Biodiversity and Global Change

Lobster Die-off!

An Event-based Science Unit

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Peabody Fellows

Biodiversity and Global Change Program

The Peabody Fellows Biodiversity and Global Change Program aims to improve science teaching and learning among middle and high school teachers and students in Connecticut around the topic of Biodiversity and Global Change. Global change is among the most scientific and societal issues of the 21st century as humans have an increasing impact on the environment. Understanding how global changes affect biological diversity, and vice versa, requires an integrated knowledge of the earth and life sciences. The curriculum unit, “Lobster Die-off!” developed as part of this project studies one of the local effects of worldwide issues such as ocean warming, pollution and invasive species.

Please note this unit is still in draft form. All comments are welcome.

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from the Institute of Museum and Library Services,
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Lobster Die-off!

An Event-based Science Unit

Introduction

Lobster Die-off! is a unit covering life science concepts related to the 1999 die-off of lobsters in Long Island Sound. It begins by exposing students to news coverage of this actual event that brought about significant changes in the Long Island Sound ecosystem off the coast of Connecticut and the Connecticut economy. It offers an opportunity for students to understand how natural systems are interrelated and that a problem in the environment may have multiple influences or causes.

The impetus for creating this unit came about through a presentation on the American lobster die-off by research scientist Carmela Cuomo, Ph.D. during the Yale Peabody Museum's 2005 Biodiversity and Global Change Teachers' Institute. This unit was made possible through generous contributions from the Bay and Paul Foundations and the Institute for Museum and Library Services *Museums for America* Award.

The Peabody Fellows Program of the Yale Peabody Museum seeks to educate students, to encourage them to experience the diversity of the natural world with a positive attitude toward scientific inquiry, and to promote the incorporation of science and scientific inquiry methods in the classroom. The program works closely with selected teachers to develop science curriculum units aligned with state and national science standards. The program has evolved into a respected resource for professional development that helps teachers show children new ways to view their environment, strengthen their observational and investigative skills, and instill a respect for biodiversity. It provides teachers with access to the educational resources of the Yale Peabody Museum to enhance the learning experience in their classrooms.

This event-based unit is presented in the following format: Hook-Discussion-Task-Needs Assessment-Instructional Activities-Group Work on Task-Product. The unit begins by engaging students in the problem through real-life news reports and personal stories. We call this first step "the hook" because it grabs and holds students' attention. Discussion of the event reveals students' prior knowledge of the related science concepts. An authentic task creates a need for teams of students to refine their knowledge and explore new concepts and processes. Student requests for needed information are met with hands-on instructional activities that prepare students to complete the task. The task leads to a final product that allows students to apply the science they have learned and to be assessed on the quality of their work.

We chose an event- and place-based approach to this unit for several reasons. Today's literate citizens need to know how to analyze problems, ask critical questions, evaluate competing claims, and formulate and test tentative explanations of events. They also need to acquire scientific knowledge and apply it to new situations. The event-based approach allows students to accomplish all this by placing the study of science in a meaningful, interdisciplinary context in which students can perceive the role that science plays in the lives of ordinary people.

We believe that learning is most effective when students have been actively engaged in its pursuit. Instead of merely memorizing information from a textbook, the students become active participants in an inquiry whose ultimate product is knowledge. Their instructors serve primarily as guides and advisors, assisting students as they build and test their knowledge.

Lobster Die-off! includes a range of activities and strategies. Cooperative learning structures, open-ended laboratory investigations, guided discussions, statistical analyses and performance assessments are included. The unit tells a story about a real event and contains actual news articles, interviews with people who experienced that event, and descriptions of the scientific concepts involved. The resources included here, however, are not intended to be exhaustive. Teachers will want to supplement the texts provided with their own insights, experiences, explanations and demonstrations, encouraging students to explore information at the library, on the Internet, on CD-ROMs, and from other resources. For more information on the event-based science approach to learning, we recommend that educators visit www.eventbasedscience.com.

National Science Content Standards

Scientists try to explain events by observing, questioning, experimenting and confirming. This unit uses these National Science Education Standards (NSES): *Science as Inquiry, Physical Science, Life Science, Earth and Space Science, Science in Personal and Social Perspectives, and History and Nature of Science*. The chart that follows lists the standards and examples in this unit:

Standard	Targets in This Unit	Sample Indicators
Science as Inquiry	• Abilities necessary to do scientific inquiry • Understanding about scientific inquiry	• Design a scientifically valid experiment
Physical Science	• Understanding about properties and changes of properties in matter • Motions and forces • Transfer of energy	• Explore movement of and temperature changes in water • Identify how organisms can change water chemistry
Life Science	• Understand structure and function in living systems • Populations and ecosystems • Diversity and adaptations of organisms	• Identify structures on and adaptations of a lobster • Investigate factors affecting lobster populations
Earth and Space Science	• Structure of the Earth system • Earth's history • Earth's features • Earth in the solar system	• Explore the relationship between climate and the Earth's features • Explore the history of Long Island Sound • Investigate how orbital and axis variability affect climate
Science in Personal and Social Perspectives	• Populations, resources and environments • Risks and benefits • Science and technology in society	• Investigate the relationship between population and global changes
History and Nature of Science	• Science as a human endeavor • Nature of science	• Appreciate that women and men of various ethnic backgrounds successfully engage in science every day • Recognize that scientists can draw different conclusions from the same data

The Connecticut Core Science Curriculum Framework

Included within each of the activities are the content standards that give general learning goals for the unit, supportive concepts that provide more specific information about the focus of the learning unit and expected performances which identify specific knowledge and abilities that will be assessed.

The Hook

The Hook used to engage students in global and environmental change is two-part. It begins with a real-life news report as a springboard for discussion that leads to scientific concepts related to the lobster die-off of 1999. Follow this up by having students read the four student handouts for the Hook: Lobster Tales, The Perfect Warm, On the Job: Carmela Cuomo,

Ph.D., and Conditions in Long Island Sound. The first is an article about a local lobster fisherman who experienced the die-off firsthand. His story, in which he explains how he was forced out of the work he had pursued for many years, demonstrates the impact that environmental changes can have on the lives of real people. The second offers early theories as to possible causes for the die-off. The third offers a profile of one scientist who studied the event in depth, and the fourth provides insight into Long Island Sound conditions. Small-group discussion of the answers to guiding questions allows the teacher to uncover students' prior knowledge about this event in Connecticut's recent history.

Their focus on the 1999 lobster die-off in Long Island Sound will expose students to a range of issues. At the beginning of the event, scientists were extremely puzzled. What was causing the lobsters to die, thereby destroying not only the creatures themselves, but a thriving industry related to lobster fishing? Like those scientists, students will consider a range of possibilities, including: were the lobsters suddenly exposed to harmful bacteria or parasites? Were they victims of heavy pesticide use and stormwater run-off into their estuarine habitat? Was an invading alien species of plant or bacteria killing them off? Was their habitat drastically altered as a result of climate change, and if so, were they simply unable to adapt to warmer water temperatures, or did warmer water temperatures cause hypoxia – an algal bloom that resulted in greatly reduced oxygen levels in the water, so that the lobsters could not respire?

Divide the class into teams. Designate a recorder for each team. Have each team discuss what they learned and discuss/answer the following:

1. Lobsters are crustaceans. Describe where they live.
2. Lobster harvesting is a major industry. Describe the change that took place in that industry in Connecticut between 1998 and the present.
3. Why might inshore lobsters have been at greater risk to die-off than offshore lobsters?

Have the recorder for each team write the group's best answer to each question on a large sheet of newsprint for use in a "Blackboard Share" session. Have the recorder report the team's answers using the recorded list. After all teams have reported their answers, the class should look for areas in which they see agreement or disagreement. The sheets of newsprint can be saved and used at the end of the activity as a way for students to compare their level of understanding before and after the unit.

Distribute the handout for the Hook: Charting Your Conclusions, one to each team. Then ask: What more do you need to know to understand what caused the 1999 lobster die-off in Long Island Sound? Have them work in their teams to fill out the chart, identifying what they know about the die-off so far, what they need to learn in order to understand what caused the die-off and strategies for discovering what they need to know. Share the charts as a whole class activity, then save the charts for students to refer to while completing the Task.

Following their exposure to the Hook, but before they initiate the Task, students will work independently, in pairs and in groups on a series of Investigative Activities. The activities are designed to expose students to concepts that were part of the knowledge base of scientists who worked on the problem. Those basic concepts include the physiology of lobsters, how bacteria and parasites affect living organisms, the Long Island Sound ecosystem, habitat loss, climate change, biodiversity and hypoxia. Following each Investigative Activity, it is important to hold a class discussion on the usefulness of the information gained. Students should be encouraged to brainstorm ways they can use the information in their presentations.

Student Handout: The Hook

Lobster Tales

Theories swirl like the current as the Long Island Sound lobster die-off continues. For nearly 20 years, Tony Carlo of Norwalk had spent his summers hauling lobster traps out of Long Island Sound. “We had some good years and we had some not-so-good years,” Carlo said. “No matter what, though, you knew there would always be something in those traps.”

But in late August and early September 1999, that something turned out to be a lot of dead and dying lobsters, rotting and tangled in his trawls. “I had to throw all of them back,” he said. “I stopped counting at 1,200 lobsters. It was disgusting.” In the two years since, Carlo has all but given up on his profession as a lobster fisherman; he recently opened a landscape company. “I’ve been fishing for lobsters for a long time, and I know it’s a hard business,” he said. “But this isn’t right; it isn’t normal. Now you go out there and you might pull one lobster out of seven or eight traps – if you’re lucky. All the lobsterman are picking up and moving out of here. It’s not like it used to be.”

His story echoes along the Fairfield County coastline, where lobster catches are a fraction of those in the eastern part of the Sound and in northern New England. The fishermen have their own theories about what caused – and continues to cause – the die-off, while government officials offer a different set of possible explanations. Meanwhile, two years after Tony Carlo first pulled decomposing lobster carcasses from his traps, the animals have yet to make a comeback.

To help understand the problems, some knowledge about this crustacean is needed. Lobsters are solitary, territorial crustaceans that live in a variety of different habitats preferring areas that have a rocky or soft mud bottom to one that is sandy. Inshore lobsters like those in Long Island Sound are thought to move in localized areas during their lifetime, while offshore lobsters often migrate long distances from the edge of the continental shelf to inshore waters in late spring and summer and back again in the fall. Lobsters eat a variety of slow moving bottom-dwelling shellfish like mussels, clams, sea urchins, starfish, worms, crabs – even small fish. They are nocturnal animals that generally avoid sunlight, and will seek out crevices in the rocks to spend the daylight hours, especially in shallow waters.

Lobster harvesting has been a Long Island tradition since colonial times. Lobsters are primarily harvested in Long Island Sound with baited pots that are set at the bottom and marked by buoys. The lobster pots today are similar to the pots that were used throughout the Northeast for decades. But in recent years the lobster industry has implemented several improvements, one of which is an increase in the size of the opening in the pots, allowing more and undersized lobsters to return to open waters.

The American Lobster is one of the most important seafood products harvested in New York and Connecticut both in terms of the total value of lobsters landed and the number of commercial fishermen who make their living in the lobster fishery. Earning a dockside value in New York alone of over $29 million in 1998 according to the National Marine Fisheries Service statistics, the lobster catch was greater than the value of all fin fish combined in 1996, 1997, and 1998. Their decline since fall 1999 is therefore a cause for great concern.

It appears then that the problems that are currently concerning scientists, and lobstermen, surround populations in specific areas. In Long Island Sound there have been abnormally large lobster die-offs caused at least in part by diseases since 1999. Scientists are exploring multiple avenues in order to discover the origins of these unusually large die-offs. Some factors include:

- 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 use
- pollution
- changes in dissolved oxygen levels

For more information, see www.seagrant.sunysb.edu/LILobsters/aboutlobsters.htm

Student Handout: The Hook

The Perfect Warm – The Long Island Sound Die-Off by Mike Crowe

In September 1999 the lobster fishery in western Long Island Sound sustained a sudden 98 percent die-off.

The disaster put many lobster fishermen in the Sound out of business. The states of New York and Connecticut began investigations into the dramatic event. The immediate focus was on a parasite, a paramoeba, found in the flesh of some lobsters. Another early suspect were the pesticides used in the West Nile virus scare that same fall.

At the Fishermen's Forum held in March '05, in Rockland, Me., scientists who have studied the problem in the years since, presented their findings in an all-day seminar. Scientists from Maine, Connecticut, New York, Georgia and Canada reported on various aspects of the problem; a few had some of the same conclusions to offer.

Some fishermen were convinced that the die-off was the result of chemicals sprayed along the coast. The chemicals were sprayed to kill mosquitoes believed responsible for the West Nile virus. Others blamed the paramoeba. None of the scientists identified a very specific cause, but many at the Forum agreed that lobsters are very temperature-sensitive. This, many agreed, could be critical to understanding whatever it was that killed the lobster in such great numbers.

For more information, see www.fishermensvoice.com/archives/perfectwarm0905.html

Student Handout: The Hook

On The Job: Carmela Cuomo, Ph.D., Marine Benthic Biogeochemical Ecologist

Dr. Carmela Cuomo's job title is a special one: Marine Benthic Biogeochemical Ecologist. Marine means salt water. Benthic means "at the bottom." Biogeochemistry involves the study of the chemical, physical, geological and biological processes and reactions that control the make-up of the natural environment. Ecology is the study of interrelationships between living things and their non-living parts of the environment.

Dr. Cuomo presented information gathered as a research scientist at Yale University in New Haven, Conn. Cuomo coordinates the marine biology program at the University of New Haven. Having done research on low oxygen marine systems, she was one of the scientists asked to study the lobster die-off and the conditions of the lobster habitat at that time. Cuomo's presentation brought together lobster stress factors that had been known to exist in the Sound. These factors and others were brought together, she believes, by a weather event that led to a weakening of lobsters to a point where practically anything would have . Other scientists at the Forum had studied the effects of various substances in the environment on the health of lobsters.

All interested parties were asking the same questions: What was the cause and what was the cure? They also wondered how to prevent this from occurring elsewhere.

Student Handout: The Hook

Conditions in Long Island Sound

What do the researchers know about conditions in Long Island Sound in 1999? In the fall of 1998, lobster deaths and reports of a new disease were coming in from widely dispersed geographical locations. In the fall of 1999, the focus zeroed in on Long Island Sound, where the second successive year of high mortality was taking a toll on lobster landings. Elsewhere, landings remained high. What was different about the Sound?

Lobsters are long-lived animals. Their natural life expectancy is estimated to be somewhere between 50 and 100 years. The largest lobsters ever measured weighed in at more than 40 pounds! For some reason, lobsters in Long Island Sound don't seem to grow this large or live this long. They grow faster than lobsters elsewhere and have a life expectancy of only five or six years. Large lobsters seemed to be extremely rare or non-existent in the Sound.

Small lobsters molt more frequently than large lobsters. Molting is a physiologically demanding and weakening process. Therefore, lobsters are more susceptible to death when they are molting. If a large lobster is afflicted with an ailment, it has more time to deal with the problem before it has to go through a molt (shed).

Chemicals had been sprayed along the Connecticut Coastline to kill mosquitoes believed to be responsible for West Nile Disease. Hypoxia had been a recurring problem in western Long Island Sound since the early 1990's and a moderately severe hypoxic event occurred in LIS during the summer of 1999 (Cuomo) A parasite called paramoeba was found in the flesh of some lobsters. Western Long Island Sound is described as heavily industrialized. A large amount of organic material is released into the sound from 140 sewage treatment plants.

As reported by Dr. Cuomo, surface temperatures for 1999 were high (exceeding 22^{o} C) for an extended period of time. The winter of 1999 was followed by an above-average warmer summer, resulting in warmer than normal surface water temperatures. An August storm in 1999 caused an unusual mixing event in which temperature, salinity, and oxygen experienced a rapid change in the bottom waters of western Long Island Sound. In September 1999, stratification was re-established by the rainfall caused by Tropical Storm Floyd. Bottom temperatures were recorded at 24^{o} C. This destratification resulted in a rapid 1^{o} C increase in the bottom water temperatures in LIS over a 6- hour period. Bottom water temperatures remained above 21 ^{o}C for September.

Student Handout: The Hook **Charting Your Conclusions**

What we know about the lobster die-off in Connecticut	What we want to know about the lobster die-off in Connecticut	Strategies for learning what we want to know

The Task

The culminating product for this unit is a 10- to 15- minute newscast. Students will take on the role of a news team to produce a newscast on one of five possible causes of the lobster die-off. Teams may choose to perform their newscast live for the rest of the class or play a videotape they produce themselves. After the class is divided into teams, each team should meet to develop a list of questions they wish to have answered before they are ready to start the task, as well as the different sub-tasks involved and the team members who will be responsible for each. A student handout is provided to help facilitate this team-organizing activity. Background information to help students begin answering their questions is provided by Discovery Files.

Different phases of the Task allow the teacher to monitor the progress of each team. You may want to schedule team and/or individual checkpoints to keep students focused and moving ahead. If some students finish science activities early, you may want to let them begin working on the task.

Plan to allow students some class time to organize and practice their newscasts. Some may be able to meet and work outside of class, but others will need in-class time.
Have all team members keep an activity journal containing their notes, ideas, results, charts, graphs, and art developed as the activities are completed. This activity journal will be very helpful to students as they prepare for the task itself. Toward that end, teachers will want to provide class time for students to write in their journals. It may also be helpful to create classroom space in which journals may be stored to increase the likelihood that regular journal entries will be made.

Once sufficient background has been covered, have students identify roles within their teams. With teacher assistance, most students will do a good job of matching their skills and interests to the requirements of each role. Some students will need extra guidance to help them develop their newscast. Teachers will want to keep a set of reference books in the classroom during the course of the unit.

Performance assessment is reflected within all the activities and within the final task itself. The unit can be completed in four to six weeks, depending on how much time the teacher chooses to devote to each activity. A four-week framework is outlined here. We recommend setting up the Winogradsky Column for Activity 6 at the beginning of the unit since the activity must be completed in weekly stages. Upon completion of the Investigation Activities, students will be ready to take on the challenge of the Task: an in-depth look at one of a number of influences upon the lobster die-off. At the end of the presentations, you will want to engage in a whole class discussion, allowing teams the opportunity to hypothesize which of the influences studied is believed by scientists to be the actual cause of the die-off. Remind students that even scientists disagree on this final cause, but a majority of them have formed similar conclusions based on the available evidence.

Four-week Unit Framework

Week 1 (Topic: Lobsters)

Hook and Task introduction

Set up Activity 6: A Microbial City

Activity 1: Lobster Food Web

Activity 2: Lobster Physiology, Parts 1, 2, and 3

Week 2 (Topic: Long Island Sound and Biodiversity)

Activity 3: Long Island Sound

Activity 4: Temperature Tracking

Activity 5: Temperature and Biodiversity

Activity 6: A Microbial City, Week 2 Observations

Week 3 (The Task)

Activity 6: A Microbial City, Week 3 Observations

Students work on the Task

Week 4 (Presentations)

Activity 6: A Microbial City, Week 4 Observations

Students work on the Task

Student presentations and evaluations

Student Handout: The Task

You've seen the news. The lobster industry in Connecticut is collapsing. Lobsters, once in plentiful supply in Long Island Sound's waters off Connecticut, are dead and dying. People who have spent their lives as lobster fishermen can no longer work at what they know how to do.

What is happening? What is killing off the lobsters in Long Island Sound? Is it hypoxia? Higher water temperatures due to climate change? Disease? Pollution, such as chemicals sprayed to control mosquitoes that have gotten into the Sound through run-off? Or it the over-exploitation and over-harvesting of the lobsters themselves?

The 1999 lobster die-off in Long Island Sound was a real event that still has repercussions today in Connecticut's economy and how we view the Sound. Your team will take one of five possible issues and investigate it in detail, presenting your findings to the rest of the class. Then, as a class you can hypothesize which issue or issues actually brought about the lobster die-off. Finally, your teacher will share with you the findings of scientists who studied the die-off and what they now conclude really happened.

Your Task

People are concerned about what is happening in Long Island Sound. Reacting to those concerns, the local television station has decided to air a special segment each night for one week on the possible causes of the lobster die-off. The station has hired your news team to produce the special. Your task has two parts: the production itself and a presentation, in which you will either dramatize or videotape your special news segment for the rest of the class. Each news team will focus on one possible cause of the lobster die-off and create their special segment.

Part 1: The Production

The program must contain general information about lobsters and their physiology, as well as the estuary habitat of Long Island Sound where they live. Your special segment must include facts about how the possible cause you are investigating affects lobsters. The News Editor at your television station wants you to document the accuracy of your presentation, so you will need to keep a log. The log should contain all notes, science activities, charts, graphs, and/or photocopied materials you use to prepare your news segment.

The Roles

There will be four members on your team. Each member has a different job to perform. The jobs are producer, scriptwriter, director and prop manager. When you first meet with your team, decide how you will assign the jobs. Make a list of who will do each job and submit the list to your teacher. Also discuss whether or not you are ready to begin. Is there anything about lobsters or Long Island Sound that you need to know more about? How might you go about gathering the information that you need? Let your teacher know about any concerns you have about getting started.

Job Descriptions

Producer will:

1. Write the portion of the script about the American lobster and develop visual aids that describe the American lobster and how it is being affected by the issue your team is investigating.
2. Write a memo to the News Editor of the station to keep that person informed about your team's daily progress.

3. Develop an outline of your news segment for the News Editor of the station at least three days before you are ready to videotape or dramatize it. Provide a description of the topics you plan to present.
4. Keep a time line of the production schedule and ensure that the team is staying on schedule.
5. Take part in the dramatic presentation as needed.

Scriptwriter will

1. Write the portion of the script and develop visual aids that explain what effect if any the issue you are investigating has on biodiversity in Long Island Sound. Explain the effects on the lives of people in Connecticut.
2. Work with the other members of your news team to develop the final script of the program, indicating the scenes, character names and words to be spoken.
3. Assist the director in helping other team members with their jobs.
4. Take part in the presentation.

Director will:

1. Assist the producer to write the portion of the script and develop visual aids that explain how the issue you are investigating affects lobsters and how it may contribute to the lobster die-off.
2. Select a musical theme for the news segment and assist other members of the team with their jobs.
3. Organize and direct rehearsals for the presentation.
4. Take part in the presentation as needed.

Prop Manager will:

1. Write the portion of the script and develop visual aids that describe background information surrounding the issue your team is investigating. Present facts about the issue.
2. Prepare a large, colorful and creative poster announcing the name of your news segment.
3. Create or gather all necessary props, posters, charts, maps and other materials needed for the news segment.
4. Operate the camera (if the team is producing a video) or take part in the presentation as needed.

Part 2: The Presentation

The final part of this unit is the performance itself. All members of your news team will perform the program. The performance should include guest "experts," played by members of your team. Experts could include lobster fishermen, marine biologists, concerned citizens and others.

Your team may decide whether to videotape the program or perform it live in the classroom. The program will be between ten and fifteen minutes long. Be creative in developing your presentation.

About Lobsters

Before proceeding to the Investigative Activities, you will want to review and set up Activity 6: A Microbial City. Students will subsequently make observations at the end of each week and record data using the Student Handout for Activity 6.

Activity 1: Lobster Food Web

Objectives

Students will understand where lobsters fit in a Long Island Sound food web.

CT Science Content Standard

6.2 An ecosystem is composed of all the populations that are living in a certain space and the physical factors with which they interact

- Populations in ecosystems are affected by biotic factors, such as other populations, and abiotic factors, such as soil and water supply.

NSES Content Standards

- Populations and ecosystems
- Diversity and adaptations of organisms

Materials

Discovery File: What is a Lobster?

Long Island Sound Study's "Inside a Long Island Sound Food Web"

Procedure

1. Have students read the Discovery File: What is a Lobster? If time allows, have students research more on lobster natural history.
2. Hand out Long Island Sound Study's "Inside a Long Island Sound Food Web":

http://www.longislandsoundstudy.net/soundhealth/Poster_Letter_size.pdf

Have students draw in a lobster and draw connections to other organisms in the web. Have students write an explanation about where and why connections were made.

3. Discuss connections. Are there any additional plants or animals that should be included?

Scoring rubric

- The student's connections to and from the lobster on the food web are reasonably accurate and titled and labeled properly. The explanation of lobster interrelationships are well written and reasonably accurate. 3 points
- The student's connections to and from the lobster on the food web are partially accurate and titled and labeled properly. The explanation of lobster interrelationships is complete but shows some lack of understanding of concepts and is not written clearly and properly 2 points
- The student's connections to and from the lobster on the food web are wholly inaccurate and incompletely titled and labeled. The explanation of lobster interrelationships is incomplete and shows significant lack of understanding of concepts or is not written clearly and properly. 1 point

Discovery File: What is a Lobster?

What is a Lobster?

What does a lobster have in common with a grasshopper? Well, more than you might think. It might be hard to believe that lobsters are actually related to insects, but like insects, they belong to the invertebrate phylum Arthropoda. Insects and lobsters are animals that have an exoskeleton (outer skeleton) and jointed legs.

Unlike insects, lobsters belong to the class Crustacea, along with other marine organisms like crabs, crayfish and shrimp. A crustacean is an invertebrate animal with several pairs of jointed legs, a hard protective outer shell, two pairs of antennae, and eyes at the ends of stalks. Because lobsters have ten legs, they belong to the order Decapoda (latin for ten feet). The American Lobster or true lobster (as opposed to the spiny lobster) is classified as follows: Kingdom: Animalia, Phylum: Arthropoda, Subphylum: Crustacea, Class: Malacostraca, Order: Decapoda, Family: Nephropidae, Genus: Homarus, Species: Americanus.

Lobsters live on rocky, sandy, or muddy bottoms from the shoreline to beyond the edge of the continental shelf. They generally live singly in crevices or in burrows under rocks. Although many studies have suggested that lobsters are primarily scavengers, that is, animals that consume already dead organic life-forms, recent studies have shown that they primarily feed on live fish, dig for clams, sea urchins, and feed on algae and eel-grass. They occasionally eat other lobsters, too. An average adult lobster is about 230 mm (9 inches) long and weighs 700 to 900 g (1.5 to 2 pounds). Lobsters grow throughout their lives, molting or shedding their exoskeleton or outer body covering as they increase in size.

Like all arthropods, lobsters are largely bilaterally symmetrical, although they have unequal, specialized claws, a **cutter claw** for tearing food and a **crusher claw** for crushing food. The anatomy of the lobster includes the **cephalothorax** which is the head fused with the upper body, both of which are covered by the **carapace**, or shell. The **walking legs** of the lobster extend from the cephalothorax. Lobsters have two **antennae** on their heads that serve as sensory organs. Lobsters have compound **eyes** at the end of short stalks. Because they live in a murky environment at the bottom of the ocean, however, their vision is poor and they rely on their antennae as sensors. The spine-like projection on the front part of a lobster is called the **rostrum.** The **abdomen** is sometimes referred to as the "tail" of the lobster. It includes the **pleopods** or swimming legs, sometimes called swimmerets. The **telson** is the fan-like part at the end of the abdomen.

Lobsters have a simple **brain**, a collection of nerve endings. Its **heart** is a simple nerve-muscle system. The **nerve cord** connects the brain to major muscles and organs of the body. The lobster extracts oxygen from the water with the use of twenty **gills** attached to the base of the legs and to the sides of the body.

In general, lobsters move slowly by walking on the bottom of the seafloor. However, when they are in danger and need to flee, they swim backwards quickly by curling and uncurling their abdomen. A speed of five meters per second has been recorded.

[STAND IN PAGE FOR LOBSTER FOOD WEB VISUAL]

Activity 2: A Lobster's Body

Objectives

Students will identify the different body parts of a lobster, preparatory to relating how changes in the Long Island Sound ecosystem affected lobsters physiologically.

CT Science Content Standard

7.2 Many organisms have specialized organ systems that interact with each other to maintain dynamic internal balance

- Multicellular organisms need specialized structures and systems to perform basic life functions

NSES Content Standards

- Structure and function in living systems
- Diversity and adaptations of organisms

Materials

Student Handouts for Activity 2: Part 1 (a, b, and c): A Lobster's Body (Dorsal, Ventral and Interior Views); Part 2: Lobster Labels, and Part 3: Lobster Word Search.

Procedure

1. Complete a classroom crayfish dissection using the guide provided or have students view the online virtual crayfish dissection located at http://biog-101-104.bio.cornell.edu/BioG101_104/tutorials/animals/crayfish.html

2. Guide students in defining the terms dorsal (from the top), ventral (from the bottom) and interior (inside) and physiology (about the body). Working in pairs, students identify the following lobster physiology terms on the three A Lobster's Body handouts: Dorsal, Ventral and Interior Views: abdomen, antennae, brain, carapace, cephalothorax, crusher claw, cutter claw, eyes, gills, heart, nerve cord, pleopods, rostrum, telson, walking legs. List the lobster physiology terms on the chalkboard or refer students to the handout Lobster Labels. Review the lobster handouts. Then have students complete the handout Lobster Labels by matching up each body part with its description. Answer Key: 1. j, 2. m, 3. n, 4. o, 5. e, 6. g, 7. f, 8. h, 9. d, 10. a, 111 l, 12. k, 13. b, 14. c, 15. i.
3. As a follow up, students complete the word search puzzle of words relating to lobster physiology. Correct using the key below.

N	E	R	V	E	C	O	R	D		C		
							H	C		U		
C	A	R	A	P	A	C	E	R	A	T		
	N					Y	A	U	B	T	B	
	T				E		R	S	D	E	R	
C	E	P	H	A	L	O	T	H	O	R	A	X
	N							E	M	C	I	
	N	O	S	L	E	T		R	E	L	N	
	A						S	C	N	A		
	E		E	T	S	B	O	L		W		
R	O	S	T	R	U	M		A	L			
S	D	O	P	O	E	L	P	W		I		
W	A	L	K	I	N	G	L	E	G	S	G	

Scoring Rubric

Assess students on the basis of the lobster diagrams labeled correctly, the number of correct lobster physiology terms defined using the keys for these activities.

- Almost all lobster parts correctly labeled and terms correctly defined. 3 points
- Most lobster parts correctly labeled and terms correctly defined. 2 points
- Few lobster parts correctly labeled and terms correctly defined. 1 point

Activity 2, Part 1a Student Handout

Lobster Physiology: Dorsal View

Name ________________________________

Directions: Identify the body parts from the list of lobster physiology terms on the lobster dorsal view below.

[LOBSTER DORSAL VIEW VISUAL TO COME HERE]

Activity 2, Part 1b Student Handout

Lobster Physiology: Ventral View

Name ________________________________

Directions: Identify the body parts from the list of lobster physiology terms on the lobster ventral view below.

[LOBSTER VENTRAL VIEW VISUAL TO COME HERE]

Activity 2, Part 1c Student Handout

Lobster Physiology: Interior View

Name ________________________________

Directions: Identify the body parts from the list of lobster physiology terms on the lobster interior view below.

[LOBSTER INTERIOR VIEW VISUAL TO COME HERE]

Activity 2, Part 2 Student Handout: Lobster Labels

Name ___________________________

Directions: Match the names and descriptions below. Write the letter of the description in the space next to each lobster body part.

1. ____ Antennae	a. Organ used for seeing; in the lobster they are moveable, stalked and compound
2. ____ Cephalothorax	b. Bundle of nerves that connects the brain to major muscles and organs of the body
3. ____ Rostrum	c. Swimmerets or swimming legs
4. ____ Abdomen	d. Appendages that allow a lobster to be mobile on the bottom of the ocean floor
5. ____ Carapace	e. The top of the hard exoskeleton, or shell of the lobster
6. ____ Crusher Claw	f. The smaller of the lobster's claws, used in tearing flesh to help feed
7. ____ Cutter Claw	g. The heavier of a lobster's claws, used to crush food.
8. ____ Telson	h. The second segmented section of lobster. A lobster's tail
9. ____ Walking legs	i. Used to extract oxygen from the water
10. ____ Eyes	j. A pair of slender movable organs of touch on the head
11. ____ Brain	k. Simple nerve-muscle system
12. ____ Heart	l. In the lobster, a collection of nerve endings or ganglia
13. ____ Nerve cord	m. Joined head and thorax or upper body segment
14.____ Pleopods	n. Spine-like projection on the front part of a lobster
15. ____ Gills	o. Often called the tail, the second segmented section of a lobster.

Activity 2 Student Handout: Lobster Word Search

Name __________________________

Directions: Circle the following words related to lobster physiology in the puzzle. Words may appear forwards, backwards, up, down and diagonally.

abdomen	crusher claw	nerve cord
antennae	cutter claw	pleopods
brain	eyes	rostrum
carapace	gills	telson
cephalothorax	heart	walking legs

N	E	R	V	E	C	O	R	D	A	C	B	D
A	N	M	K	T	E	R	H	C	L	U	P	O
C	A	R	A	P	A	C	E	R	A	T	Q	W
E	N	R	T	Y	U	Y	A	U	B	T	B	I
J	T	K	L	Z	E	X	R	S	D	E	R	C
C	E	P	H	A	L	O	T	H	O	R	A	X
V	N	B	N	M	W	R	T	E	M	C	I	P
S	N	O	S	L	E	T	W	R	E	L	N	G
H	A	K	J	Y	T	S	S	C	N	A	P	D
L	E	R	E	T	S	B	O	L	I	W	N	P
R	O	S	T	R	U	M	R	A	L	N	I	L
S	D	O	P	O	E	L	P	W	E	I	A	K
W	A	L	K	I	N	G	L	E	G	S	G	S

A Sense of Place: Long Island Sound

Activity 3: Where and What is Long Island Sound?

Objectives

Students will be familiar with the geography of the Sound, will understand that the Sound impacts Connecticut's economy, and will understand that the Sound is an estuary.

Connecticut Science Standards

TO COME

NSES Content Standards

TO COME

Materials

Map showing Connecticut and Long Island Sound

Background

Part of the reason the lobster die-off was chosen as a topic for this unit was its relationship to Connecticut and Long Island Sound. The Sound an important feature of Connecticut's landscape and traditionally has played an important role in CT'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.

More than eight million people live in the Long Island Sound watershed that includes Connecticut, parts of other New England states and New York. The development in this region has increased some types of pollution, altered land surfaces, reduced open spaces, and restricted access to the Sound.

Procedure

1. In order to help give students a sense of place, share the map of Connecticut's coast that shows where the Sound is located. Help them identify the four major rivers that provide freshwater to this estuary ecosystem: the Connecticut, Thames, Housatonic and Quinnipiac. Then help them identify the two connections to the Atlantic Ocean that provide the salt water to the Sound: The Race at the eastern end of the Sound and the East River at the western end.

2. As a whole class activity, have students divide into teams and see which team can come up with the most ways in which Connecticut residents benefit from living on or near the Sound.

3. Ask if students can define the word **estuary**. Guide students in understanding the meaning of estuary: a place where salt water and fresh water meet and mix. Then have them read the Discovery File: Long Island Sound: An Estuary Ecosystem. As an extension activity, you may want to share the Discovery File: How the Sound Came to Be.

Discovery File: An Estuary Ecosystem

Long Island Sound is an ecosystem, that is, a community of organisms that interact with one another and with their environment. The elements of an ecosystem are interdependent – so much so that if one part of the physical environment changes or is destroyed, the entire ecosystem can be affected.

Within a single ecosystem, a number of habitats may exist. A habitat is the place where a plant or animal lives. A habitat provides certain basic needs of any organism including food, oxygen or water, space and shelter. Different habitats found in the Long Island Sound ecosystem include sandy beaches, tidal flats, salt marshes, and intertidal zones.

Long Island Sound is also an estuary – a protected coastal body of water in which salt water from the ocean meets and mixes with fresh water from a river or stream. Long Island Sound is a very large, very complex estuary. It encompasses two sources of salt water from the Atlantic Ocean (the Race at the eastern end of the Sound and the East River at the western end of the Sound) and four major rivers: the Connecticut River, Thames River, Housatonic River and Quinnipiac River, as well as many streams. Long Island Sound contains estuaries within estuaries where each of these rivers or streams enters the larger Sound.

The Sound is located at 41 degrees North latitude, 73 degrees West longitude, is about 110 miles long and 21 miles long at its widest point. Its average depth is 65 feet, although it is 350 feet deep at its deepest point. Long Island Sound is a place of rich biodiversity with many different kinds of plants and animals. The organisms of the Sound must often adapt to significant fluctuations of temperature and salinity (how "salty" the water is).

The salinity of the Sound can vary greatly, depending on the time of year, weather and tides. Ocean saltwater has a salinity of 35 parts per thousand (35 ppt). The average salinity of the Sound is 28 parts per thousand (28 ppt). Where the Quinnipiac River enters New Haven Harbor, the salinity of the surface water can be as low as 15 ppt after a rainstorm. Cold salt water has a higher density than warmer fresher water. This results in thermal stratification, giving the waters of the Sound a unique circulation pattern.

The Sound was formed during the last ice age more than 20,000 years ago. A glacier known as the Laurentide ice sheet nearly a mile thick covered the region, and ground up about 20 meters of surface sediments as it gradually moved south. The area that would become the Sound was a fresh water lake up until about 15,000 to 19,000 years ago. At that time, the level of the sea rose until it met the level of the fresh water. Sea levels continued to rise to the level of the current shoreline and the Sound became the estuary that it is today.

(Adapted from *Long Island Sound in a Jar* by Heather M. Crawford, published by Connecticut Sea Grant, Groton, Connecticut, 1999.

Discovery File: How the Sound Came to Be

The surface of the Earth is made up of series of rigid plates that move. When these plates collid, mountains are formed and oceans disappear; when these plates separate, oceans form and continents split apart. Sometimes the plates just move past each other, triggering earthquakes as they go. A very long time ago, 500 million years in fact, eastern Connecticut and western Connecticut were separated by a portion of the Iapetus Ocean, much like modern-day Japan is separated from the Asian mainland. Over time, plates began to collide and the Iapetus Ocean started to close, bringing the land that now makes up eastern Connecticut into contact with the land that forms modern-day western Connecticut. By the time the Iapetus Ocean was done closing, all of the Earth's continents were arranged into one giant continent called Pangaea (which mean "all one Earth"). This collision formed the Appalachian Mountain chain, which includes the Berkshire Mountains in western Connecticut. The collision took a many thousands of years to happen, but over time, the two sides of the state of Connecticut were pushed into each other. As the rocks were squeezed together, they also heated not enough to melt them, but enough to change them. Geologists call rocks that have changed in response to heat and pressure metamorphic rocks. You can see these metamorphic rocks, such as marble, when you drive along roads in the western and eastern parts of the state of Connecticut.

The supercontinent Pangaea did not stay together very long. In fact, it started to break apart around the time that the dinosaurs started to roam the Earth. This time, about 200 million years ago, is called the Mesozoic Era by geologists. One of the places that Pangaea started to break apart was right in the middle of the state of Connecticut! A rift valley formed as the eastern and western sides of the state started to move away from each other. This valley became filled with water and formed a very large rift lake. The water level in the lake fluctuated – it went up and down over time. Sometimes it was very deep and other times it was shallow enough for dinosaurs to walk in it. The dinosaur footprints found at Dinosaur State Park in Rocky Hill, Connecticut were once on the bottom of this rift lake. The sediments that filled the bottom of this lake eventually formed the black and red sedimentary rocks that can be seen along Interstate 91. As the continents continued to rift apart, lava started to flow into the rift valley, forming the igneous rocks that also can be seen along Interstate 91. The rift valley in Connecticut was not the only rift basin to form as Pangaea broke up. In fact, several formed along the east coast of North America – including one in New Jersey, one in Canada, and one directly to the east of these. This last one eventually opened up faster than all the others and became the Atlantic Ocean. The rest of the rift basins, including the one in the middle of Connecticut, stopped opening and are known as failed rift basins. The bedrock geology of the state of Connecticut consists, then, of rocks recording three different episodes in Earth history – when the Iapetus Ocean existed, when the Iapetus Ocean closed, and when the Atlantic Ocean formed.

One of the last great shaping influences here in Connecticut was the Laurentide Ice Sheet, the most recent **glacier** to come through about 10,000 years ago. This glacier still exists, but you have to travel into Canada to find it. At one time, the glacier covered all of Connecticut, most of Canada, and much of the northern third of the United States. It was several miles thick and weighed many, many tons. Everything under the glacier was under massive pressure. Although a glacier is made from ice and snow, it is not solidly frozen like an ice cube. The pressure melts some of the ice at the bottom of the glacier into a sort of slush, which then flows along the bottom of glacier towards oceans or lakes at the edge of the glacier. This slush carries along anything that is not firmly attached to the ground underneath. So, rock, sticks, trees, and more get carried along by the glacier. As objects are moved along by the slush, they bump into each other, as well as the ground over which the glacier is moving. This bumping and grinding causes softer rocks to crumble when them come into contact with **harder** rocks.

When the Laurentide ice sheet came, many of the softer rocks in Connecticut were crushed and crumbled into sand by the glacier and now make up the soil of Long Island. Long Island was at the very edge of the Laurentide ice sheet in this area of the world. The river valleys in Connecticut collected a rich array of ground up rocks as the glacier melted and the waters flowed through the state into Long Island Sound. The minerals left in those ground up rocks support the rich **diversity of species** found in Connecticut and Long Island Sound today.

Biodiversity and Global Change

Lobster Die-off!

An Event-based Science Unit

Published by the Peabody Fellows Program
Peabody Museum of Natural History, Yale University
New Haven, Connecticut, USA

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Peabody Fellows

Biodiversity and Global Change Program

The Peabody Fellows Biodiversity and Global Change Program aims to improve science teaching and learning among middle and high school teachers and students in Connecticut around the topic of Biodiversity and Global Change. Global change is among the most scientific and societal issues of the 21st century as humans have an increasing impact on the environment. Understanding how global changes affect biological diversity, and vice versa, requires an integrated knowledge of the earth and life sciences. The curriculum unit, "Lobster Die-off!" developed as part of this project studies one of the local effects of worldwide issues such as ocean warming, pollution and invasive species.

Please note this unit is still in draft form. All comments are welcome.

This program is supported by a Museums for America grant

from the Institute of Museum and Library Services,

and the Bay and Paul Foundations.

About Lobsters

Before proceeding to the Investigative Activities, you will want to review and set up Activity 6: A Microbial City. Students will subsequently make observations at the end of each week and record data using the Student Handout for Activity 6.

Activity 1: Lobster Food Web

Objectives

Students will understand where lobsters fit in a Long Island Sound food web.

CT Science Content Standard

6.2 An ecosystem is composed of all the populations that are living in a certain space and the physical factors with which they interact

- Populations in ecosystems are affected by biotic factors, such as other populations, and abiotic factors, such as soil and water supply.

NSES Content Standards

- Populations and ecosystems
- Diversity and adaptations of organisms

Materials

Discovery File: What is a Lobster?

Long Island Sound Study's "Inside a Long Island Sound Food Web"

Procedure

1. Have students read the Discovery File: What is a Lobster? If time allows, have students research more on lobster natural history.
2. Hand out Long Island Sound Study's "Inside a Long Island Sound Food Web": www.longislandsoundstudy.net/soundhealth/Poster_Letter_size.pdf

   Have students draw in a lobster and draw connections to other organisms in the web. Have students write an explanation about where and why connections were made.
3. Discuss connections. Are there any additional plants or animals that should be included?

Scoring rubric

- The student's connections to and from the lobster on the food web are reasonably accurate and titled and labeled properly. The explanation of lobster interrelationships is well written and reasonably accurate. 3 points
- The student's connections to and from the lobster on the food web are partially accurate and titled and labeled properly. The explanation of lobster interrelationships is complete but shows some lack of understanding of concepts and is not written clearly and properly. 2 points
- The student's connections to and from the lobster on the food web are wholly inaccurate and incompletely titled and labeled. The explanation of lobster interrelationships is incomplete and shows significant lack of understanding of concepts or is not written clearly and properly. 1 point

Discovery File: What is a Lobster?

What is a Lobster?

What does a lobster have in common with a grasshopper? Well, more than you might think. It might be hard to believe that lobsters are actually related to insects, but like insects, they belong to the invertebrate phylum Arthropoda. Insects and lobsters are animals that have an exoskeleton (outer skeleton) and jointed legs.

Unlike insects, lobsters belong to the class Crustacea, along with other marine organisms like crabs, crayfish and shrimp. A crustacean is an invertebrate animal with several pairs of jointed legs, a hard protective outer shell, two pairs of antennae, and eyes at the ends of stalks. Because lobsters have ten legs, they belong to the order Decapoda (Latin for ten feet). The American Lobster or true lobster (as opposed to the spiny lobster) is classified as follows: Kingdom: Animalia; Phylum: Arthropoda; Class: Crustacea; Subclass: Malacostraca; Order: Decapoda; Family: Nephropidae; Genus: Homarus; Species: americanus.

Lobsters live on rocky, sandy, or muddy bottoms from the shoreline to beyond the edge of the continental shelf. They generally live singly in crevices or in burrows under rocks. Although many studies have suggested that lobsters are primarily scavengers, that is, animals that consume already dead organic life-forms, recent studies have shown that they primarily feed on live fish, dig for clams, sea urchins, and feed on algae and eel-grass. They occasionally eat other lobsters, too. An average adult lobster is about 230 mm (9 inches) long and weighs 700 to 900 g (1.5 to 2 pounds). Lobsters grow throughout their lives, molting or shedding their exoskeleton or outer body covering as they increase in size.

Like all arthropods, lobsters are largely bilaterally symmetrical, although they have unequal, specialized claws, a **cutter claw** for tearing food and a **crusher claw** for crushing food. The anatomy of the lobster includes the **cephalothorax** which is the head fused with the upper body, both of which are covered by the **carapace**, or shell. The **walking legs** of the lobster extend from the cephalothorax. Lobsters have two **antennae** on their heads that serve as sensory organs. Lobsters have compound **eyes** at the end of short stalks. Because they live in a murky environment at the bottom of the ocean, however, their vision is poor and they rely on their antennae as sensors. The spine-like projection on the front part of a lobster is called the **rostrum.** The **abdomen** is sometimes referred to as the "tail" of the lobster. It includes the **pleopods** or swimming legs, sometimes called swimmerets. The **telson** is the fan-like part at the end of the abdomen.

Lobsters have a simple **brain**, a collection of nerve endings. Its **heart** is a simple nerve-muscle system. The **nerve cord** connects the brain to major muscles and organs of the body. The lobster extracts oxygen from the water with the use of twenty **gills** attached to the base of the legs and to the sides of the body.

In general, lobsters move slowly by walking on the bottom of the seafloor. However, when they are in danger and need to flee, they swim backwards quickly by curling and uncurling their abdomen. A speed of five meters per second has been recorded.

[STAND IN PAGE FOR LOBSTER FOOD WEB VISUAL]

Activity 2: A Lobster's Body

Objectives

Students will identify the different body parts of a lobster, preparatory to relating how changes in the Long Island Sound ecosystem affected lobsters physiologically.

CT Science Content Standard

7.2 Many organisms have specialized organ systems that interact with each other to maintain dynamic internal balance

- Multicellular organisms need specialized structures and systems to perform basic life functions

NSES Content Standards

- Structure and function in living systems
- Diversity and adaptations of organisms

Materials

Student Handouts for Activity 2: Part 1 (a, b, and c): A Lobster's Body (Dorsal, Ventral and Interior Views); Part 2: Lobster Labels, and Part 3: Lobster Word Search.

Procedure

1. Complete a classroom crayfish dissection using the guide provided or have students view the online virtual crayfish dissection located at http://biog-101-104.bio.cornell.edu/BioG101_104/tutorials/animals/crayfish.html

2. Guide students in defining the terms dorsal (from the top), ventral (from the bottom) and interior (inside) and physiology (about the body). Working in pairs, students identify the following lobster physiology terms on the three A Lobster's Body handouts: Dorsal, Ventral and Interior Views: abdomen, antennae, brain, carapace, cephalothorax, crusher claw, cutter claw, eyes, gills, heart, nerve cord, pleopods, rostrum, telson, walking legs. List the lobster physiology terms on the chalkboard or refer students to the handout Lobster Labels. Review the lobster handouts. Then have students complete the handout Lobster Labels by matching up each body part with its description. Answer Key: 1. j, 2. m, 3. n, 4. o, 5. e, 6. g, 7. f, 8. h, 9. d, 10. a, 11. l, 12. k, 13. b, 14. c, 15. i.
3. As a follow up, students complete the word search puzzle of words relating to lobster physiology. Correct using the key below.

N	E	R	V	E	C	O	R	D		C		
							H	C		U		
C	A	R	A	P	A	C	E	R	A	T		
	N					Y	A	U	B	T	B	
	T				E		R	S	D	E	R	
C	E	P	H	A	L	O	T	H	O	R	A	X
	N							E	M	C	I	
	N	O	S	L	E	T		R	E	L	N	
	A			Y			S	C	N	A		
	E		E	T	S	B	O	L		W		
R	O	S	T	R	U	M		A	L			
S	D	O	P	O	E	L	P	W		I		
W	A	L	K	I	N	G	L	E	G	S	G	

Scoring Rubric

Assess students on the basis of the lobster diagrams labeled correctly, the number of correct lobster physiology terms defined using the keys for these activities.

- Almost all lobster parts correctly labeled and terms correctly defined. 3 points
- Most lobster parts correctly labeled and terms correctly defined. 2 points
- Few lobster parts correctly labeled and terms correctly defined. 1 point

Activity 2, Part 1a Student Handout

Lobster Physiology: Dorsal View

Name ________________________________

Directions: Identify the body parts from the list of lobster physiology terms on the lobster dorsal view below.

[LOBSTER DORSAL VIEW VISUAL TO COME HERE]

Activity 2, Part 1b Student Handout

Lobster Physiology: Ventral View

Name ________________________________

Directions: Identify the body parts from the list of lobster physiology terms on the lobster ventral view below.

[LOBSTER VENTRAL VIEW VISUAL TO COME HERE]

Activity 2, Part 1c Student Handout

Lobster Physiology: Interior View

Name ________________________________

Directions: Identify the body parts from the list of lobster physiology terms on the lobster interior view below.

[LOBSTER INTERIOR VIEW VISUAL TO COME HERE]

Activity 2, Part 2 Student Handout: Lobster Labels

Name ___________________________

Directions: Match the names and descriptions below. Write the letter of the description in the space next to each lobster body part.

1. ____ Antennae	a. Organ used for seeing; in the lobster they are moveable, stalked and compound
2. ____ Cephalothorax	b. Bundle of nerves that connects the brain to major muscles and organs of the body
3. ____ Rostrum	c. Swimmerets or swimming legs
4. ____ Abdomen	d. Appendages that allow a lobster to be mobile on the bottom of the ocean floor
5. ____ Carapace	e. The top of the hard exoskeleton, or shell of the lobster
6. ____ Crusher Claw	f. The smaller of the lobster's claws, used in tearing flesh to help feed
7. ____ Cutter Claw	g. The heavier of a lobster's claws, used to crush food
8. ____ Telson	h. The second segmented section of lobster. A lobster's tail
9. ____ Walking legs	i. Used to extract oxygen from the water
10. ____ Eyes	j. A pair of slender movable organs of touch on the head
11. ____ Brain	k. Simple nerve-muscle system
12. ____ Heart	l. In the lobster, a collection of nerve endings or ganglia
13. ____ Nerve cord	m. Joined head and thorax or upper body segment
14.____ Pleopods	n. Spine-like projection on the front part of a lobster
15. ____ Gills	o. Often called the tail, the second segmented section of a lobster

Activity 2 Student Handout: Lobster Word Search

Name ___________________________

Directions: Circle the following words related to lobster physiology in the puzzle. Words may appear forwards, backwards, up, down and diagonally.

abdomen
antennae
brain
carapace
cephalothorax
crusher claw
cutter claw
eyes
gills
heart
nerve cord
pleopods
rostrum
telson
walking legs

N	E	R	V	E	C	O	R	D	A	C	B	D
A	N	M	K	T	E	R	H	C	L	U	P	O
C	A	R	A	P	A	C	E	R	A	T	Q	W
E	N	R	T	Y	U	Y	A	U	B	T	B	I
J	T	K	L	Z	E	X	R	S	D	E	R	C
C	E	P	H	A	L	O	T	H	O	R	A	X
V	N	B	N	M	W	R	T	E	M	C	I	P
S	N	O	S	L	E	T	W	R	E	L	N	G
H	A	K	J	Y	T	S	S	C	N	A	P	D
L	E	R	E	T	S	B	O	L	I	W	N	P
R	O	S	T	R	U	M	R	A	L	N	I	L
S	D	O	P	O	E	L	P	W	E	I	A	K
W	A	L	K	I	N	G	L	E	G	S	G	S

A Sense of Place: Long Island Sound

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Objectives

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Connecticut Science Standards

TO COME

NSES Content Standards

TO COME

Materials

Map showing Connecticut and Long Island Sound

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Procedure

1. To help give students a sense of place, share the map of Connecticut's coast that shows where the Sound is located. Help them identify the four major rivers that provide freshwater to this estuary ecosystem: the Connecticut, Thames, Housatonic and Quinnipiac. Then help them identify the two connections to the Atlantic Ocean that provide the salt water to the Sound: The Race at the eastern end of the Sound and the East River at the western end.
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Discovery File: Long Island Sound: An Estuary Ecosystem

Long Island Sound is an ecosystem, that is, a community of organisms that interact with one another and with their environment. The elements of an ecosystem are interdependent – so much so that if one part of the physical environment changes or is destroyed, the entire ecosystem can be affected.

Within a single ecosystem, a number of habitats may exist. A habitat is the place where a plant or animal lives. A habitat provides certain basic needs of any organism including food, oxygen or water, space and shelter. Different habitats found in the Long Island Sound ecosystem include sandy beaches, tidal flats, salt marshes, and intertidal zones.

Long Island Sound is also an estuary – a protected coastal body of water in which salt water from the ocean meets and mixes with fresh water from a river or stream. Long Island Sound is a very large, very complex estuary. It encompasses two sources of salt water from the Atlantic Ocean (the Race at the eastern end of the Sound and the East River at the western end of the Sound) and four major rivers: the Connecticut River, Thames River, Housatonic River and Quinnipiac River, as well as many streams. Long Island Sound contains estuaries within estuaries where each of these rivers or streams enters the larger Sound.

The Sound is located at 41 degrees North latitude, 73 degrees West longitude, is about 110 miles long and 21 miles long at its widest point. Its average depth is 65 feet, although it is 350 feet deep at its deepest point. Long Island Sound is a place of rich biodiversity with many different kinds of plants and animals. The organisms of the Sound must often adapt to significant fluctuations of temperature and salinity (how “salty” the water is).

The salinity of the Sound can vary greatly, depending on the time of year, weather and tides. Ocean saltwater has a salinity of 35 parts per thousand (35 ppt). The average salinity of the Sound is 28 parts per thousand (28 ppt). Where the Quinnipiac River enters New Haven Harbor, the salinity of the surface water can be as low as 15 ppt after a rainstorm. Cold salt water has a higher density than warmer fresher water. This results in thermal stratification, giving the waters of the Sound a unique circulation pattern.

The Sound was formed during the last ice age more than 20,000 years ago. A glacier known as the Laurentide ice sheet nearly a mile thick covered the region, and ground up about 20 meters of surface sediments as it gradually moved south. The area that would become the Sound was a fresh water lake up until about 15,000 to 19,000 years ago. At that time, the level of the sea rose until it met the level of the fresh water. Sea levels continued to rise to the level of the current shoreline and the Sound became the estuary that it is today.

(Adapted from *Long Island Sound in a Jar* by Heather M. Crawford, published by Connecticut Sea Grant, Groton, Connecticut, 1999.)

Discovery File: How the Sound Came to Be

A long time ago, eastern Connecticut and western Connecticut were separated by a small sea. Then, the ground began to move; the two shores of the sea began to come closer together. This happened, slowly, over thousands of years, but eventually the two halves of the state met and started grinding against each other. This grinding created lots of **pressure** and **friction** that heated up the rocks in the ground. If you push the palms of your hands together and try to twist them, you can get an idea of what the rocks were going through. Well, the rocks got really hot, not hot enough to melt, but they just sort of cooked. When the grinding stopped the rocks did not look exactly like they did before; they had **metamorphosed**, forming **metamorphic rock**. The marble that is sometimes found in the northwest corner of the state is another example of metamorphic rock.

When pieces of land move, and there are lots of pieces of land moving still today, we call the process **plate tectonics**. When two plates move in different directions, the land on the two plates moves too. Think about what happens to a book lying across the edges of two tables when one of the tables moves. This is what happens to the land over a tectonic boundary. Two major events happen along these **boundaries** between the plates, **earthquakes** and **volcanoes**. Can you think of anyplace where there has been a recent earthquake or volcano? As the eastern and western halves of Connecticut met, volcanoes erupted along the meeting place. The molten rock oozing out of the volcanoes cooled to form **igneous rock**. The trap rock found from Meriden and Southington south to the coast is a legacy of this geological period.

One of the last great shaping influences here in Connecticut was the Laurentide ice sheet, the most recent **glacier** to come through about 10,000 years ago. This glacier still exists, but you have to travel into Canada to find it. At one time, the glacier covered all of Connecticut, most of Canada, and much of the northern third of the United States. It was several miles thick and weighed many, many tons. Everything under the glacier was under massive pressure. Although a glacier is made from ice and snow, it is not solidly frozen like an ice cube. The pressure melts some of the ice at the bottom of the glacier into a sort of slush, which then flows along the bottom of glacier towards oceans or lakes at the edge of the glacier. This slush carries along anything that is not firmly attached to the ground underneath. So, rock, sticks, trees, and more get carried along by the glacier. As objects are moved along by the slush, they bump into each other, as well as the ground over which the glacier is moving. This bumping and grinding causes softer rock to crumble when they come into contact with **harder** rocks.

When the Laurentide ice sheet came, many of the softer rocks in Connecticut were crushed and crumbled into sand by the glacier and now make up the soil of Long Island. Long Island was at the very edge of the Laurentide ice sheet in this area of the world. The river valleys in Connecticut collected a rich array of ground up rocks as the glacier melted and the waters flowed through the state into Long Island Sound. The minerals left in those ground up rocks support the rich **diversity of species** found in Connecticut and Long Island Sound today.

Biodiversity and Global Change

Lobster Die-off!

An Event-based Science Unit

Published by the Peabody Fellows Program
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Peabody Fellows

Biodiversity and Global Change Program

The Peabody Fellows Biodiversity and Global Change Program aims to improve science teaching and learning among middle and high school teachers and students in Connecticut around the topic of Biodiversity and Global Change. Global change is among the most scientific and societal issues of the 21st century as humans have an increasing impact on the environment. Understanding how global changes affect biological diversity, and vice versa, requires an integrated knowledge of the earth and life sciences. The curriculum unit, "Lobster Die-off!" developed as part of this project studies one of the local effects of worldwide issues such as ocean warming, pollution and invasive species.

Please note this unit is still in draft form. All comments are welcome.

This program is supported by a Museums for America grant
from the Institute of Museum and Library Services,
and the Bay and Paul Foundations.

Activity 4: Temperature Tracking

Objective

To investigate how water temperature differences can create a current.

Background

The warming effects of the sun directly affect the surface of the ocean. Where the sun's rays are more direct, the temperatures of the water may be warmer. Where the sun's rays are less direct, the ocean temperatures will be colder. As the upper layers of the water are warmed or cooled, the layers may develop different water temperatures than layers of water below. A sharp change in temperature between layers is called a thermocline. The density of the water is affected by temperature. As the density of water at the surfaces increases, it sinks beneath the less dense water below it. Some of the major deep water currents in the world's oceans are generated by changes in density.

CT Science Content Standard

5.1 Sound and light are forms of energy.

- Describe how light is absorbed and/or reflected by different surfaces.

9.1 Energy cannot be created or destroyed; however, energy can be converted from one form to another.

- Energy is transferred by conduction, convection and radiation.

NSES Content Standards

- Properties and changes in matter
- Motions and forces
- Transfer of energy

Part 1

Materials

Clear plastic box

3 Celsius thermometers

Tape

Several ice cubes made with uncolored water

Several ice cubes made with colored water

Watch with a second hand

Procedure

1. Have students read the Discovery Files related to Long Island Sound and Biodiversity: Long Island Sound Habitat Changes, Alien Invaders, Climate, and Wind and Water.
2. Have students conduct an experiment to demonstrate how water temperature differences can create a current. Take a clear plastic box and attach the three thermometers with tape to the inside of the box as shown in Figure 1. The thermometers will be positioned in three different places: at the top, middle and bottom of the box.

[FIG 1 TO COME HERE]

3. Fill the box with warm tap water so that all the bulbs of the thermometer are covered by water. Distribute the Activity 4 handout: Temperature Data Sheet. Set up a data sheet as shown in Figure 2. Record the three thermometer readings in the start row. Use the watch to time the intervals. Call out each interval. Have students record the three thermometer readings for each interval as it occurs.
4. Students add several uncolored ice cubes to the water at the left end of the box. Which thermometer do they predict will become cold first?
5. Students read the thermometers every 15 seconds after the ice cubes are in place. Have them record these readings and stop when the readings on the three thermometers change.
6. Did students' predictions in Step 4 prove to be correct? Students develop a hypothesis to explain the results of the experiment.
7. Students add several colored ice cubes to the water at the left end of the box. Observe the plastic box from the side. Do students' observations support the hypothesis? Where is the thermocline?
8. Students create a graph that shows the movement of the colored water. Have students determine what conclusions may be drawn from their graphs. Guide students in answering such questions as:
    a. What can you conclude about the temperature of water at different layers of the ocean?
    b. How do these different temperature layers seem to move?
    c. What would happen to the movement of water if somehow the temperature layers were reversed?
    d. Could this have an impact on the living things that inhabit the ocean?

Part 2

Materials:

1 Large wide-mouth glass jar,

1 Small, long-shaped jar

Strong string

Warm water

Cold water

Food coloring

FIG 2 TO COME HERE

Procedure:

1. Fill the large jar with cold water.
2. Tie a string around the neck of the smaller jar.
3. Fill the small jar with very warm water and put in a few drops of a vivid food coloring to color this water.

4. Students predict what will happen.
5. Place the small jar into the larger jar and observe the movement of warm water. Students answer the following: How does the warm and cold water move? What would happen if you put warm water in the larger jar and cold water in the smaller jar? Which way would the cold water move?

Scoring Rubric

The observation of students as they conduct the experiment, and then a formal evaluation of the quality of their explanation of the cause of ocean currents, will result in both individual and group assessment of this activity.

- Explanation is neat, well-written and contains logical information supported by a diagram. 2 points
- Explanation fails in one aspect but is otherwise complete. 1 point
- Explanation is incomplete. 0 points

Activity 4 Student Handout

Temperature Data Sheet

Time (sec.)	Top Thermometer reading (C)	Middle Thermometer Reading (C)	Bottom Thermometer Reading (C)
Start			
15			
30			
45			
60			
75			
90			

Discovery File: Long Island Sound Habitat Changes

A habitat is the place where an organism lives. All habitats provide food, oxygen/water, space and shelter. The habitat of a deer is the woods. The habitat of a butterfly is a meadow or area where the nectar plants on which it feeds are found. When an organism's habitat changes, the organism must adapt or die. Lobsters inhabit shallow water along the sea floor. Up until recently, Long Island Sound provided excellent habitat for the American lobster. We often think of habitat destruction as a physical loss such as the cutting down of trees. In the case of an organism that inhabits salt water, habitat loss can mean simply the changing or alteration of the habitat in such a way that it can no longer support a kind of organism. Consider the changes to Long Island Sound described below that are believed to have contributed to the lobster die-off.

I. Oxygen levels and hypoxia

Oxygen is dissolved in sea water. We breathe oxygen when we take in air using our lungs. Lobsters and other sea creatures breathe oxygen when they take in water through their gills. Since the 1970s, the amount of oxygen in the waters of western Long Island Sound has been dropping to a level that is stressful to lobsters. This reduction in oxygen is called hypoxia ("hypo" is Greek for "under" or "beneath" and "oxia" meaning "oxygen.") The reasons for this reduction are an increase in nutrients such as nitrogen flowing into Long Island Sound from sewage and fertilizers. When the Long Island Sound watershed becomes more developed, there is more pavement and more fertilizers used on lawns. More pavement causes more water with fertilizers (nutrients) to flow into Long Island Sound. Sometimes during a big rainstorm, sewage treatment plants will release untreated sewage. Once in the Sound, these extra nutrients cause more algae to grow. When they die, bacteria break them down and use oxygen in the process, causing dissolved oxygen, or oxygen in the water, to go down.

II. Sulfide and Ammonia

When bottom sediments (sea floor soils) do not receive sufficient oxygen, a different type of bacteria (anerobic – literally "without oxygen") takes over and releases increased amounts of sulfide and ammonia compounds. These compounds make lobsters sluggish.

III. Temperature

Lobsters prefer temperatures below 20.5 degrees Celsius. The summer temperature of sea floor waters in Long Island Sound has been rising since the 1970s, creating a condition that is stressful to lobsters. This also causes an increase in thermal stratification, which makes the problem of decreased oxygen even more severe.

IV. *Neoparamoeba paraquedensis*

An increase in this parasite created an additional stress on lobster populations. The parasite is one of forty lobster parasites found naturally in the Sound. Scientists believe that *Neoparamoeba paraquedensis* can become more dangerous to lobsters and also reproduce more quickly when conditions favor it.

Discovery File: Alien Invaders

Long Island Sound is an environment forever vulnerable to change. Over the past decade, more than 100 alien species of plants and animals have been introduced into the Sound environment. The non-native species have taken up residence in nearly every ecological niche and are now comfortably settled in and competing for resources with the local residents.

Animals and plants are introduced from all parts of the globe, tagging along on the outside of ships, in ballast tanks, blown along on stray water currents or even intentionally introduced for reason long since forgotten.

These organisms have a potential to become invasive species. An invasive species is an organism that is "non-native" (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

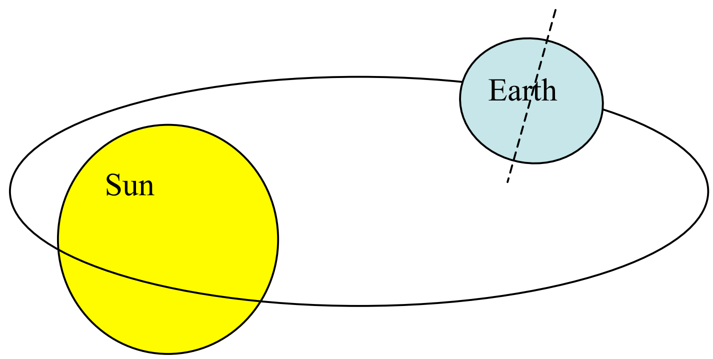
These new organisms cause problems for the existing organisms, compromising all areas of the Sound. All species, including endangered species are compromised by these introduced species. Introduced species may be eating native species, their food, destroying their habitat and or taking their place within the habitat. This process changes the habitat and puts pressures on native species that may not be adapted to compete with the new arrivals.

In the early months of the lobster die-off, it was thought that invasive organisms might be playing a role. But scientists soon discounted that possibility. For more information, see: www.invasivespecies.gov and www.nemw.org/biopollute.htm. Also see *Galapagos Islands: Nature's Delicate Balance at Risk* by Linda Tagliaferro, and published by Lerner Publishing, 2001; and *Food Chains* by Alvin Silverstein, Virginia Silverstein, and Laura Silverstein Nunn, published by Twenty-First Century Books/Millbrook Press, 1998.

Discovery File: Climate

Climate is a description of the temperature and weather found in a particular location. The climate of a particular location is determined by several factors including the sun, local geography and local bodies of water.

The most important factor in climate is the sun, specifically, the way that the sun and the Earth interact. The Earth rotates on its **axis** once every day. This **rotation** is what causes the differences in sunlight between night and day. Even as the Earth is rotating, it is also revolving around the sun. A full **revolution** takes one year to complete. As the Earth is rotating, it is doing so on a slightly tilted axis. The axis is tilted at about 23 degrees off center. This tilt, combined with the revolution, causes the seasons to change. Between the **vernal equinox** in the spring and the **autumnal** equinox in the fall, the northern **hemisphere** is pointing toward the sun. During the other half of the year, the southern hemisphere is pointing toward the sun. When do you think Australia, located in the southern hemisphere, experiences summer? The higher the **latitude**, the more drastic the temperature changes are between the seasons. Here in Connecticut, we are about half way from the **equator** to the North Pole, so we have significant temperature change between summer and winter.



After latitude the next most influential factor in determining climate is the water in the area. Water and land trap and release **heat** at different rates. Water heats and cools much more slowly than land. To prove this you can do a simple experiment. Put a thermometer in a glass of water and another one in a pile of soil. Which thermometer heats up faster? Look at a map, Rome, Italy and New York City, USA are both at about the same latitude. Italy is surrounded on three sides by the Mediterranean Sea; New York City only has water on one side. Which city do you think has the more moderate climate?

Finally, geography plays a part in local climate as well. An area at a higher **altitude** is going to have a cooler climate than one at sea level. For example, there is a glacier at the top of Mt. Kilimanjaro in the middle of Africa, an otherwise very hot place. However, geography plays a bigger role than simply changing altitude; mountains and glaciers can interrupt wind patterns.

Discovery File: Wind and Water

Wind and water **circulate** around the globe carrying heat and **nutrients** from one location to another. As you know, the Earth is rotating. The Earth is rotating faster than the atmosphere around it, which causes the basic prevailing West to East wind patterns. You can think of this wind as being sort of like the wind that hits your face when you go on a roller coaster ride. You are moving, but the atmosphere around you is not. The prevailing winds are not the only type of air movement, though.

There is another type of air movement caused by **thermal expansion**. This air movement causes air to move between the poles and the equator. When the sun shines on the Earth, it always reaches the equator, so the equator is always hot. The sun also reaches other latitudes, but the sunlight at higher latitudes is not as direct as at the equator. That is, because higher latitudes receive less direct sunlight, the air there is not as hot. Because it gets more heat, the air at the equator expands. When the air expands, every molecule takes up more space than it did before. As the hot air expands, it pushes other air out of the way. It cannot push down, the ground is too hard; it has to push up. So hot air will rise. When the extra air moves into the upper atmosphere, it joins other air that was already there, causing the pressure to rise. At the poles, there is less direct sunlight, so the air there does not absorb as much heat as the air at the equator. As a result of the ice at the poles and the smaller amounts of direct sunlight at the poles, the air there does not expand, so it does not cause high pressure in the upper atmosphere. So, at the poles, there is high pressure at the ground level and low pressure in the upper atmosphere. At the equator it is just the opposite; there is low pressure at the ground level and higher pressure in the upper atmosphere. Have you ever seen what happens at a doorway when the door is opened for recess? Lots of kids are all together in the hallway and everybody wants to go outside where there is lots of room. Air is like that, too. In places that have high pressure, like the upper atmosphere over the equator, the air moves to some place with more room, like the upper atmosphere over the poles. What do you think air at ground level does?

All of this air movement causes the climate in a particular place to have hot or cold, wet or dry winds. Cold, wet winds bring rain and snow. Hot dry winds absorb moisture and dry out the land. As an example, look at the Cascade Mountains on the west coast of the United States. The prevailing wind comes off the Pacific Ocean, so it is very wet. When the air hits the mountain, it must go up because it can't turn around. As the air moves up, it cools. Cold air holds less water than hot air, so it rains. By the time the air get over the mountain, it has very little water left in it, so the land on the Eastern side of the Cascade Mountains is much drier than the land on the Western side of the mountains. Where does your rain come from?

Water movement on Earth is very similar to air movement. Water at the equators absorbs more direct sunlight than water at the poles. Furthermore, water at the poles is covered by white ice. Which do you think absorbs more heat, dark water or white ice? Since water, like air, expands when it is heated, the warmer water pushes on the cooler water causing a pattern of currents like the Gulf Stream. Where does the Gulf Stream flow?

Every substance contains energy from the movement of its particles called thermal energy. The higher the temperature of a substance, the greater is its thermal energy. The direction of energy transfer is always from a warmer thing to a neighboring cooler thing. Water tends to move from areas of warm water to areas of cold water.

The oceans and their marine life are affected by annual variations of temperature and solar radiation. Seasonal changes take place first in the upper layers because it is here that solar radiation is absorbed and heat is exchanged with the atmosphere. Deeper waters are affected later.

Activity 5: Temperature and Biodiversity

Objective

To understand the relationship between bottom water temperature and lobster health.

CT Science Content Standards

TO COME

NSES Content Standards

TO COME

Procedure

1. Explain that lobsters prefer colder water. When the water gets warmer 20.5 degrees Celsius (69 F), lobsters are stressed. They will move to colder water, if they can. This is not so easily done in a contained body of water such as Long Island Sound. If unable to get to colder water, lobsters suffer not only from the warmer water, but also from the changes that occur to the water near the bottom. More decomposition occurs, releasing more unhealthy chemicals into their surroundings. Some parasites, such as the lobster neoparamoeba, can become more numerous in warmer water.
2. Working in teams of 2-3, have students decide on a way to graph two sets of data: the Mean Bottom Water Temperature of Long Island Sound from 1993--2003, and Lobster Landings (number of lobsters caught) from 1993–2003. They can use an x-y graph, blocks, columns or other visual aids to plot the two sets of data.

3. Have students write brief explanation of the trends observed answering the following questions:
   a. In what year did the lobster landings drop the most?
   b. What relationship do you see between the drop in lobster landings and water temperature?
   c. How might you explain what happened to the lobsters in this time?
   d. What do you think causes the water temperature to go up in the bottom of Long Island Sound?
   e. What other information would you like to have about lobsters and their environment to help you understand what they need to survive?

4. Have students read the Discovery Files: Greenhouse Effect and About Climate Change.

Scoring Rubric

- The student's graph of lobster landings and temperature trends is reasonably accurate and titled and labeled properly. The explanation of the graph is well written and addresses all required topics completely and accurately. 3 points
- The student's graph of lobster landings and temperature trends is partially accurate or incompletely titled and labeled. The explanation of the graph is complete but shows some lack of understanding of concepts and is not written clearly and properly. 2 points
- The student's graph of lobster landings and temperature trends is wholly inaccurate and incompletely titled and labeled. The explanation of the

graph is incomplete and shows significant lack of understanding of concepts or is not written clearly and properly. 1 point

Activity 5 Student Handout Temperature and Biodiversity

Data Tables

Mean Bottom Water Temperature of Western Long Island Sound from 1993 – 2003

Year	Temperature (C)
1993	20.3
1994	19.2
1995	19.6
1996	18.9
1997	18.9
1998	19.2
1999	20.3
2000	19.9
2001	20.2
2002	20.6
2003	19.3

Lobster Landings from 1993–2003

Year	Lobster Landings (mean catch per tow)
1993	11.6
1994	10.0
1995	8.0
1996	10.0
1997	19.8
1998	10.3
1999	11.3
2000	6.8
2001	4.2
2002	2.7
2003	4.1

Discovery File: Greenhouse Effect

Have you ever seen vendors selling roses around Valentine's Day? In February, here in Connecticut, my rose bushes are all covered in snow and certainly are not blooming. So, where do all of those roses come from? Today, most of those roses are flown in by airplane from warm places in Central America, but some are still grown in a big glass building called a greenhouse. In a greenhouse, sunlight comes in through the glass and turns into heat. The heat cannot escape back through the glass very well, so the whole building stays warm all winter. Here on planet Earth, the gases in our atmosphere act like the glass of a greenhouse. Sunlight comes in through our atmosphere and turns into heat, but it has trouble escaping back into space. Our atmosphere has been trapping heat in this way from very early in the Earth's history, but now it is trapping more heat than it used to. Some gases, like carbon dioxide and methane, are better at trapping heat than others. These gases are called greenhouse gases. Some greenhouse gases are created naturally. For example, volcanic eruptions and feeding cows both emit greenhouse gases, but, recently, scientists have noticed that human activities, like burning gasoline in a car's engine, produce much more greenhouse gas than natural activities do. More greenhouse gas means that more heat is trapped on Earth. What do you think more heat will do to the temperature on Earth?

As you might have guessed, the temperatures on Earth, all over the Earth, have been increasing quite a lot in the past hundred years. Now this might seem cool; after all, who doesn't like summer? But, consider the lobster. Lobsters need cool water to survive. As the temperature on Earth gets hotter, the water temperatures get hotter, too. Lobsters need cool water to live, so what happens to lobsters as their habitat changes and the water grows warmer?

Discovery File: About Climate Change

The Earth's average temperature has changed a great deal over the past 10,000 years because of natural causes. During the past 100 years, however, average global air temperature has increased sharply. A major part of the increase is the result of greenhouse gases released as a result of human activities.

Carbon dioxide is the most abundant and important greenhouse gas. It plays an important role in keeping the earth's temperature stabile. Fossil fuels, including coal, oil and natural gas, are largely made up of carbon. Carbon is an essential building block for life on earth and for our climate. In different forms it cycles through our atmosphere, biosphere, lithosphere and oceans. 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. Trees take in carbon dioxide, so the massive destruction of trees results in more carbon dioxide being released into and remaining in the atmosphere.

Climate change is taking place at a much more rapid rate than at any other time in earth's history. Rapid climate change is altering ecosystems and the species that live in them. Some effects of rapid climate change include droughts, floods and storms, all of which can lead to human problems of disease, death, displacement and hunger. Even small changes in the global temperature can effect big changes in the climate.

(Adapted from *The Climate Change Backpack Presenter's Guide*, published by the New England Science Center Collaborative, Mary Lou Krambeer, Coordinator, Bethlehem, NH: 2003.)

Activity 6: A Microbial City

Objective

Using the column device of the 19th century microbiologist Sergei Winogradsky, students will create a skyscraper of mud, teeming with ancient microbes that are still dominating the earth today. Through manipulation, observation, recording, and discussion, students will understand the following concepts:

1. The Winogradsky column resembles flooded environments on earth. Its cities are essentially raised core samples of soil displaying what lives in its different layers and regions.

2. Various microorganisms live at different levels due to unique environmental conditions, and they have been dominating the earth for over 3 billion years.

3. There exists in the columns a downward oxygen gradient and an upward hydrogen sulfide gradient. Species of bacteria that use hydrogen sulfide and are sensitive to oxygen grow near the bottom of the column.

4. The colorful areas represent photosynthetic bacteria—observable without a microscope! The microbes are using different wavelengths of light to make their food.

CT Science Content Standards

5.2 Perceiving and responding to information about the environment is critical to the survival of organisms.

- Describe how light absorption and reflection allow one to see the shapes and colors of objects.

6.4 Water moving across and through earth materials carries with it the products of human activities.

- Explain how human activity may impact water resources in Connecticut, such as ponds, rivers and the Long Island Sound ecosystem.

9.8 The use of resources by human populations may affect the quality of the environment.

- The accumulation of mercury, phosphates and nitrates affects the quality of water and the organisms that live in rivers, lakes and oceans.

NSES Content Standards

- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms
- Structure of the earth system

Background

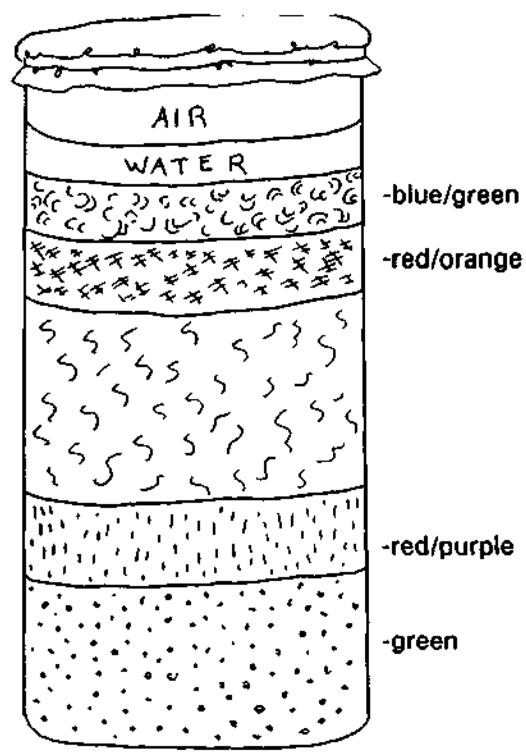
The Winogradsky column "city" that students will create bears some striking similarities to Earth: the energy source is the same size as ours; it possesses oxygen in its atmosphere; it is composed of soil and mud. And, like the earth, these factors support a diverse and extraordinary array of life. One difference is that the surface of our cylindrical "planet" is completely flat and flooded by a thin film of water.

The city consists of translucent column "buildings" populated by microbial life forms living in soil and water. These are the same life forms that exist in flooded environments on our own planet earth— pond bottoms, salt marshes, and flooded agricultural fields like rice paddies.

The "planet" at first appears lifeless, but with an influx of energy and some simple management, the cities and its spectacular microcreatures can be seen!

On the right is a picture of what one building in the Winogradsky "city" looks like.

The life forms pictured are bacteria. Students will discover that there are many different types of bacteria. Through the Winogradsky "cities," they can see that the bacteria look different and that they live in different places.



Environmental Factors in the City

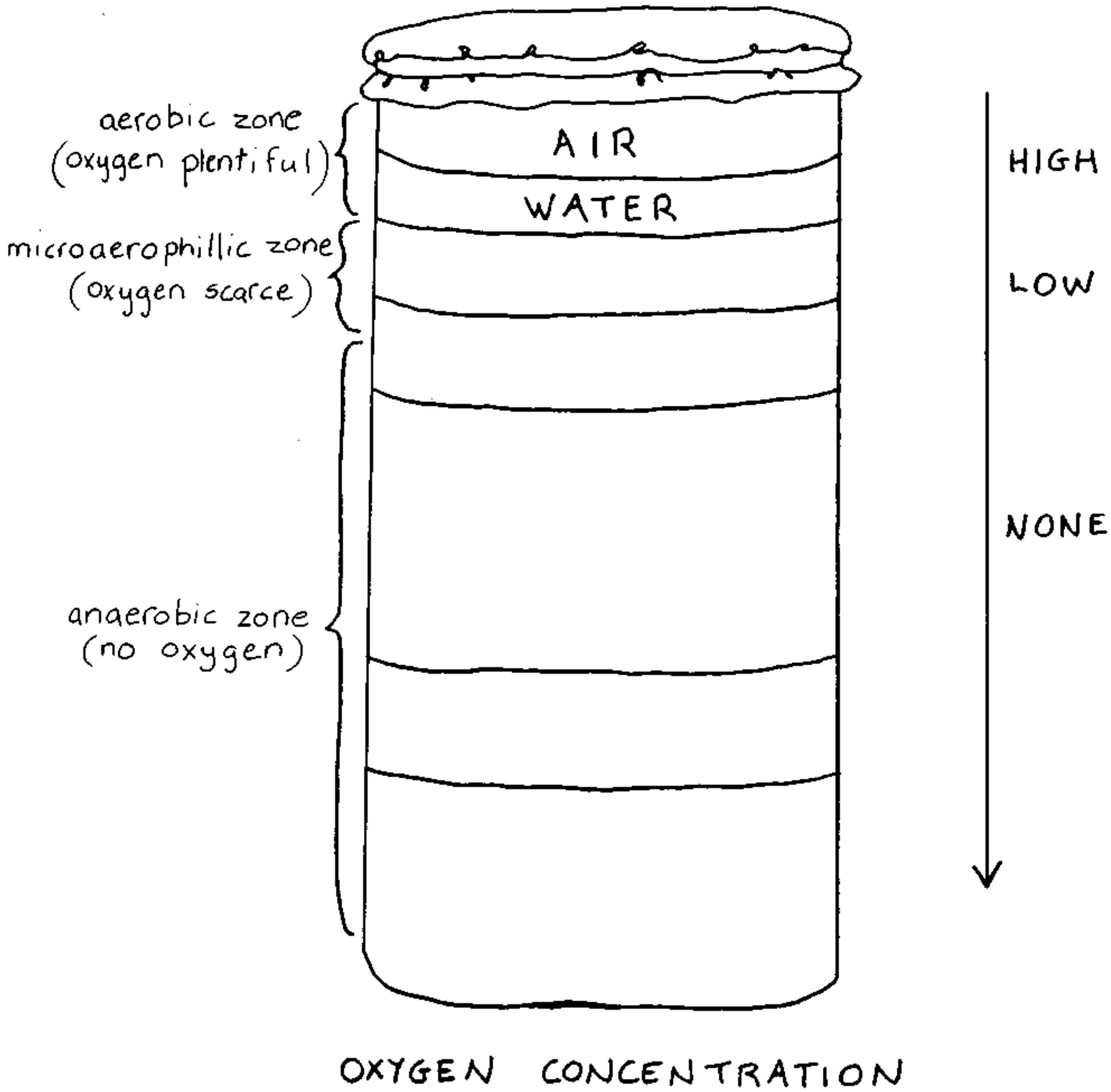
The bacteria in the Winogradsky column live at different levels in the buildings because the environmental conditions at each level are unique. The following elements help determine at which level or area specific bacteria within the city live.

The amount of oxygen present is a major determinant of microbial populations and their place in the column. Oxygen dissolves into water from air at the top of the buildings. As we go deeper down the skyscraper to the lower levels, the amount of oxygen decreases. We can even think of going downward in the building as going back in time! For many millions of years in Earth's early history, there was no oxygen in the atmosphere. The upper green level evolved more recently, and was responsible for producing the oxygen in Earth's atmosphere before algae and plants existed.

Most of the organisms with which you are most familiar require oxygen to live. Some live in the water at the top of the column. They are creatures that you might find in a pond on planet Earth—for example, fungi, green algae, and bacteria.

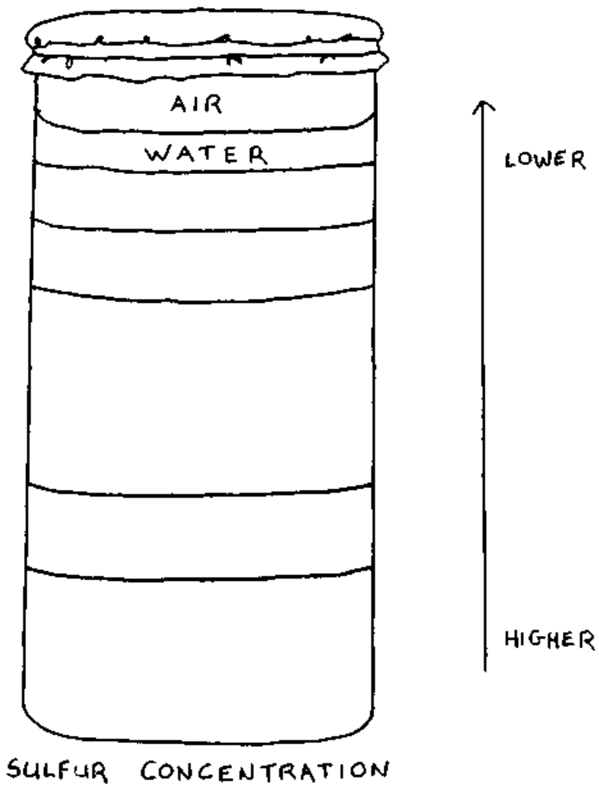
But certain types of bacteria that dominated the earth throughout most of its 3-billion-year life history, and which can be seen in the upper red layer, can live where there is only little or no oxygen. Still other bacteria live where there is no oxygen at all. These include bacteria living in the lower red and green layers.

There is an oxygen gradient in the buildings. A "gradient" is a steadily increasing or decreasing concentration of a substance over a distance. The oxygen gradient in one of the buildings is represented by the diagram on the following page.


aerobic zone
(oxygen plentiful)
AIR
WATER
HIGH
microaerophillic zone
(oxygen scarce)
LOW
NONE
anaerobic zone
(no oxygen)
OXYGEN CONCENTRATION

Sulfur (Hydrogen Sulfide)

Another elemental gradient in the microbial skyscraper is sulfur. Sulfur is released after living organisms die, as bacteria and fungi decompose the tissue and body parts. Often these dead parts are buried by falling particles, so the sulfur is released from below the soil and diffuses upward. A sulfur gradient in the columns looks like this:

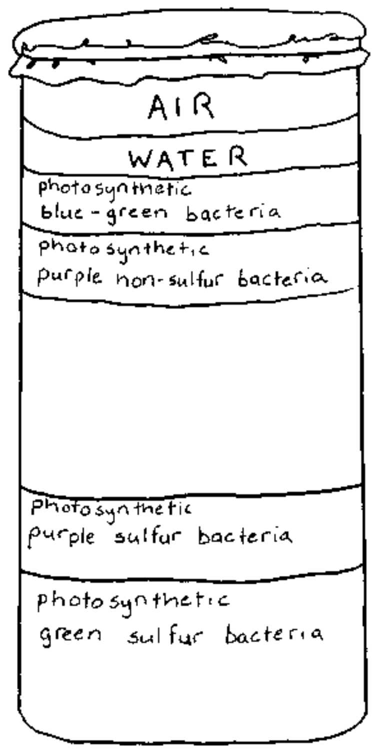


Sulfur is released in a form called hydrogen sulfide, which has the familiar smell of rotten eggs. You may have smelled this while walking by the edge of a pond, stream, or mudflat. You smelled this because the hydrogen sulfide gradient reached the surface of the water and diffused into the air.

Some bacteria need to live where the concentration of hydrogen sulfide is high. The bottom three layers in the buildings use hydrogen sulfide gas to make food from sunlight. The upper green layer is using water to make food from sunlight, just like plants and algae do. The process of making food from sunlight is called "photosynthesis."

Photosynthesis in the Winogradsky Column

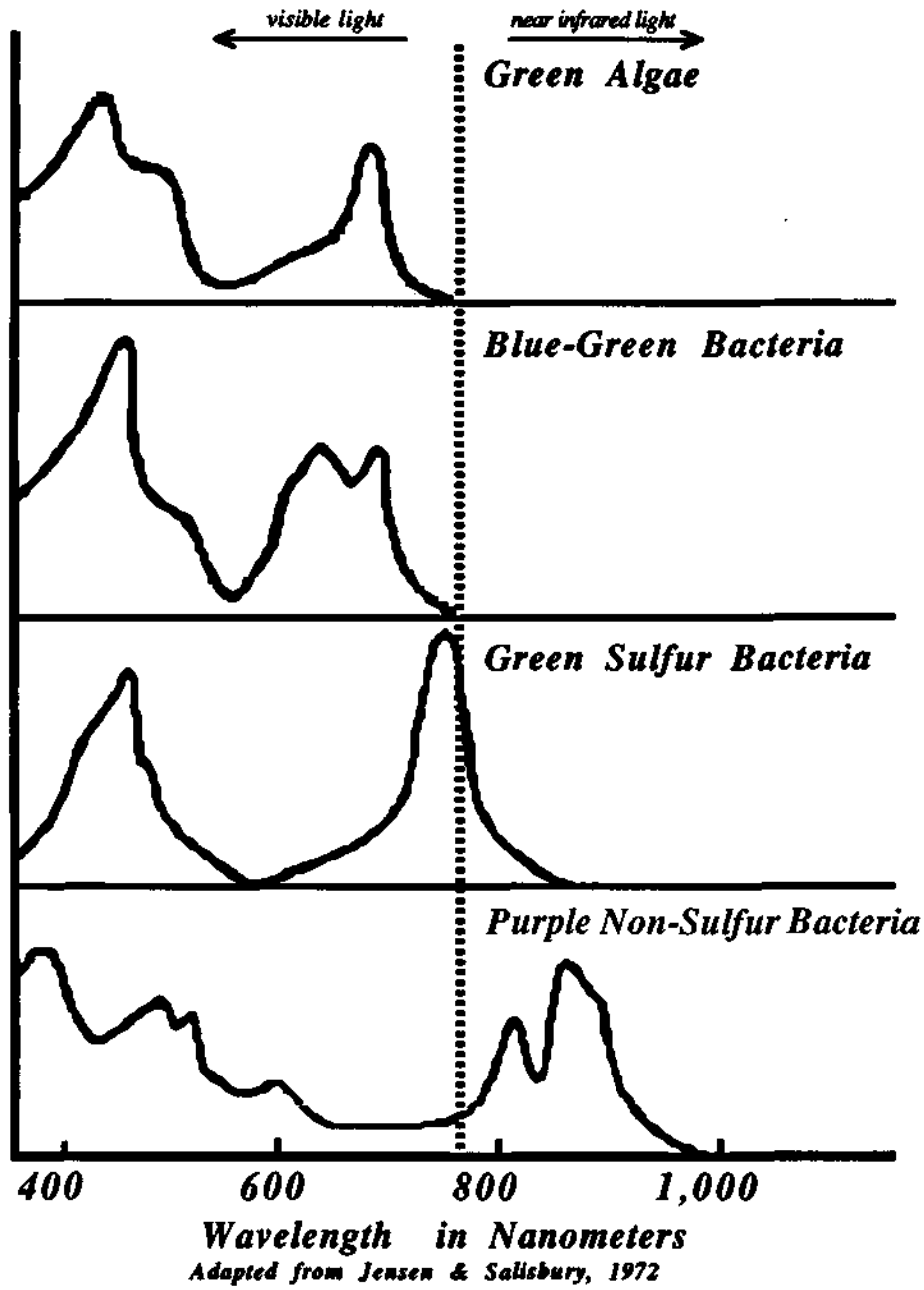
All the colored layers in the buildings are making food from sunlight. We can label them as follows:



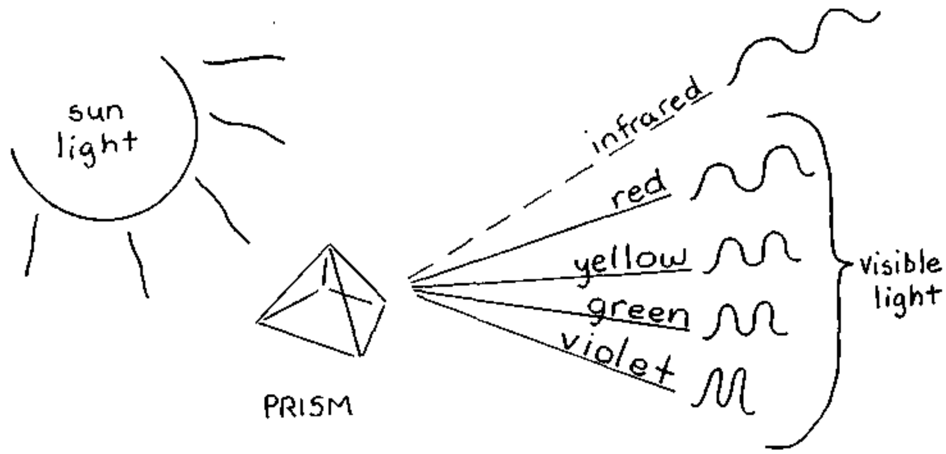
In addition, there may be a layer of green algae above the cyanobacteria (blue-green bacteria). You might ask: how can enough sunlight for photosynthesis penetrate below the soil? To us, it is dark underground, or deep underwater, because our eyes see only light that is in the colors of the rainbow. The different colors of the rainbow that we see are really light rays that are moving at different wavelengths. We can see light only in the wavelengths from purple to red; yet beyond purple, and before red, there is still light. However, we cannot see these wavelengths. The lower level of green and the purple bacteria use some of these "invisible" wavelengths, the infrared (or "before the red") wavelengths.

The bacteria in the upper layer do not use these wavelengths to make food, so the infrared light shines through to the lower levels.

Here is a diagram of the wavelengths used by different photosynthetic microalgae and bacteria that may be seen in the cities:



The peaks on each graph show which wavelength is used primarily for photosynthesis. The peak for each microbial population is different, which results in the whole spectrum of light, rather than only a small fraction, being used to make food. This arrangement, along with the abundance of water, sources of hydrogen sulfide gas, and carbon make the Winogradsky column "city" fertile, much like environments on earth, such as salt marshes, ponds, and rice paddies. These are among the most productive on our planet.


sun light
PRISM
infrared
red
yellow
green
violet
visible light

Materials

Two-liter soda bottle prepared as described below

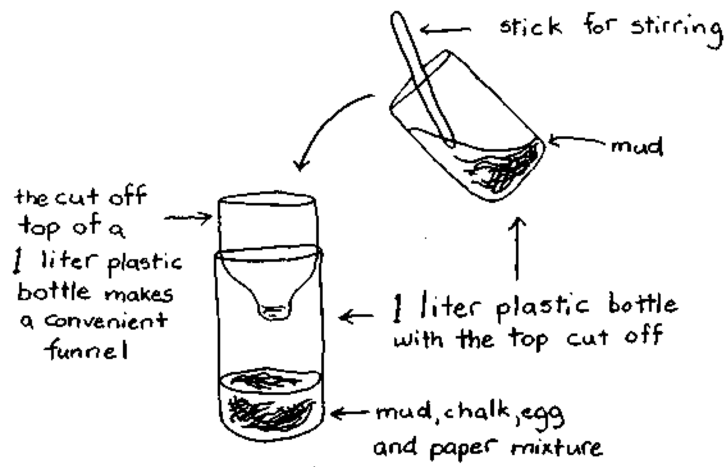
Large bucket or two of soil, mud, or sand

Water

Food Source for organisms in the column. See below.

Procedure

1. Have students bring in different soil samples from home and other local environments. Soils from shallow pond bottoms, mudflats (salt marshes are optimal), or beachfronts (the gooier and smellier the better) may form the layers more rapidly because they already contain large numbers of each kind of bacteria. Try also garden, forest, or field soil.
2. With good scissors or a razor blade, make a small cut (about 2-3 cm long) near the top of the plastic bottle, approximately at the level where the bottle significantly widens below the neck. This should be done before class, so that when you pass out the bottles to the students, all they must do is use sharp scissors to complete the cut all the way around. For younger students, you may want to cut the bottles completely yourself.
3. Collect the water. If your soil or sand comes from a marine environment, use seawater. Otherwise, use pond or stream water from where you collected the soil, or use tap water that has sat out for one day (allowing the chlorine to evaporate).
4. Finally, you will need a quick food source for the organisms in the column. Hard-boiled egg yolks or the entire raw egg provide an excellent sulfur and protein source. You can also use cheese, or powdered calcium sulphate. For a long-term carbon source to provide carbon dioxide, you can use shredded newspaper. A short-term carbon source in the form of calcium carbonate (lime) is helpful but not essential. You can also sprinkle in some chalk dust or plaster of Paris.
5. Be sure to go through the construction in a well-ventilated area. Open windows and even a fan or two are recommended. Although students will complain about odor, as soon as both the smell dissipates and the colors begin, they will happily accept the skyscrapers!
6. To fill the column, mix the soil with enough water to make it the consistency of heavy cream. Pick out most sticks, rocks, or leaves from the mixture so it is smooth. Mix your sulfur source and carbon source(s) with a little of the mud mixture and then pour it into the column. You may need to use a funnel along with a pencil (to poke the mixture through if the opening is narrow). We recommend using the top of the plastic bottle each student (or the teacher) removed with a razor blade or scissors as a funnel.
7. Pour a few centimeters of mud through the funnel; then, with one hand covering the top opening of the bottle and the other holding the bottle on the side, strike the base of the column firmly onto the table once to allow the mixture to settle evenly. Any air bubbles in the column will trap oxygen and prevent that area from becoming anaerobic.


stick for stirring
mud
the cut off top of a 1 liter plastic bottle makes a convenient funnel
1 liter plastic bottle with the top cut off
mud, chalk, egg and paper mixture

8. Continue filling the column, hitting the base on a table every few centimeters until the column is filled to within 4 or 5 cm of the top. Allow the column to settle for 24 hours so there is about 1 cm of clear water on the surface. If there is too much or too little water, add or remove some (you can use an eyedropper).

9. Cover it with clear plastic wrap fastened with a rubber band. Each student should write his or her name and the date on a small piece of masking tape and fasten it to the lower portion of the bottle. Place the microbial skyscraper in a well-lit place, such as a bright window that does not get too much sunlight (north-facing). Better still, set up an incandescent light(s) of 40-60 watts illuminating the top and sides (placed far enough away so as not to heat the column). One incandescent light fixture will be enough for five to ten columns. You can keep it lit continuously or on a 12-hour timer.

10. Have students observe the column at weekly intervals and record their observations.

11. Be aware that too much heat will kill some of the bacteria. Also, do not allow columns to dry out. Top them off with water as needed. Columns can take between three and six weeks to become established with the different layers or regions of colorful bacteria. The kinds of bacteria may change during this time. You may not get all the layers, and they may be more mixed together than in straight lines, but you will get to see different kinds of bacteria without a microscope.

12. Follow up by having students read the Discovery File: Sewage and Nutrient Loading.

Activity 6 Student Handout A Microbial City

Observation Sheet

Student name ____

Soil habitat ____

Date column established ____

Date first colors ____

Number of cm color from top of mud layer________________

Week 2, fill in for each colored area/layer:

Number of cm _________ color from top of mud ____________
Number of cm _________ color from top of mud ____________
Number of cm _________ color from top of mud ____________
Number of cm _________ color from top of mud ____________

Observations/notes:

Week 3

Number of cm _________ color from top of mud ____________
Number of cm _________ color from top of mud ____________
Number of cm _________ color from top of mud ____________
Number of cm _________ color from top of mud ____________

Observations/notes:

Week 4

Number of cm _________ color from top of mud ____________
Number of cm _________ color from top of mud ____________
Number of cm _________ color from top of mud ____________
Number of cm _________ color from top of mud ____________

Observations/notes:

Discovery File: Sewage and Nutrient Loading

For many years, Connecticut has dealt with the runoff of rainfall, agriculture, and sewage in the same ways, diverting them into Long Island Sound. It is also the course of action for the other states that line the shores of the Sound. No one thought twice about it until recently when organisms from the bottom of the Sound began to die off in large numbers. It was at this time scientists were asked to investigate the problem causing the unhealthy conditions of the Sound.

One of the causes they found was nutrient loading. Nutrient loading is the increase of nitrogen and phosphorous compounds that are making it into our bodies of water due to the lack of wetlands and over-use of agricultural and developed lands. These compounds, when they are found in large quantities, prove to be harmful to aerobic aquatic organisms, organisms that grow only in the presence of oxygen. These organic wastes provide lots of nutrients for anaerobic organisms, organisms that grow in the absence of oxygen, bacteria and fungi. These organisms flourish in these nutrient-rich environments, taking all of the oxygen out of the water and adding methane gas. This type of oxygen-depleted environment is unhealthy for the other organisms that also live in the Sound. When environments are in this state, they are considered hypoxic.

Hypoxic environments exist when conditions contain the following factors: elevated water temperatures, organic carbon loading from agriculture, elevated sediment temperatures, poor bioturbation, dissolved oxygen levels and water stratification. These factors combined create a disastrous environment over a long period of time. The problem that persists in Long Island Sound is that this type of hypoxic environment, usually only present briefly in summer, is now taking place for longer time periods, killing off already distressed organisms.

Some measures can be taken to improve conditions in Long Island Sound. Safeguards can be put in place to protect the Sound from excess sewage and stormwater runoff. Wetlands can be re-established to catch nutrients and stop the free flow into the Sound. The Sound can be left alone to allow natural biotic and abiotic factors to balance themselves.

For more information on nutrient loading, its causes, and how to prevent it, see www.greenfacts.org/index.htm; and

www.dnr.state.md.us/coastalbays/water_quality/nutrient_load.html lobster die-off podcast:

https://live-yalesite703.pantheonsite.io/sites/default/files/documents/teachers/evans_041907.mp3