Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2017 Volume II: Watershed Science

Lobster Die-off in the Long Island Sound

Curriculum Unit 17.02.05
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One of the things I love most about being a teacher is that each day I get to see the direct impact of the work I do. Over the past six years, I have seen just how high the stakes are for my students. But every skill or life-lesson I teach them can open the door for opportunities and put them on the life path to becoming engaged global citizens in an ever-changing society. The world around us is filled with challenges and analyzing case studies related to watershed science will prepare my students to think about both the local and global impacts our actions have on our water supply and water quality.

John S. Martinez, which has a new magnet theme based on STEM topics related to the Sea, fits perfectly with the Watershed Science unit. Participating in the Watershed Science seminar greatly increased my own background knowledge about the subject matter. And I can now in turn impact my students understanding about the material.

The fifth grade Next Generation Science Standards include a performance expectation specifically related to this topic: 5-LS2-1: Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

John S. Martinez is located right along the Mill River, which enters into the Long Island Sound. Students will gain core knowledge about the chemistry of inland waters and use the lobster die-off as a case study to see the affect environmental factors have on organisms that live in the Long Island Sound.

Introduction to the Unit

This curriculum unit will allow you to enrich my student's knowledge and understanding of the world around them, which is filled with water. Academically, students will gain exposure to real-world scientific connections. They will engage in cutting edge work of the discipline and application for watershed science in our everyday lives. And finally, this unit will provide students with a deeper understanding of STEM careers and hopefully spark their interest in pursuing a degree in the sciences, related to watershed.

Students will learn about the role pollutants play in a watershed by examining the lobster die-off in the Long

Island Sound. [1] Student will become experts on the six major factors that scientists believe may have contributed to the lobster die-off including:

- bacterial infections that cause the breakdown of the exoskeleton
- a parasite that attacks the nervous system
- higher than normal water temperatures
- environmental effects of pesticide and insecticide use
- pollution
- changes in dissolved oxygen levels

After learning about the various potential causes of the lobster die-off student will develop their own explanation citing evidence in order to defend what they believe caused this.

This unit will allow students to investigate the 1999 die-off of lobsters in the Long Island Sound. Students will use a variety of texts to understand the changes in the Long Island ecosystems. Students will gain a deeper understanding of how systems are connected, particularly land and sea ecosystems, and the types of environmental influences that can influence the lobster population. This will allow our students to gain a deeper understanding about the environment around them, develop scientific inquiry skills, and enhance their problem-solving skills.

Lobster

Species Background

The American lobster, also known as *Homarus americaus* , lives in the cold waters of the Northeastern United States and Canada. [2,3] The American lobster are typically greenish brown in color, but other species come in blue, yellow, red, and white. [3] All lobster turn red once they are cooked. Inshore populations of lobster are harvested from Canada through New Jersey. [2] On the other hand, offshore populations are found from the Gulf of Maine through the Hudson River canyon. While some mixing of these two groups does occur, they are considered to be separate populations. The Long Island Sound offers both inshore and offshore lobster habitats, making its waters an important These inshore and offshore waters that surround Long Island Sound are an important to the lobster population as a whole. [2]

Lobsters are very territorial and aggressive crustaceans that prefer to live alone. [3] When they feel threatened by assume a fighting position and wave their large claws. [3] While they live in a variety of different habitats they prefer places that have a rocky or soft mud surface, compared to sandy ones. [2] A lobster's diet consists of slow moving bottom-dwelling shellfish including: mussels, clams, sea urchins, starfish, worms, crabs, and even small fish. If food is extremely scares they are also known to resort to cannibalism. [3] They are nocturnal animals that avoid sunlight and burrow or find tiny rock crevices to spend the daylight hours in. [3]

Reproduction

Lobsters live a long life and grow slowly by molting or shedding its shell. They reproduce typically in the summer or fall. A female can produce up to 80,00 eggs at a time, but an average one-pound lobster produces

about 8,000 to 12,000 eggs. [3] Each egg is about the size of a pin and when a female is covered in these eggs she is said to be “berried” because the eggs resemble a cluster of berries (Figure 1). [3] Only about 0.01% of the eggs produced by the female will develop and survive longer than six weeks. [3] Reproduction occurs when a recently molted soft-shelled female mates with a hard-shelled male. [2] The female will then fertilize the eggs about a year after mating. She will carry the eggs on her abdomen until they hatch the following spring or early summer. It is important to note that it is illegal for fisherman to catch and keep an egg-bearing female or any lobster that is too small. [3] Once hatched, the larvae go through a planktonic stage, which lasts for about a month, after which they will permanently settle to the bottom surface. [2]

Figure 1. A “berried” female lobster carrying eggs on her pleopods. The tail flipper second from left has been notched by researchers to show that she is an active breeding female. (NOAA, 2011. Copyright fee licensing under Creative Commons.)

On average, lobster can shed times exoskeleton, or molt up to ten times during their first growing season.

However, scientists note that the rate of growth and number of molts is dependent upon a variety of environmental factors including: the food supply, water temperature, sex, and geographic area. [2] After this first growing session, lobsters typically only molt once or twice each year. Lobster are not fully mature until about four to nine years after hatching. [2]

Researchers believe inshore lobster in the Long Island Sound move only small amounts during their lifetime. However, offshore lobster migrate much longer distances from the edge of the continental shelf to inshore waters to mate in the late spring and summer and then back to the shelf areas in the fall.

The Lobster Industry

There is a great concern for this species, which offers great economic and ecological importance. Lobster harvesting has been a Long Island tradition since early colonial times. The primary method of harvesting lobster in the Long is using baited pots that are set at the bottom of the Sound and marked by buoys. [2] The lobster pots that are used today are similar to the pots that have been used throughout the Northeast region for years. [2] One notable advancement that lobster industry has meet in recent years to allow young and undersized lobster to return to the water is increasing the size of the opening in the pots. [2]

The American Lobster is one of the most important seafood products harvested in New York and Connecticut, both for the value it brings to the economy and helps commercial fisherman maintain their livelihood. both in terms of the total value of lobster and the number of commercial fishermen who make their living in the lobster fishery. [2] For example, in 1998 the lobster industry in New York brought in $29 million. And according to National Marine Fisheries Service statistics, "the lobster catch was greater than the value of all fin fish combined in 1996, 1997 and 1998." [2] Their declines since 1999 has therefore raised a great concern for the Long Island Sound community.

Connection to the Long Island Sound

The lobster die-off has a strong connection to Connecticut and Long Island Sound. The Sound is an important part of Connecticut and it also plays a vital role in the state's economy. The Sound provides "feeding, breeding, nesting and nursery areas for a diversity of plant and animal life, and contributes billions of dollars each year to Connecticut's economy from boating, commercial and sport fishing, swimming, and sight-seeing." [1]

Long Island Sound

More than eight million people live in the Long Island Sound watershed which includes Connecticut, New York, and several other New England states. [1] The urbanization of this region has led to an increase in pollution, altered land surfaces, reduced open spaces, and limited access to the Sound. [1]

The Long Island Sound is an ecosystem, or a "community of organisms that interact with one another and with their environment." [1] The elements of an ecosystem are interdependent. For example, if one part of the environment changes or is altered, the entire ecosystem can be impacted. [1]

Within one ecosystem, a variety of habitats can co-exist. A habitat is defined as a "place where a plant or animal lives." [1] A habitat provides an organism with the basic needs of life such as, food, oxygen, water, space and shelter. Several different habitats can be found in the Long Island Sound ecosystem including: sandy beaches, tidal flats, salt marshes, and intertidal zones. [1]

Location

The Long Island Sound is also an estuary, or a "protected coastal body of water in which salt water from the ocean meets and mixes with fresh water from a river or stream." [1] However, the Long Island Sound not like other estuaries, as it is not only large, but also made up of many estuaries within the estuary. The Sound receives salt water the Atlantic Ocean and fresh water from four major rivers (the Connecticut River, Thames River, Housatonic River and Quinnipiac River) and many streams. [1]

Figure 2. The Long Island Sound is shown highlighted in pink between Connecticut and Long Island. [5]

The Long Island Sound is in fact a "sound." This geographical term is used to describe a body of water found between an island and mainland. The Long Island Sound lies between Connecticut, to the north, and Long Island, New York to the south. The Sound is located at 41 degrees North latitude and 73 degrees West longitude. [1] It is about 110 miles long and 21 miles wide. [1] The Sound's watershed covers an area of 15,820 square mile and is inhabited by about 14.6 million people. [3] Its average depth is 65 feet, but its deepest points can reach up to 350 feet. On a globe, it's also important to recognize that the Sound is almost directly between the North Pole and the Equator. As a result, the temperatures can get as cold as -1°C in the winter and as hot as 22°C in the summer. [6] This change in temperature from Artic to tropical conditions gives the Sound four distant seasons and creates fluctuations in biotic and abiotic factors throughout the year. Biotic factors are living or once living parts of an environment including plants, animals, bacteria, and fungi. Abiotic factors are non-living and include light, temperature, weather, soil, water, air, and minerals. [6] Long Island Sound is home to many different species of plants and animals. As a result of its changing abiotic and biotic factors, species that live in of the Sound must often adapt to significant changes in temperature and salinity, a measurement of how "salty" the water is. [1]

Salinity

Salinity of the Sound is dependent on the time of year, weather, and tides. [1] The average salinity of ocean saltwater is 35 parts per thousand (35 ppt). [1] The average salinity of the Sound is 28 parts per thousand (28

ppt). [1] This is roughly equivalent to 28 grams of salt per liter of water. Salinity does vary at various entry points throughout the Sound. For example, after a rainstorm the salinity of water entering the New Haven Harbor from the Quinnipiac River can be as low as 15ppt. Salt water that is cold has a higher density than warmer fresher water. [1] This results in stratification, where the water on top is lighter than the water on the bottom, a stable situation, which is important to creating habitat and creating the circulation pattern.

Formation of the Long Island Sound

The Sound was formed over 20,000 years ago during the last ice age when a glacier, known as the Laurentide, covered the entire region with ice almost a mile thick. [1] As the glacier moved south it caused about 20 meters of sediments on the surface of the land to erode. [1] The area that was dug up by the glacier filled with fresh water 15,000 to 19,000 years ago and during this time, the sea level rose to the level of the fresh water, becoming what we now call the Long Island Sound. [1] Long Island was formed by the glacial moraine which is where the rock and soil are deposited at the end of the glacier. Sea levels continued to rise to the level of the current shoreline and the Sound became the estuary that it is today when the land barrier broke at Race Point.

Long Island Sound Habitat Changes

A habitat is a place where an organism lives. All habitats provide basic necessities of life including: food, oxygen, water, space and shelter. [1] When an organism's habitat changes, the organism must adapt or migrate, or it can die. For examples, a lobster's habitat is shallow water along the sea floor. Until the 1990s the Long Island Sound provided American lobster with a wonderful habitat. Habitat destruction is often thought of as a physical loss of resources. such as deforestation or cutting down trees to build homes. For lobster however, habitat loss can occur simply by changing conditions of the surrounding water. The following are several changes to Long Island Sound that are believed to have contributed to the 1999 lobster die-off.

Oxygen levels and hypoxia

Oxygen is dissolved in sea water. While we as humans breathe oxygen through our lungs, lobster and other aquatic life breathe oxygen when they take in water through their gills. [1] The amount of oxygen on the sea floor of the Sound has been dropping since the 1970s. This decrease in oxygen levels is called hypoxia and it is believed to have created a stressful environment for the lobster. [1] Several factors have led to this decrease in oxygen levels, including an increase in nutrients such as nitrogen flowing into Long Island Sound from sewage and fertilizers. As the Long Island Sound watershed has become more developed there is more pavement, more sewage, and more fertilizers used on lawns. [1] More pavement causes more water with fertilizers (nutrients) to flow into Long Island Sound. The effluent of a sewage treatment plant is a point source for nutrients. Also, sometimes during a big rainstorm, sewage treatment plants will release untreated sewage to the Sound due to combined sewer overflow. Once in the Sound, these extra nutrients cause more algae to grow. [1] When they die, they sink to the sediment and bacteria break them down and use oxygen in the process, causing dissolved oxygen, or oxygen in the water, to go down. Since the water is stratified, the low oxygen in bottom waters is not easily replenished from the atmosphere.

Sulfide and Ammonia

When sediments on the bottom of the sea floor do not receive enough oxygen, a different type of bacteria, that does not need oxygen, can take over. [1] These bacteria releases hydrogen sulfide, which is a poison. Concentrations of ammonia can also get high enough to be toxic to lobsters. The types of bacteria that survive without oxygen are called anaerobic bacteria. Thus, a secondary impact of anoxia caused by nutrient loading is the production of these toxic compounds.

Pollution

For many years, Connecticut and other states the boarder the Long Island Sound have dumped the runoff of rainfall, agriculture, and sewage into the Sound. Until recently, people did not consider the impact this pollution was having to organisms on the bottom of the Sound. The 1999 lobster die-off led scientists and researchers to uncover what was causing large numbers of lobster and other organisms to die.

One of the causes they found was nutrient loading. Nutrient loading is the increase of nitrogen and phosphorous compounds in a body of water. This is usually due to a lack of wetlands, agricultural runoff, and urbanization of land. [1] When nitrogen and phosphorus levels increase to high levels in the water, they can become harmful to aerobic aquatic organisms. [1] Anaerobic organisms on the other hand thrive when these compounds increase, leading to an increase in bacteria and fungi. These anaerobic organisms then take oxygen out of the water and add methane gas. This oxygen depletion can lead to hypoxic conditions, which are dangerous of many organisms in the Sound, including lobster. [1]

Hypoxic environments exist when any of the following conditions occur including, “elevated water temperatures, organic carbon loading from agriculture, elevated sediment temperatures, poor bioturbation, dissolved oxygen levels and water stratification.” [1] When a combination of any of these factors are present over long periods of time it can create a very harmful environment. [1] While hypoxic environments usually are present for short periods of time, such as during the summer months, this problem has existed in the Sound for a much longer period of time now, leading to the death of organisms, like the American lobster. [1]

Freshwater run-off during rain storms has also increased along the Sound. Run-off transports a variety of non-point source pollutants into local water bodies and the Long Island Sound, including pet waste, automobile fluids, fertilizers, herbicides, pesticides, and debris. [7] These materials have a negative impact on the water quality. [7]

The good news is that actions can be taken to improve conditions in Long Island Sound. By preventing excess sewage and storm runoff from entering the Sound cities can greatly reduce pollution to the water. One way of doing this is by creating storage tanks to hold water during major storms. Also, by helping re-build wetlands we can “catch nutrients” and stop them from freely flowing into the Sound watershed. [1]

Temperature

Lobsters prefer temperatures below 20.5 degrees Celsius. However, lobster in the Sound are being subject to stressful conditions, as the temperature on the sea floor of the Sound has been rising since the 1970s. For example, in September of 1999 the water at the bottom of the Sound reached temperatures of 24 degrees Celsius. [1] This also causes an increase in stratification, mentioned earlier, which coupled with the decrease in oxygen levels further complicates the situation for lobster in the Sound.

Neoparamoeba paraquedensis

Increasing temperatures have also lead to an increase in the *Neoparamoeba paraquedensis* parasite leading to additional stress on lobster populations. The parasite is just one of more than forty lobster parasites found in the Sound. Scientists believe that *Neoparamoeba paraquedensis* has become more dangerous to lobster in recent years, because the parasite it able to reproduce more quickly in the warmer water. [1]

Climate

Climate is a description of the "temperature and weather found in a particular location." [1] The climate of an area is based on the amount of sunlight it receives, the local geography of the region, and local bodies of water. [1]

Sunlight is the most influential factor on the climate of region. The Earth rotates on its tilted axis once every day. This rotation of Earth on its axis causes day and night. While the Earth is rotating it is also revolving around the sun. The Earth makes one full revolution each year. The 23.5 degree axis of the Earth's axis combined with the revolution causes the change in seasons. Connecticut is located in the northern hemisphere, which means that it is getting the most direct sunlight from the spring through the fall. From the fall through the spring the northern hemisphere is pointing away from the sun leading to colder temperatures. Areas that have higher latitude, those that are located further from the equator have more dramatic changes in temperature. [1] The Sound is located at 41 degrees North latitude, making it about half way between the equator and the North Pole. This latitude location causes significant temperature change between summer and winter for the Sound. [1]

Another important factor in determining climate is the water located near the area. Water and lad trap and release heat at different rates. [1] Water heats and cools much slower than land. A simple experiment that can be used to demonstrate this concept is placing a thermometer in glass of water and another in a sample of soil. [1]

The third factor that plays a role in climate is the geography of the area. Locations that have higher altitude have colder climates than areas located closer to sea level. Another geographic feature that impacts climate is proximity to mountains and glaciers, which can block and disrupt wind patterns. [1]

Wind and Water

When wind and water circulate they carry heat and nutrients from one location to another. [1] While the Earth is rotating on its axis, the atmosphere around it does not rotate as fast as the Earth itself. [1] This causes the West to East patterns of the wind. [1]

Another type of air movement in addition to winds is thermal expansion. Thermal expansion causes air to move between the poles and the equator. Areas located close to the equator receive the most direct sunlight and as a result are hotter than areas further from the equator. The sunlight that reaches areas of higher latitude is not as direct making the air in these areas cooler, than air along the equator. [1] Air at the equator as a result expands because it is hotter. This expansion causes air molecules to occupy more space, causing other air molecules to be pushed. The air cannot push the ground down and as a result pushes up. [1] This explains why hot air rises. When this extra air moves into the upper atmosphere, it joins with the air that was

already there, causing the pressure of the atmosphere to also rise. [1] Areas close to the poles do not receive direct sunlight and therefore air there does not absorb as much heat as air along the equator. The air at the poles does not expand, causing less pressure in the upper atmosphere. [1]

Areas near the poles have higher pressure at the ground level and lower pressure in the upper atmosphere. On the other hand, areas near the equator have lower pressure near the ground and higher pressure in the upper atmosphere. The higher pressured air in the upper atmosphere over the equator moves to the upper atmosphere over the poles, since it has more room available. [1]

This air movement from the upper atmosphere of the equator to the upper atmosphere of the poles causes changes to climate. Some places as a result have hot or cold winds and wet or dry winds. [1] Cold and wet winds bring rain and snow, while hot and dry winds dry out the land because they absorb moisture. [1] Mountains and other landforms can change the wind pattern. When air hits a mountain, it must go up and over it. As the air travels up the mountain it cools. This cold air holds less moisture than hot air so it lets the water out as rain. When the air finally reaches the top of the mountain it often has very little water left in it. This causes land on the eastern side of mountains to be drier than the land on the western side of mountains. [1]

Water movement on the Earth's surface shows similar patterns to air movement. Like the air at the equator, water at the equators absorbs more direct sunlight than water at the poles. Water at the poles is also covered by ice. Water, like air, expands when it is heated causing warmer water to push colder water. This expansion of water is the cause of water currents, like the Gulf Stream, which causes warm water from the Gulf of Mexico to Florida to travel up the eastern coastline of the United States and eventually end up in the Atlantic Ocean.

Both air and water contain energy from the movement of its particles, which is called thermal energy. [1] Substances with higher temperatures have a higher thermal energy. [1] And energy transfer always goes from warmer to colder substances. Water as a result moves from areas of warmer water to areas of colder water. [1]

These annual fluctuations in temperature and the amount of sunlight, affects marine sea creatures, like lobster. The water that is first impact by these seasonal conditions is in the upper layers of the ocean because it is involved in direct heat exchange with the atmosphere from solar radiation. Lower layers of the ocean and sea floor are affected later because they do not receive direct heat exchange with the atmosphere or absorb solar radiation from the sun. [1]

Greenhouse Effect

In a greenhouse, short wave radiation comes in through the glass and turns into long wave radiation. As the long wave radiation tries to escape, it cannot pass through the glass very well, so the whole building stays warmer all winter. On Earth, the gases in our atmosphere act like the glass of a greenhouse. [1] Short wave radiation comes in from the sun and long wave radiation tries to escape back to space. While our atmosphere has been trapping heat this way since the early days of the Earth scientists are now concerned because the Earth is trapping more heat than it used to.

Carbon dioxide and methane are examples of greenhouse gases because are better at trapping heat than other gases. [1] Some greenhouse gases are created naturally; for example, volcanic eruptions and marshes emit greenhouse gases. In recent decades though scientists have noticed that human activities, like burning

gasoline in a car's engine, produce much higher levels of greenhouse gas than natural activities do. [1] This increase in greenhouse gas has led to an increase in the amount of heat trapped in the Earth's atmosphere. [1] This excess heat trapped in the atmosphere has also led to an increase in the temperature of the Earth. While many people love the warmer months of the year, these rising temperatures do not offer favorable conditions for lobster. Lobster prefer cool places and the rising temperatures of the atmosphere have also led to rising temperatures of the water creating a significant habitat change for lobster that must adapt to these warmer environmental conditions. [1]

About Climate Change

While the Earth's average temperature has changed over the past 10,000 years, much of this is due to natural causes. [1] Over the past 100 years, scientists have seen a much more dramatic increase in the average global air temperature. [1] Much of this temperature increase is the result of increased release of greenhouse gases by human activities,

Carbon dioxide is the most abundant and most important greenhouse gas. [1] It plays a vital role in keeping the earth's temperature at a point that can support life. Fossil fuels, including coal, oil and natural gas, are all made up of carbon. [1] When fossil fuels, such as coal, oil and natural gas, are burned, carbon dioxide is released. This carbon dioxide can build up in the earth's atmosphere. The amount of carbon dioxide and other greenhouse gases in the atmosphere is increasing rapidly, as a result of human activities that include fossil fuel combustion and deforestation. In essence, these gases act like a greenhouse, reflecting heat back to the earth's surface. Some amount of greenhouse gasses is needed to make the earth hospitable for life, but too much can stress organisms and ecosystems.

Climate change is taking place much quicker than it has in any other time in Earth's history. This rapid climate change is greatly impacting ecosystems and the species that live in them. Some noticeable effects of this rapid climate change include droughts, floods and storms. [1] These issues have in turn been linked to an increase human problems such as, disease, death, displacement, and hunger. [1] While these change in global temperature may seem small they can have major impacts on the climate. [1]

Alien Invaders

The Long Island Sound has experienced many changes in its lifetime. One of the most unpredictable changes it has undergone is the introduction of non-native species to its waters. Over the past few decades, the Sound has become home to over 100 invasive species. [1] This species also referred to as alien species of both plants and animals are not native to the Sound. By invading the Sound, they have forced native species to have to compete for resources. [1]

Non-native species have been introduced to areas around the world, and aquatic ones most often reach their new habitats on the outside of ships, in ballast tanks, become pushed along in a water current, and some are even intentionally introduced to a region to solve one problem and often create another. [1] Every non-native species has the potential to become an invasive one. An organism is classified as an invasive species when its introduction to an ecosystem causes or is likely to cause economic harm, environmental harm, or harm to human health. [1]

Invasive species cause a variety of problem for native organisms in the Long Island Sound. While all species

are affected by these new organism, endangered species are often most affected by these invaders, as they often eat native species, their food, destroy their habitat, or take the place of the existing species within the habitat. This can put a great deal of pressure and stress on native species that may not be “adapted to compete with the new arrivals.” [1]

Disease

Researchers have also investigated whether this decline in lobsters could be the result of disease. A number of diseases are associated with lobster death including: parasitic paramoeba, shell disease, red tail, and other bacterial diseases. [7,8]

One potential lobster killer is a parasitic paramoeba that enters the lobster’s nervous system and destroys nerve tissue. [7] After the parasite attacks the lobster, death usually occurs within 24 hours. [8] Additionally, shell disease, a bacterial infection that eats away at the lobster’s exoskeleton, has shown an increase in the Sound in recent years. Researchers believe America lobster are more susceptible to this disease because they are so aggressive. When they fight and molt they damage their exoskeleton, providing an entry point for the bacteria. [8] Another lobster disease, *Gaffkemia* , or red tail, affects the lobster’s circulatory system. [8] Some believe that the lobster illnesses are due to other changes like temperature, climate, storms, or pollution making lobster more susceptible to diseases and parasites. [8] One piece researches do not have data on is how many of the lobster killed by disease were egg-bearing females, affecting the next generations of lobster for years to come. [8]

Lobster Landings Today

A lobster landing refers to the pounds of lobster caught by commercial lobstermen harvested in their traps. Only lobster above the legal minimum size and those not carrying eggs can be caught. [9] This indicator is “reflective of fishery management practices, socioeconomic conditions, and species population abundance. [9] In the 1980s American lobster harvested in the Sound increased, with the peak average lobster landing in 1997. [9] Lobster die-offs were most severe during the years of 1999 to 2002. [9]

Scientists have attributed a combination of warmer temperatures and poor water quality to lobster stress, making them more susceptible to disease and limiting their ability of reproduce. [7] Ultimately a variety of factors are believed to have caused a rapid drop in American lobster population. [9] Two of the management control systems that were put in place to help restore the lobster populations in the Sound were increasing the size restrictions of lobster that can be caught and limiting the number of adult female lobster that can be caught. [9] And when these efforts did not have an impact the states of New York and Connecticut worked with the Atlantic States Marine Fisheries Commission to put in place a fall lobster harvest closure beginning in 2013. [9] The idea behind this closure was to “reduce fishing exploitation by 10% in order to help restore the [American lobster] population.” [9] Connecticut and New York have also created effort reduction programs to buy-back lobster traps thus allowing compensation for lobsterman impacted by the lobster-die off and reducing the number of lobster that can be caught be decreasing the number of traps that can be harvested. [7] Connecticut has seen relatively stable landings since 2011, but New York has continued to see a decline in

landings and in 2014 it saw its worst year in history. [9]

In addition to lobster, researcher have also noted recent decreases in the number of blue crabs and sea urchin in regions of the Northeastern United States, including the Sound. It is unclear whether the cause of their decline is related to the lobster die-off.

Classroom Activities

KWL Chart [1]

A KWL Chart is a great way to engage students in there learning before, during, and after a unit. At the beginning of the unit students should record their responses to the first two columns of the chart (shown below). The first column is the "know" column where students record what they already know about lobsters or lobster die-off. The second column is the "Want" to know column where students write down questions that they want to learn more about during the unit. This column is also a great place for students to refer back to during the unit, as they learn answers to their questions. Finally, the third column, which stands for "Learn" is a place for students to record what they learned in the unit.

What do I know about lobster die-off in Connecticut?	What do I want to know about lobster die-off in Connecticut?	What did I learn about lobster die-off in Connecticut?

While a KWL chart can be used for individual students it is also a great anchor chart to post in the classroom. After students complete the chart individually teachers can then engage students in a whole group discussion and create a classroom chart that the class can refer back to over the course of the unit.

Temperature of the Long Island Sound

A great way to incorporate mathematics and scientific inquiry skills into this unit is through graphing. Students can utilize graphing as a way to compare the relationship between water temperature and lobster health. Below is a list of average temperatures at the bottom of the Wester Long Island Sound and the data from average lobster landings from 1993-2003. [1]

Year	Temperature (degrees Celsius)	Lobster Landings (average pounds of lobster caught per catch)
1993	20.3	11.6
1994	19.2	10.0
1995	19.6	8.0
1996	18.9	10.0
1997	18.9	19.8
1998	19.2	10.3
1999	20.3	11.3
2000	19.9	6.8
2001	20.2	4.2
2002	20.6	2.7

2003	19.3	4.1

Students should graph this data using a double line graph. One line will represent the average temperature at the bottom of the sea floor from 1993-2003 and the other line will show the average pounds of lobster caught in a catch from 1993-2003.

Some questions that you could ask students after they have plotted the points on the graph include: Between what years did the number of lobster landings drop the most? Is there a relationship between the number of lobster landings and water temperature? What might have caused the temperature changes at the bottom of the Sound?

Lobster News Report

One activity for students to engage in as a way to summarize their learning throughout the unit is creating a news report performance task. This news report could be in the form of a news broadcast (video), newspaper article (written), or visual display (image). In groups of three to four students should work together to synthesize their knowledge of one of the major possible causes of the lobster die-off in the Long Island Sounds. [1]

The GRASPS model is great way to frame student performance tasks. GRASPS stands for goal, role, audience, situation, product/performance, and standards. [10] And is a way to construct or format performance tasks. [10]

Goal

The goals section provides a statement of the task and informs students of the goal problem, challenge, or obstacle in the performance task. [10]

Example: Your goal is to inform locals of the possible causes of the lobster die-off in the Long Island Sound.

Role

The role defines the role of the student in the task and states the job students have. [10]

Example: You are a news team.

Audience

The audience identifies the target audience within the context of the scenario, such as a client or company. [10]

Example: You target audience is people that live near the Long Island Sound.

Situation

The situation explains the context of the scenario. [10]

Example: You need to convince people the lobster die-off is a serious problem.

Product

The product tells students what they will create. [10]

Example: You will create a news broadcast, newspaper article, or visual image in order to inform local New Haven residents of the

Standards

The standards provide students with a clear picture of success or rubric of how their success on the performance task will be measured. [10]

Example: You work will be scored based on: knowledge of lobster, the habitat they live in, information about your cause of the lobster die-off.

Teacher Resources

Connecticut Sea Grant. “Long Island Sound Curricular Resource Guide.” *Connecticut Sea Grant* . Last modified March 2, 2010. http://web2.uconn.edu/seagrant/publications/marineed/curricpt2.pdf. This resource provides a variety of student activities related to the Long Island Sound.

NGSS Lead States. *Next Generation Science Standards: For States, By States - 5.Matter and Energy in Organisms and Ecosystems* . Washington: The National Academies Press, 2013. http://www.nextgenscience.org/dci-arrangement/5-ls2-ecosystems-interactions-energy-and-dynamics. Provides an overview of performance expectations, science and engineering practices, disciplinary core ideas, and crosscutting concepts related to the 5 th grade standards related to matter and energy in organisms and ecosystems.

Student Resources

BrainPop. “Invasion!!” *Brainpop* . Accessed May 25, 2017. https://www.brainpop.com/games/invasion/. In this game students can explore the effects of invasive species by participating in a game simulation, in which they must stop carp (a non-native species) from invading Lake Michigan.

BrainPop. “Ecosystems.” *BrainPop* . Accessed May 15, 2017. https://www.brainpop.com/science/ecologyandbehavior/ecosystems/ This video on ecosystems can help upper elementary and middle school understand what makes up an ecosystem.

Flocabulary. “Ecosystems.” *Flocabulary* . Accessed July 2, 2017. https://www.flocabulary.com/unit/ecosystems/. This video on the ecosystems can help upper elementary and middle school students remember the connection between organisms in an ecosystem

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9. Long Island Sound Study. Lobster Landings. *Long Island Sound Study.* Last modified June 3, 2017. http://longislandsoundstudy.net/indicator/lobster-landings/
10. Wiggins, Grant and Jay McTighe. *Understanding by Design Professional Development Workbook.* Alexandria, VA: Association for Supervision and Curriculum Development. 2004.

Appendix A. Implementing District Standards

Next Generation Science Standards

Performance Expectations

5-LS2-1: Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems

The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as “decomposers.” Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem. (5-LS2-1)

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste material (gas, liquid, or solid) back into the environment. (5-LS2-1)