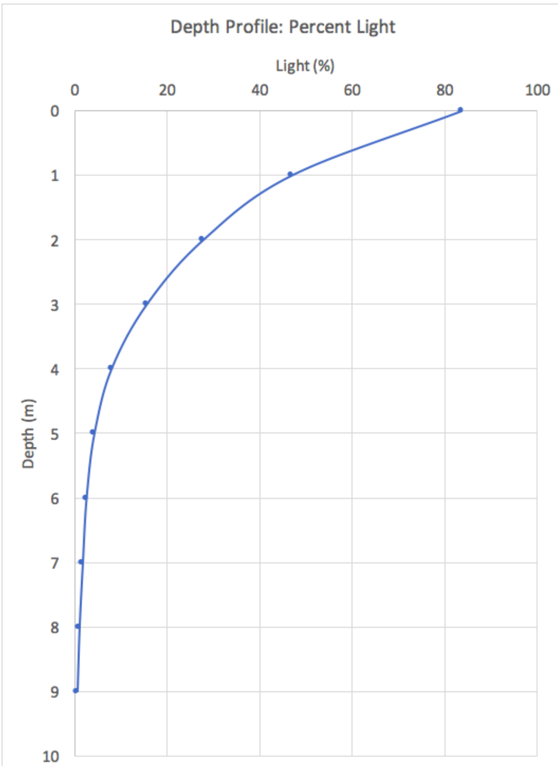
Dissolved Oxygen



Interpretation for teachers: The data provided is from a typical day in May, measured in milligrams per liter (mg/L), to nearest the one hundredth place. Oxygen is dissolved into the water in two ways: diffusion from the atmosphere, and via photosynthesis by primary producers. Windy, wavy conditions can increase the diffusion rate of oxygen into the water. The (oxygen) saturation of water changes with temperature, salinity, and pressure. Cold water can absorb more oxygen than warm water, and freshwater can absorb more than saltwater. The data show an almost linear decrease in oxygen concentration with depth, with very little change between meter one and meter 2, however this decrease still represents near-saturation at the surface and the bottom. Oxygen can be depleted from the ecosystem by marine organism respiration and microbial decomposition. A thermocline can sometimes prevent oxygen from diffusing into deeper layers of the water, leading to hypoxia in the bottom layers. A well-mixed estuary like this part of Long Island Sound does not typically experience this phenomenon.

Extension: In the long term, dissolved oxygen has been decreasing in Long Island Sound. This could be related to warming waters, and increasing salinity in the area from anthropogenic climate change. Many organisms are highly reliant on healthy oxygen levels in the estuary, such as the blue crab. Blue crabs represent an important recreational fishery, and a predator to juvenile fish in estuary ecosystems. Blue crabs are trapped within a hypoxic or anoxic layer, where they suffocate. This could lead to food web imbalance, and economic stress for humans.

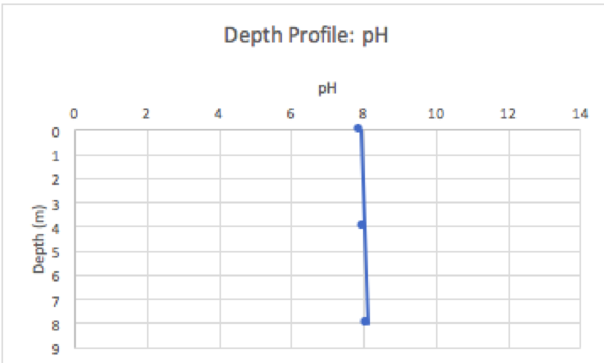
Light

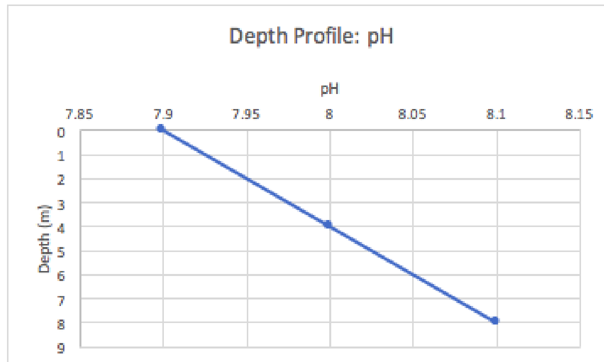


Interpretation for teachers: The data provided are measured in μmols^{-1} m^{-2} to the nearest hundredth place. The "deck sensor" measures the ambient sunlight above water, and the "underwater sensor" measures the light penetrating to each meter of depth. Students should calculate the percent of available light for each depth, and graph those numbers in a depth profile. Light penetration drops off drastically within the first few meters. Much of the initial decrease is due to refraction and reflection on the surface. Below that, light penetration is impacted by suspended and dissolved substances. Both sediment transported by the river, and phytoplankton blooming near the surface absorb or reflect light, effectively preventing light from making it to the bottom. Typically, a reading of greater than 1% at the bottom is considered a good reading.

Extension: The amount of sunlight reaching the bottom of the estuary is important to aquatic plants and algae. In Long Island Sound, eelgrass beds are an important habitat for many juvenile animals and a valuable nitrogen sink. If turbidity prevents adequate sunlight from reaching these seagrass beds, commercially and recreationally important species would be impacted. Humans can help the situation by controlling runoff from the watershed to improve water clarity.

pH

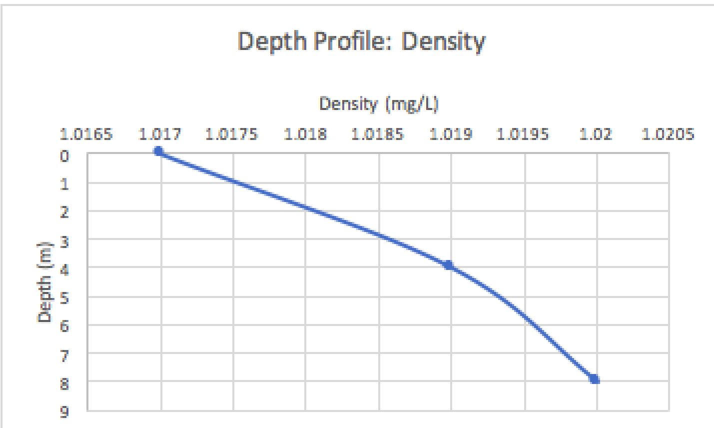




Interpretation for teachers: The pH scale inversely relates the concentration of hydrogen ions in a solution, and ranges from 0 to 14. Solutions with a pH that is greater than seven are considered basic, or less than seven are considered acidic. Solutions with a pH of seven are neutral, neither acidic nor basic. The scale is logarithmic, so a pH of 5.0 is ten times as acidic as 6.0. Many things can impact the pH of water, including salinity and dissolved Carbon Dioxide. When sodium chloride (and/or other salts) dissolves in water, the sodium and chlorine ions reduce the number of hydrogen ions, and increase the pH. Seawater has a pH ranging from 7.4-8.5, but more typically on the higher end of that scale. Carbon dioxide, when dissolved in water, reacts to form carbonic acid, which lowers the pH of the water. In the data provided, the pH of the water was only tested at three discrete depths, using indicator solution in water samples. These are adequate to show changes throughout the water column, however. This data may be explained by changes in salinity from surface to bottom and diffusion of atmospheric carbon dioxide into surface water.

Extension: In the long term, Long Island Sound is becoming more acidic, likely due to anthropogenic carbon emissions diffusing into the surface water. Many marine animals are sensitive to changes in pH, particularly shelled animals like mollusks and arthropods. The shells of these animals are composed largely of calcium carbonate, which is very basic and is dissolved in acidic conditions. The species of concern in this case is dungeness crab, whose larvae are unable to energetically compensate for acidic conditions. As a popular food for humans, there are both economic and food web considerations if pH continues to drop in the world's oceans.

Density



Interpretation for teachers:
Density is the measurement of mass per unit of volume. The density of water varies according to its temperature and salinity. Cold water is more dense than warm water, and salty water is more dense than freshwater. A cubic centimeter (cm) of distilled water at 4 degrees Celsius has a density of 1.000 g/cm³. Ocean water, being more saline, has a density of about 1.030 g/cm³. Dense water will sink below less dense water. Therefore, the ocean is often composed of layers of water of different densities. For example, in an estuary where a river meets the ocean, fresh water flows out over the more dense salty ocean water. Layering also occurs where cold deep ocean water lies beneath the warm surface water. The zone where the two layers of different water densities meet is called the pycnocline. The data provided was gathered from water samples at 3 depths: surface (0 meters), midwater (4 meters) and bottom (8 meters). The reading was taken using a hydrometer. The graph shows that the density of water increases with depth, with a much greater increase between surface and midwater than from midwater to bottom, suggesting that the pycnocline is between surface and midwater.

Extension: Layers of water that form due to density differences often do not mix readily. There are animals that travel through the pycnocline and may stir up nutrients from the bottom layers into the upper ocean. Large and small organisms alike (whales, krill mats, shrimp, jellyfish) could contribute to this process. Some scientists are skeptical, however, because studies that suggest the mixing were flawed. There are other physical processes that distribute nutrients from below the pycnocline, like upwelling, and it is difficult to definitively attribute mixing to animals crossing the pycnocline. The nutrients carried from below are necessary components for photosynthesis in marine plants and phytoplankton, so the presence of the pycnocline has an impact on those organisms.

Secchi Disk: Water Color and Clarity

This study does not require students to create a graph, but instead to use a satellite map of the Thames River, river mouth, and greater estuary to make predictions about color and clarity. Water clarity is a measure of how clear or cloudy the water is. This is important because the water clarity will determine how much light is able to penetrate into the water. Sunlight is essential for photosynthesising marine plants and phytoplankton. It also allows animals that depend on their eyesight to find food or to avoid predators. The more transparent (clear) the water is, the deeper the light will reach. Water color is an indication of what is suspended in the water - this can include phytoplankton, suspended sediment, dissolved organic material and even pollution. Water color and water clarity are related. Typically open ocean waters are an indigo blue color because the water is clearer - sediment that washes down rivers mostly settles out before the water reaches the open ocean, and open ocean water has less nutrients and therefore less phytoplankton than coastal waters. In an estuary like Long Island Sound, brownish-green colors are common because these waters are nutrient-rich, abounding in phytoplankton, and may also contain sediments from rivers. Water color in coastal areas like Long Island Sound is highly influenced by weather, because storms can dramatically increase the amount of sediment travelling down rivers. Student explanations should reference the Forel-Ule scale readings and secchi depths to indicate the clarity and color changes are due to suspended sediments and phytoplankton density in the water.

Extension: Poor water clarity can cause seagrass dieback. Runoff from the watershed can reduce clarity (and alter color) by transporting sediment and nutrients from the land. The water can be brown from the suspended sediments, or excess nutrients in the water can cause an algal bloom-- when phytoplankton reproduce so rapidly that they reduce the amount of light penetrating to depth. Since seagrass beds are important nursery habitat for many local fish, diebacks would impact success of popular sport and commercial fisheries. Humans have an impact by their use of the watershed, but would also be affected by changes to fish populations.

Gravity Core: Sediment Types

This study does not require students to create a graph, but instead to use a satellite map of the three sites near the mouth of the Thames River to make predictions about bottom types in decreasingly sheltered areas. In the estuary, the sediment type on the bottom depends on how fast the water is moving. Areas with fast-moving water and/or big waves are sandy or gravelly, while areas with slow-moving water and smaller waves are muddier. Another important factor that affects bottom type is the location in or near the river. Rivers carry sediment from land areas down to Long Island Sound, and that sediment settles out of the water in and near the mouth. In this example, the muddiest areas are on the edges or slow-moving parts of the river, and areas of high flow or waves in the middle of the river and outside the mouth are sandier. Students should identify the core sample with sand would be in the least sheltered area (Seaflower Reef), and the core with the highest percentage of clay would be from the most sheltered area (Mitchell Beach), which means the final core came from the intermediate Black Ledge.

Extension: Sediment type can affect the organisms that can live in the sediment. Silt and fine sand (Black Ledge, Seaflower Reef) are good habitats for burrowing animals such as clams and worms, both because they can more easily burrow in it, and because so much food (in the form of organic debris) settles out of the water in these quieter areas. Extremely muddy areas often have a sulfur smell - this is because bacteria eating the organic matter consume all the oxygen, leaving the sediment below the surface fit only for anoxic bacteria (which stink like rotten eggs). Some animals do still live in this type of sediment too - they just have to have special adaptations to get enough oxygen! For example, lugworms have special gills and blood cells that allow them to extract even very low levels of oxygen from the water that moves through their burrows. Benthos are important to the food web-- filter feeders like clams consume plankton and are important prey for larger organisms, and the bacteria and detritivores (worms, etc) break down waste products and dead plants and animals into nutrients that can be taken up by the primary producers.

Navigation: Stratification

This study does not require students to create a graph, but instead they must interpret a graph of a whole year of air and water temperatures to make predictions about stratification in the water. The air temperature affects the water temperature, because heat can be transferred between air and water. When the air temperature is higher than the water temperature, this causes stratification or layering in the water. When the air temperature is colder than the water temperature, something different happens. The top layer of water, which is in contact with the cold air, cools down. Cold water is denser than warm water, so the cold water sinks to the bottom. This causes mixing of the water column. During times of the year when the air is colder than the water, the water in Long Island Sound is usually mixed, so there’s not much difference in temperature between the top and the bottom. The data provided average monthly temperature. January and February are not included due to a very small sample size. Students may include these months in their predictions, but it should be noted that there is no data to support these predictions.

Extension: Stratification (and reduced mixing) can result in a bottom layer that is low or devoid of oxygen. Organisms that dwell at the bottom such as certain fish, crabs/lobsters, sea stars and others will suffer or die during hypoxic events. Hypoxia in Long Island Sound is largely caused by excess nitrogen runoff from the watershed. Nitrogen accelerates photosynthetic phytoplankton growth, which keeps the surface layer oxygenated. However, when those phytoplankton (and any organisms in the water column) complete their life cycles and die, they sink to below the pycnocline and are decomposed. This decomposition process consumes oxygen, and eventually the oxygen is depleted. The Nitrogen from the watershed is from a variety of sources such as agriculture, stormwater runoff, and, most importantly, sewage treatment plants. Humans have developed management plans to reduce nitrogen runoff, starting with closer regulation of wastewater treatment and point-source pollution sources, as well as protecting coastal environments which serve as natural filters.