Hudson River Ecology:
Curriculum and Course

A college level introductory curriculum and course based on Hudson River Ecology through field science and supporting in-classroom lessons and activities.

We acknowledge that the Center for the Urban River at Beczak is located on land in Yonkers with a rich cultural, natural, and political history that long predates colonization by Europeans, traditionally inhabited by the Munsee Lenape and Wappinger tribes. We recognize the land we inhabit as stolen land, taken forcibly from these nations and their related bands, and that it does not rightfully belong to us. We respect the indigenous people of this land as leaders in our field and advocates for environmental justice. We have much to learn from these communities and will strive to listen to and support them through progressive, responsible, and inclusive partnership.

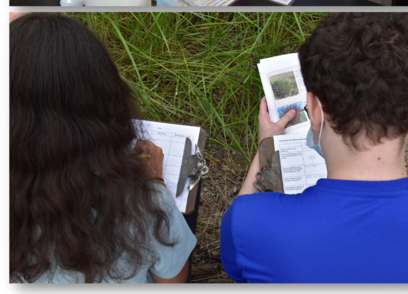
This guide was written by Elisa Caref, Director of Education, and Katie Lamboy, Science Coordinator and Environmental Educator. Special thanks and acknowledgement to the CURB Staff and interns - Ryan Palmer, Jason Muller, Aubrey Baker, Molly Gallant and the inaugural student participant group.

This Project has been funded by a grant from the New York State Environmental Protection Fund through the Hudson River Estuary Program of the New York State Department of Environmental Conservation.

SARAH LAWRENCE COLLEGE
CENTER FOR THE URBAN RIVER AT BECZAK

NEW YORK STATE OF OPPORTUNITY
Department of Environmental Conservation

A Letter To Teachers



The goal of the Curriculum is twofold: to create a framework for the Sarah Lawrence College Center for the Urban River at Beczak (SLC CURB) to run a college-level Ecology course for High School students each summer at the Center, and also to provide a curriculum for teachers who want to incorporate local ecology into their lessons. While many of the lessons revolve around in-person activities at CURB through the lens of the Hudson River Estuary and Watershed, we offer classroom alternatives wherever possible. However, we are always happy to host field trips at CURB if that is something your class will be able to do!

Each of the lessons follows a 5-E model, which centers student learning and engagement. The 5 Es stand for Engage, Explore, Explain, Elaborate, and Evaluate. Some lessons also have a 6th E, Extension. Each lesson includes notes for teachers to help think about how to incorporate the lessons into a classroom model, as well as New York State Science Standards, Vocabulary needed, a materials list, estimated timing, and any necessary resources.

This curriculum is devised to be used as a whole set, or to pick and choose lessons piecemeal to fit into a standing curriculum. There may even be specific activities within lessons that can be chosen as a one-off lesson for teachers to use with their class. The ecological theme of each lesson is described before the lesson title to help figure out where it can fit in.

We encourage questions and suggestions to help continue to improve our curriculum and lessons! Please get in touch with Elisa Caref, Director of Education, at ecaref@sarahlawrence.edu, or Katie Lamboy, Science Coordinator & Environmental Educator, at klamboy@sarahlawrence.edu.

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Suggested Order of Lessons

The lessons presented in this packet have natural connections and provide educators with smooth transitions between topics. Below are the suggested order of lessons that has been used by CURB staff along with the topic associated with the lessons. Every lesson has at least one activity or component that can be done in the classroom. Asterisks indicate that the entire lesson can be done in the classroom, with no outdoor or field trip activity needed.

The Hudson River: A Short Introduction

The Hudson River is a waterway full of history, science, literature, and art.

At the Sarah Lawrence College Center for the Urban River at Beczak (SLC CURB), the river provides a bountiful source of educational content. Educators at the center use the river to explore, research, and help students develop environmental understanding. To begin this adventure of exploration, we must first look at the beginning of the river itself.

The Hudson River makes its start as a small lake atop the shoulder of the highest point in New York state, Mount Marcy. The little lake's incredibly descriptive name gives homage to the waters' source - rain. Lake Tear of the Clouds begins the journey of the river's freshwater to its dissolution 315 miles south, where it meets New York Harbor. The river is host to three different kinds of water along the way.

Water trickling from the lake and the added water from the neighboring tributaries along its way south is considered freshwater, here meaning water without salt. From the physical barrier of the Dam of Troy to the southern tip of Manhattan island, the river has a tidal influence, bringing the river the additional name of Estuary. Here, the northern freshwater is meeting and mixing with the saltwater traveling from the ocean through tides, making a solution called brackish water. The final water at the southernmost area of where the river meets the Atlantic Ocean is considered saltwater with the highest salt content.

The tidal movement of the water in the Hudson Estuary and all other estuaries are controlled by the gravitational force of the moon on the water. Every 12.5 hours, the tidal pull ebbs and floods the partially salty water. In brackish-water Yonkers, there is about a four foot difference between high and low tide. Brackish water doesn't necessarily travel all 153 miles up to Albany, but there is still a two foot difference between high and low tide at the Dam of Troy. These tidal changes leave room for marshes along the banks that are critical nurseries for many of the river's most prominent species. Ebbing water brings small critters out to the ocean and flooding brings important nutrients back into the estuary. The shallow saltwater marsh behind CURB at Harbishaw park is home to many different species of animals and is a vital part of the flowing ecosystem.

This guide will focus on the ecology of the Hudson River Estuary at CURB and the many important pieces needed to host a healthy ecosystem. From a deeper look into the different aspects of a watershed to ecosystem restoration, this guide will provide a variety of lessons and activities to help you explore these subjects with your students.

I. Introduction

Estuary Model: Introduction to Estuaries and Watersheds

Estimated Lesson Duration: 45 min

Engage

Let's look at this map/model together:

What are we looking at? Is this the whole Hudson River? (no). This is the lower 35 miles of the Hudson River Estuary and its watershed. What is an **estuary**? What is a **watershed**?

Explore/Explain

To introduce the Hudson River Estuary, if classes can't visit CURB, teachers can use the videos at this website: Hudson River Estuary Model Videos to showcase the model. Each of the three videos is between five and seven minute long and cover the following topics: estuarine literacy, local geography, brackish water, tides, storm surge, human impacts/pollution, and restoration.

Elaborate/Evaluate

Students can work on the worksheet questions and lab activities for each video, linked and attached below:

Worksheets

Extension

Have students create their own watersheds using only paper, markers (non-permanent), and water! Crumple up a piece of paper and spread it out a little bit. Note that there are now ridges (high points) of the paper, as well as valleys (low points). Have students trace the ridges more clearly with their marker. When they are done tracing all of the ridges, use a spray bottle to spray water gently onto the paper. Watch as the water collects in different valleys depending on where the ridges are facing. Do all watersheds act the same? What causes water to fall in one direction or another? What if there was a huge storm, or erosion on one of the mountains? Would the water still collect in the same place?

Classroom Modification Tips

This lesson can be done fully in the classroom, assigned as homework, or some mix of the two. There is a longer set of activities, linked above, that may need more time and/or an individual internet connection for each student.

Vocabulary

Brackish Water: A mixture of fresh and saltwater that can be found in an estuary

Bridge: A structure carrying a road or path across an obstacle such as a river

Current: A body of water moving in a definite direction

Estuary: Where a freshwater system meets a saltwater system

Flooding: The covering or submerging of normally dry land with a large amount of water

Freshwater: Water where salt content is nearly 0 ppt

Geography: The study of physical features of the earth and its atmosphere

Island: A piece of land surrounded by water on all sides

Marshland: Land consisting of marshes (an area of low-lying land which is flooded in wet seasons or at high tide)

Peninsula: A piece of land surrounded by water on three sides

Pollution: The presence or introduction into the environment of a substance or thing that is harmful or has poisonous effects

Precipitation: Rain, snow, or hail fall to the ground from the clouds

Runoff: The draining away of water from land into waterways; sometimes collection pollutants along the way

Saltwater: Water found in oceans that has a salt content higher than 34 parts per thousand (ppt)

State Line: The boundary between two states

Tide: The gravitational influence of the moon causing a rising and falling effect on water

Tributary: A river or stream flowing into a larger river or lake

Water Cycle: The cycle of processes by which water circulates between the earth's oceans, atmospheres and land

Watershed: An area of land that drains flowing waters into a common outlet

Standards

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity

HS-ESS2-5.Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

HS-ESS3-4.Evaluate or refine a technological solution that reduces impacts of human activities on natural system

Estuary Model worksheet - student version

Geography video

1. What are some of the different waterways that are shown in the model and how do they interact with one another? Give an example of interactions between each of the following: River, Tributary, Sound, Bay, Ocean

Watershed video

1. How does the watershed play a part in the movement of water from our freshwater system to the ocean system?

2. What is the influence of tidal change on the watershed? How is this tied to flooding?

3. How does animal anatomy and evolution help them to adjust to fluctuating salt levels throughout the estuary?

Pollution video

1. What are some ways pollution moves through the estuary system?

2. What are some engineering measures we can use to prevent waterway pollution other than green infrastructure such as marshlands?

Estuary Model Worksheet - Teacher version

Geography video

1. What are some of the different waterways that are shown in the model and how do they interact with one another? Give an example of interactions between each of the following: River, Tributary, Sound, Bay, Ocean
   Hudson River, empties into and mixes with the Atlantic Ocean. Sawmill River as a tributary of the Hudson. Bronx River as a tributary to the Long Island Sound/East River. Long Island Sound connects the Atlantic Ocean on both sides. Jamaica Bay acts as an inlet for the Atlantic Ocean.

Watershed video

1. How does the watershed play a part in the movement of water from our freshwater system to the ocean system?
   If water falls on the land as rain or snow, it enters tributaries which empty out into the Hudson, which eventually mix with water from the Atlantic Ocean, forming brackish water for our estuary.

2. What is the influence of tidal change on the watershed? How is this tied to flooding?
   The tide changes about every 6 hours in the lower Hudson watershed. That means that high tide brings more saltwater from the ocean, and low tide brings fresh water back towards the ocean twice a day. There is a 4-foot difference between high and low tide in Yonkers.
   Some low-lying areas can be flooded at very high tide if they are at sea level. We see this in the video at the top of the model around Croton and also near the Atlantic Ocean in the Rockaways.

3. How does animal anatomy and evolution help them to adjust to fluctuating salt levels throughout the estuary?
   Fish that can survive in full saltwater and freshwater have special regulatory cells to help them adapt to their environment and regulate osmosis.

Pollution video

1. What are some ways pollution moves through the estuary system?
   Pollution moves very easily throughout the water. Pollution that floats in the water moves especially quickly around the waterways, especially with tidal changes that bring the water around the Hudson River and back to the Atlantic Ocean. Pollution that's just on the ground, like litter can also be brought into the estuary system by rain, wind, and runoff. Some pollution can even be flushed down toilets, like antibiotics or other medicines, which eventually ends up in the water as well.

2. What are some engineering measures we can use to prevent waterway pollution other than green infrastructure such as marshlands?
   Planting more plants on land, using bioswales, greenroofs, greenwalls, water catchment, porous pavement all help to collect water from rain and runoff before it gets into the Hudson River. Other answers could include changing our infrastructure to get away from combined sewer overflows, coming up with ideas to trap microplastics in the water without harming animals, etc.

I. Introduction

Plant Scavenger Hunt in Habirshaw Marsh: Marsh Scavenger Hunt
Estimated Lesson Duration: 90 min

Engage

What do we know about plants in our environment? (**Photosynthesis**, food for animals, mental wellness benefits, looks good). What are some functions of the plants in the environment? (Shelter for animals, nutrients as nuts/fruit/greens, roots act as an anchor for dirt). What would our world look like without plants? Students paint a visual word picture with words that are shared on a dry erase board.

Explore

Look at the photo of Habirshaw Park above. What are some **abiotic** things we notice about this park in the photo? (Palisades Cliffs, benches, rocks, river). What are some **biotic** things we notice about this park via photo? (grass, trees, plants). Today we will be taking a deeper look at biotic plants in the tidal marsh.

Tidal marshes are an important part of the Hudson River. The **tidal marsh** we will be exploring today was constructed in 2004. Originally, the site beneath the marsh was incredibly contaminated with industrial waste and was covered by **impervious** material. Imagine there being a gigantic parking lot where you see the lush green lawn - how would that impact the neighboring Hudson River? (Things such as litter could roll directly into the river, there may not have been as many animals around, pollution such as oils could leach into the river easily). After careful preparation and removal of contaminated soil, interfering plants, and concrete, construction began on the park we see today.

One of the prominent features of this park is the access to the river and its marsh. Why are marshes so important to the estuary ecosystem? (They act as **nurseries** for different species at the juvenile stage). The marsh acts as a place where we can study different species. The **migrating** American Eel stops by our marsh each spring before their long journey to the freshwater rivers of their foreparents. But animals are not the only types of species we study.

Photo Credit: Gaudin Lab

Let's look at a photo of a marsh plant called Eastern Gamagrass together. What are some things we observe? Why would this be important in the health of a marsh? (We observe lots of roots that are clustered - **rhizomes** - this can help keep dirt in place, healthy bacteria can thrive here, more roots can equal more water uptake, roots can prevent plants from floating away). Plants such as the Eastern Gamagrass not only act as a habitat for the animals visiting, but also serve an important function as part of the tidal marsh.

We are able to study and watch how the marsh is a great buffer for large storms, by acting as a sponge to prevent large amounts of flooding. Plants that grow in salt marshes are very unique in the plant world - they are often able to withstand long periods of time submerged in salty water and can also survive in long periods of drought. We are going to continue this research by looking at some species up close and documenting the different functions of these different plants.

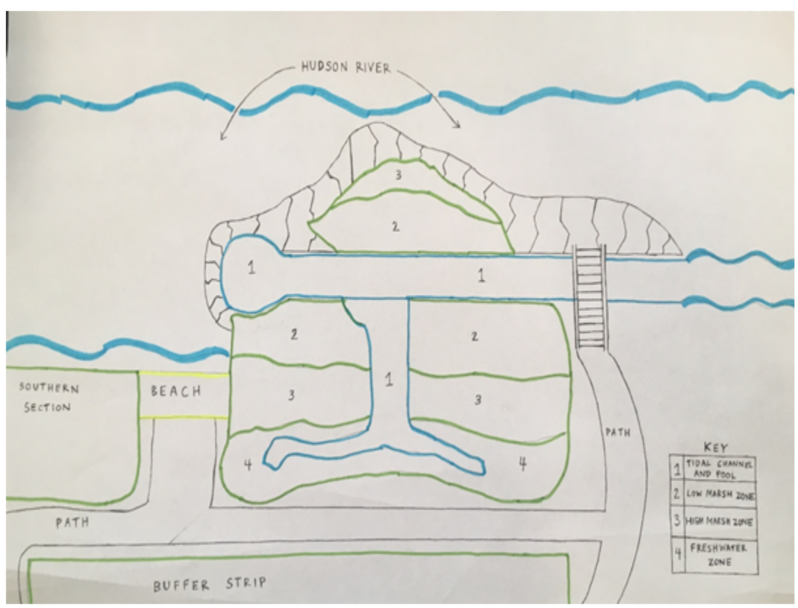
(Source information: Sustainable Shorelines Study)

Explain

Students will break into groups and each group will be given a physical copy of the CURB *Tidal Marsh Plant Guide*. We will go through how to use this guide and look at the map in real time outside so students are oriented to the park and map.

Each group will be asked to find 1 plant (and take a sample to keep in their bucket) for each of the following categories within the marsh. Students should have access to boots and gloves if the tide is on the higher side.

- 1 Herbaceous Plant
- 1 Grass/ Sedge/ Rush
- 1 Weed/ Vine
- 1 Shrub/ Bush or Tree



Students can use the guide as a way to identify what they are seeing in the field; however, their observations on the worksheet provided should be based on what they are seeing in real time. There will also be a bucket of different scientific tools for students to borrow and share (magnification glasses, petri dishes, trowels, etc.) to help support in-depth field observations.

Elaborate

Students go outside and fill out the Habirshaw Scavenger Hunt worksheet.

Evaluation

When students are back inside, we will build a virtual marsh together on the white board. Through their observations, we will draw out the different plants and show how these plants work together to create a working ecosystem and how all things within a system are connected. Students will showcase their physical plant samples (labeled with post its) to each other to look at similarities and differences, and see if they identified plants the same way or if there were discrepancies. Students can build the marsh with their post it labels.

Classroom Modification Tips

While this lesson is specific to Habirshaw Park at CURB, it could translate to any shoreline marsh, if you have access to it. The field guide will still be applicable to many local areas around the Hudson estuary, but even if you are in a freshwater area, the scavenger hunt portion of this lesson should be applicable. If you cannot get out to a shoreline with your students, you can still work on the Engage and Explore sections, or try to do this lesson using internet research or local plant field guides.

Vocabulary

Abiotic: Physical rather than biological; not derived from living organisms

Biotic: Relating to or resulting from living things, especially in their ecological relations

Impervious: Not allowing liquid to pass through

Migrating: Move from one part of a place to another

Nurseries: A place or natural habitat where animals go to breed or raise their young

Photosynthesis: Process in which plants convert carbon dioxide into food, that also generates oxygen as a byproduct

Rhizomes - the underground plant parts capable of producing the shoot and root systems of a new plant

Tidal Marsh: A collection of plants found along rivers, coasts, and estuaries that floods and drains by tidal movement of the adjacent estuary, sea, or ocean

Standards

HS-LS2-1. Use mathematical and/or computational representations to support explanations of biotic and abiotic factors that affect carrying capacity of ecosystems at different scales
HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
HS-ESS3-1.Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity

Materials Needed

- ❏ Scavenger Hunt Worksheet
- ❏ Buckets
- ❏ Magnification Glasses
- ❏ Gloves (garden)
- ❏ Trowels
- ❏ Tweezers
- ❏ Rulers
- ❏ Colored Pencils
- ❏ Marsh Field Guide
- ❏ Clipboards

II. Energy and Ecosystems

Plankton

Estimated Lesson Duration: 90 min

Engage

What do we know about energy in our environment? What about in an aquatic environment? Where does the energy come from? Who (or what) produces it? What are we talking about when we talk about energy? Food and food sources!

(Should touch on **producers**/**autotrophs** vs **consumers**/**heterotrophs**, plants, phytoplankton/algae, **photosynthesis**)

Explore

Let's look at these images in the Peek at Plankton Powerpoint of different types of **plankton** and make a chart describing their parts and attributes. What do they have in common? What is different about them?

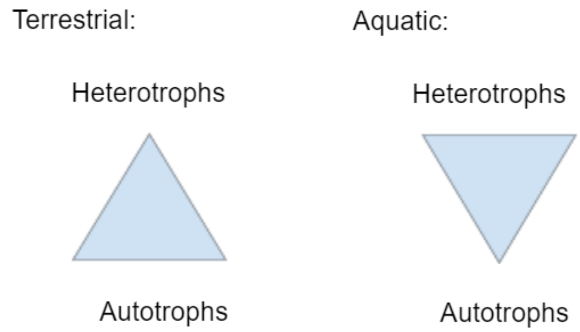
Based on these attributes, do we think we can figure out which one is a *phytoplankton* and which is a *zooplankton*? Can we think of some characteristics that we might expect other phytoplankton/ zooplankton to have? Why might they have these parts/ characteristics? (zooplankton have more discernible body parts like antenna, eyes, fins, etc., that help them move around and see and sense their environment so that they can find their food. Phytoplankton are more likely to have chloroplast cells so that they can photosynthesize, be more symmetrical because of their silicate shells [diatoms at least, of which there are many in the HR], be unicellular but also able to grow in colonies).

Explain

Why is it so important to have a diverse and large amount of plankton in the water? Why might they be important to the ecosystem? If you have time, watch this mesmerizing video: The Secret Life of Plankton.

What is the difference between autotrophs and heterotrophs in an aquatic versus terrestrial environment? **Biomass** (the total mass of organisms in a given environment) - in a terrestrial environment, autotrophs make up the majority of the biomass of the system. In an aquatic environment, it's the opposite.

(Draw this diagram below on the board).



How can the biomass be so small when the organisms make up the whole base of the **food web**? Phytoplankton are very tiny and also have very short life spans, so the ecosystems rely on there being millions of them at a time to keep a consistent food source for all the other organisms.

Besides producing food for organisms, why else are autotrophs so important for the global ecosystem? By what process do organisms produce food? Photosynthesis, of course. Does anyone know the formula for it?

$$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Even though the oxygen produced is a byproduct, phytoplankton produce over 50% of the world's oxygen!

Elaborate

Now that we know so much about plankton in the water, let's try and find them. Students can do a plankton tow if at CURB/on the Hudson River*, or find a local pond to take water samples from, or teachers can have prepared water samples from either location. Will we expect to see any of the plankton with our eyes? Why or why not? What tools might we need to get a closer look?

Since we need microscopes to see phytoplankton, this is a good opportunity to teach or reinforce microscope skills and emphasize how fun but also difficult it can sometimes be. What else can students find/look for if they can't find any plankton?

Evaluation

Have students sketch and label 3 different plankton that they find as elaborately as possible. Can they identify the types of plankton they might be? Review identification techniques, and available guidebooks/worksheets. Make sure to have as many images available as possible. There are also a trove of Identification tips and photos here: Phytoplankton of the LIS. This video also shows a number of local phytoplankton in great detail: Phytoplankton in Hudson River Park. This document showcases some Hudson River plankton found in lower Manhattan in March of 2014.

Classroom Modification Tips

There are many ways teachers can take a look at plankton with their students within the classroom:

Conduct a Tow Before Your Class: If you have access to a river before teaching, collecting samples in bottles may be a great way to bring the river into the classroom. You can make a homemade plankton tow, or if you are near an intertidal shoreline, can use this easy method described in videos here and here, and in this paper. Many plankton, especially zoo-, have a short lifespan and need comfortable travel conditions in order to still be alive when you get to the classroom. Traveling with your samples in an insulated cooler with ice packs is the best mode of transport from river to classroom. And try to leave the jars open once you get back to the classroom to allow for oxygen exchange for the organisms in the water.

Leaf Packs: Leaf packs are an easy and affordable way to obtain live specimens of mostly zooplankton; however, this process does take some planning ahead of time and is best if practiced in a calm location of a stream. Leaf packing creates an artificial habitat that can be inhabited by different plankton and macroinvertebrates over a period of time. A pack kit can be purchased or teachers can upcycle a former onion mesh packaging (the more natural the color of the pack, the better). The mesh pack then gets filled with different leaves (if one is interested in looking at the impacts of non-native plant species on plankton, this is an opportunity to fill one pack with native plant leaves vs another bag with non-native plant leaves). Once bags are filled with approximately 30 gram of leaves, the packs should be tied with a string and deployed into your local stream. After approximately one week, your pack is ready to be removed. Do so carefully and place into a bucket with the same stream water. Additional instructions on the creation and analysis of leaf packs for plankton can be found here.

Plankton Slides: If your institute has a budget or access to prepared plankton slides from somewhere like Carolina Biological Supply, this is a great way to have students study plankton up close with microscopes. Teachers are able to use the “Elaborate and Evaluate” portions of this lesson with use of the slides in lieu of the plankton tow samples.

**Plankton Tows are fun but time consuming and not the best activity for an entire group because there is a lot of standing around. We suggest doing a tow ahead of time for some students to explore while the other students are doing their own tow, or even collecting a leaf pack (or buying prepared phytoplankton slides) ahead of time to ensure some zooplankton for students to explore*

Vocabulary

Autotroph: An organism that produces its own sugars/food, usually by photosynthesis. Also sometimes called “**producer**”.

Biomass: The total mass of organisms in a given area

Food Web: A system of interlocking and interdependent food chains

Heterotroph: An organism that gets its energy by eating other organisms as food. Also sometimes called “**consumer**”.

Photosynthesis: the process by which plants and plant-like organisms such as phytoplankton use sunlight to synthesize food from carbon dioxide and water

Plankton - an organism that is free-floating in the current, usually split up into *zooplankton* (animal plankton) and *phytoplankton* (plant-like plankton)

Standards

HS-LS2-1. Use mathematical and/or computational representations to support explanations of biotic and abiotic factors that affect carrying capacity of ecosystems at different scales.

HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem

HS-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

Materials Needed

- ❏ Plankton images and books available
- ❏ Microscopes
- ❏ Slides
- ❏ Small Pipettes
- ❏ Petri Dishes
- ❏ Tub Containers
- ❏ Hand lenses
- ❏ Tweezers

Other plankton identification guides:

Kraberg, A., Baumann, M., & Dürselen, C-D. (2010). *Coastal Phytoplankton: Photo Guide for Northern European Seas.* AWI.

Larink, O., & Westheide W. (2011). *Coastal Plankton: Photo Guide for European Seas.* AWI.

II. Energy and Ecosystems

Food Web/ Organism Relationships

Estimated Lesson Duration: 60-90 min

Engage

We often talk about organisms' relationships with each other in terms of consumption and production. Some species are **producers** - creating their own energy using photosynthesis - and others are **consumers** - those that eat the producers because they cannot make their own energy. (Write the bolded words on the board, we will add to these as the lesson continues). How do they fit together? You probably know about food chains - have you ever heard of a **food web**? Food webs are much more complex than a simple chain - organisms can impact many others without directly being the **predator** or **prey**. Let's explore these types of food-based relationships with a quick activity building our own Hudson River food web.

Which aspects are positive for the ecosystem? Which might be negative? Which might humans be able to change? (Note for teachers: this part can include a separate mini lesson that can be found at the end of this section called "Hudson River Food Web". If you do that lesson, the rest of this lesson should be done after that one.)

Explore

Consumption and production are not the only types of relationships that exist among plants and animals. There are many other complex interactions in nature. For instance, have you ever heard of a parasitic relationship? How about symbiosis, which is what we usually say to describe something called mutualism? What are some examples of these? Do you know of any other types of relationships species might have with one another?

Explain

Let's go through all of the different types of ecological relationships/ interactions organisms can have with each other, and come up with some examples of each. There are positive, negative, and neutral relationships. Are negative relationships always bad for the environment, even if they're negative for a certain species? (i.e. predation is bad for the thing being eaten, but it is good for the thing eating it. Can also touch on introduced species into environments and how they can have varying impacts on the species already living there, positive, negative, or neutral. Students might know some examples of this already).

What is **parasitism**? Can you think of any examples of that?

What other kinds of relationships are there besides those that are based on food/energy consumption? Are they positive, negative, or neutral for the organisms involved?

- (++) mutualism
- (--) competition
- (+-) predation/parasitism/parasitoidism
- (00) neutral
- (-0) amensalism
- (+0) commensalism

Write each of the concepts on the board with + - 0 so they can see the positive, negative or neutral aspects of them. Go over definitions (listed below), and then split up the class into 6 groups (or pairs, if you split up 3 types of mutualism, predator/ prey and parasitism, etc), and have each group focus on one of these concepts. Have the groups spend 5 minutes coming up with examples of each of the concepts. This may require a little imagination and reliance on memory.

Share out 1 example of each from each group.

Competition - any interaction that is mutually detrimental (not good) for both participants, occurring between species that share limited resources. What are some examples of competition?

Mutualism - interactions between two species that benefit both

- 3 types: (have students give examples of each)
    - *trophic* - specialized in complementary ways to obtain energy and nutrients
    - *defensive* - organisms that receive food or shelter in exchange for protecting partners against predators

- *dispersive* - eat parts of plants (usually) that then help disperse the seed/ pollen etc.

(Symbiosis does not equal mutualism - symbiosis is just any prolonged interaction between members of 2 different species, so it can mean parasitism or mutualism. Mutualism is a mutually beneficial interaction between members of 2 different species).

Amensalism - interactions where one species has a negative experience and the other is neutral. Usually happens by accident. Can you think of any examples? For instance, if an elephant steps on an insect and the insect dies. It doesn't really have an impact on the elephant but is definitely bad for the insect.

Commensalism - when one organism has a positive experience and the other is neutral. Can you think of an example? For instance, when a bird lives in the hollow of a tree, the tree isn't really impacted one way or another, but the bird gets shelter and protection.

Neutral - when both species have neither positive nor negative experiences in an interaction. Any examples of this?

Elaborate

What else might dictate the kind of impacts organisms have on each other? Diet can be one thing, and habitat another. Why would diet impact organism relationships? What types of diets are there?

Carnivore, **herbivore**, **omnivore**. On land there are a lot of herbivores, or organisms that only eat plants. What about underwater? There are actually way more omnivores in aquatic environments, because animals have less control over what they eat, especially if they eat plankton that just drifts through the water.

What about habitats of the aquatic environment? There are three general habitat types underwater: **benthic** (bottom), **pelagic** (swimming zone) and **photic** (area where the sunlight can penetrate through the water). What might you expect to find in each of these zones?

Evaluation

Let's make this a little more real by looking at this list of organisms that live in the Hudson River (Organism Relationships Handout). Split students into groups, and using the list, have them create a drawing in their lab book (or they can cut out and tape/ glue the printed drawings) that includes every organism, and all of the relationships that we went over earlier. Make sure each organism is in the correct habitat of the river, and that you cover every one of the types of relationships. Then, have them write a description of their picture, and describe each of the organism relationships in paragraph form.

*If you are pressed for time, you can make one image of the Hudson River together by drawing in the sun, water, and benthic zone on the board and have students offer ideas for organisms, where they live, and how they are related to one another. Try to get at least one example of each relationship on the board.

Classroom Modification Tips

This lesson can easily be completed within a classroom setting.

Here are some questions students can use to guide the organism relationship comparison conversations:

- How might different student's webs interact with each other if they were combined?
- If they removed any one of the species, would the web survive or collapse? Are there some species that are more important than others?
- What kind of relationships do these species have with one another? Is it possible for these species to have multiple streams of relationships?

Vocabulary

Amensalism - interactions where one species has a negative experience and the other is neutral

Benthic - ecological zone at the bottom of a body of water

Carnivore - organism that only eats other animals

Commensalism - when one organism has a positive experience and the other is neutral

Competition - any interaction that is mutually detrimental (not good) for both participants, occurring between species that share limited resources

Consumers - An organism that gets its energy by eating other organisms as food

Food web - A system of interlocking and interdependent food chains

Herbivore - organism that only eats plants or plant-like organisms

Mutualism - interactions between two species that benefit both

Neutral - when both species have neither positive nor negative experiences in an interaction

Omnivore - organism that eats both plants and animals
Parasitism - relationship between two species of plants or animals in which one benefits and the other has a negative experience
Pelagic - ecological zone in a body of water considered the free-swimming area, not too close to a boundary like the benthic zone or a shoreline
Photic zone - ecological zone in a body of water that receives sunlight, making it possible for photosynthetic organisms to produce energy and oxygen (do photosynthesis)
Predator - animal that hunts for and feeds on other organisms
Prey - organism that gets hunted/eaten by a predator
Producers - An organism that produces its own sugars/food, usually by photosynthesis

Standards

HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in ecosystems.
HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem
HS-LS2-8. Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce
HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity

Materials Needed

- ❏ Organism Relationship Handout
- ❏ Food web organism cards
- ❏ Yarn for mini food web activity
- ❏ Notebooks
- ❏ Pencils

Amphipods

- Crustacean, laterally compressed body
- Benthic, burrow in the sediment
- 1 – 340mm (small!)
- Symbionts of gelatinous animals (jellyfish, sea anemones, etc.)
- Detritivores or mesograzers (eat algae)
- Favorite foods of juvenile fish, seahorses and pipefish

Atlantic silverside

- 15 cm (5 inches)
- School in huge groups
- Eats smaller crustaceans, annelids (worms)
- Pelagic, but live near the shore
- Eaten by predatory fish and birds

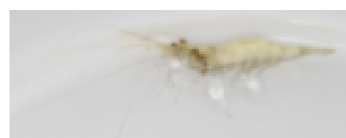
Bluefish

- Pelagic fish, juveniles spend time in estuaries
- 60 cm long
- School in loose groups
- Eat any other fish in feeding frenzies, can be cannibalistic
- Eaten by other larger fish (striped bass)

Eastern oyster

- Ecosystem engineer, creates reefs that many other species live on
- Filter feeder (eats microscopic algae/phytoplankton)
- Eaten by crabs, predatory snails, some fish (blackfish, oyster toadfish)

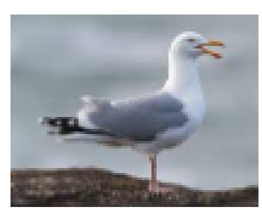
Daggerblade Grass Shrimp



- Crustacean, laterally compressed body, serrated horn (daggerblade) for defense
- 2 inches in length
- Prefers shallow water; pelagic but uses structured objects, not free swimming
- Preyed upon by smaller fish and crabs
- Prey on other smaller invertebrates, also can be detritivores or deposit feeders

Oyster toadfish

- Benthic
- As a juvenile, preyed upon by many other larger fish; is subject to very little predation as an adult
- Prey on invertebrates, especially crabs and bivalves, other fish, can be cannibalistic
- max length 38 cm



Seagull
- Terrestrial organism, breeds near water
- 40-46cm long as adults
- Omnivorous, often feeds on small/medium sized fish

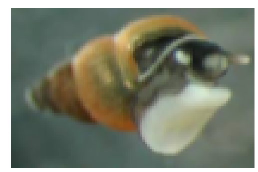
Striped bass

- maximum length 6 ft
- anadromous - adults come into the Hudson River to breed
- juveniles live in the estuary for a few years before going out to sea
- eat other fish, juveniles will also eat crustaceans
- preyed upon by humans or birds as adults, juveniles will be eaten by larger fish

Spot

- max length 14 inches
- eat detritus, crustaceans, and annelids
- preyed upon by striped bass, flounder, and other larger fish as well as birds
- form loose schools
- spend time in both the benthic and pelagic zone

Mud snail

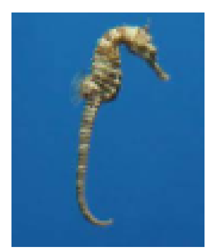


- Many different species very closely related
- grow up to 1 inch
- can be predatory, eating annelids or any other crustaceans that they can catch, mostly detritivores
- extremely slow travelers
- benthic

Lion's Mane Jellyfish

- planktonic
- bell has a max of a 20 inch diameter
- will eat anything it can catch, uses stinging cells in its tentacles to capture fish or other jellyfish
- predators can be large fish, birds, or sea turtles
- larger jellyfish can act as a floating oasis for smaller crustaceans and fish, creating moving structure

Lined seahorse



- Mostly benthic, needs structure
- feeds on almost exclusively amphipods but will eat some zooplankton or annelids if necessary
- Unappetizing, few predators but will be preyed upon by larger fish if there is nothing else around
- grows up to 6 inches

Diatoms

- Planktonic
- Microscopic
- Autotrophs
- Live in the photic zone

CURB mini lesson: *Hudson River Food Web*

Program Description: Students will explore the Hudson River Food web to discover the interdependence of plants and animals in the watershed. This interactive activity will introduce students to the concepts of producers, consumers, and decomposers, as well as specific plants and animals living in the estuary, and how pollution can affect the energy transfer process.

Supplies

- [ ] 2 balls of different colored yarn
- [ ] Food web cards printed, laminated and made into a "necklace" with yarn (or students can just hold them, or pin to shirts, etc.)

Engagement

Hudson River introduction (5 minutes): Where are we? What is an estuary? How do we get salt water from the ocean? What causes tidal changes?

Exploration

What's inside the Hudson River? What makes it their home? Who eats whom? Let's find out together. (5 minutes)

Invite or suggest specific answers and write them on the board: plankton (phyto and zoo), striped bass, Atlantic silverside, hogchoker (flatfish), worms, blue crabs, soft shell clams, Atlantic sturgeon, American eel, cormorant, wood duck, seaweed

Explanation

How do these organisms get their energy? (10 minutes)
Invite students to discuss the following, write the vocabulary words on the board:

Plants make their own energy, and are called **producers**. They use the chemical process of photosynthesis to take in sunlight and carbon dioxide, and produce glucose and oxygen. (In fact, plants underwater produce up to 50% of the world's oxygen, meaning we breathe air made largely by them!). Which organisms on this list are the producers?

So what about everything else? They're mostly **consumers** - organisms that consume other organisms. Primary consumers eat the producers themselves, and secondary producers eat those organisms, etc. Which organisms here are consumers?

There are also some other organisms on this list - **decomposers**. Decomposers eat things that have died and sink to the bottom of the river. They are an important part of the food chain because a lot of consumers eat them, so they help recycle energy. Which organisms here are decomposers?

What do we call an organism that eats only plants? **Herbivore**. Only animals? **Carnivore**. Both? **Omnivore**. Which organisms on our list fit into these categories?

Elaboration

(5 minutes) Everyone takes an organism card and reads it to themselves. Does anyone have a card that wasn't on our list/ not considered an organism? (The sun! Why is this important for the food web?)

(15 minutes) Have the students stand in a large circle at the back of the room. Place *the sun* in the middle of the circle with the ball of yarn. Ask them who gets their energy from the sun. They can refer to their cards, and will eventually call out phytoplankton or seaweed. Have the sun throw the yarn ball to the plant carrier, while the sun still holds on to a piece of the yarn. When they catch the yarn, they need to share one fact about their organism with the group. Then ask who eats the plant? They throw the yarn to that person. Keep going. At some point, ask who would eat an organism that has died, and make sure to refer to decomposers, and then who eats decomposers. Send the yarn back to the sun after the apex predators have been reached and keep going until everyone is holding some yarn.

Evaluation

Ask students to gently tug on the string they are holding. Ask any students who feel the tug to begin tugging on their string, and very quickly, all of the students will begin to feel their string being pulled. Then discuss the effects of even one small organism dying out in an ecosystem. What if we cut that thread?

What happens if pollution is added to the system? Where would that travel? Take out another ball of yarn that is a different color to represent the way pollution travels through the food web as well by repeating the *Elaboration* process above.

How does pollution move through the ecosystem? What effect does it have on the animals? How might it affect humans?

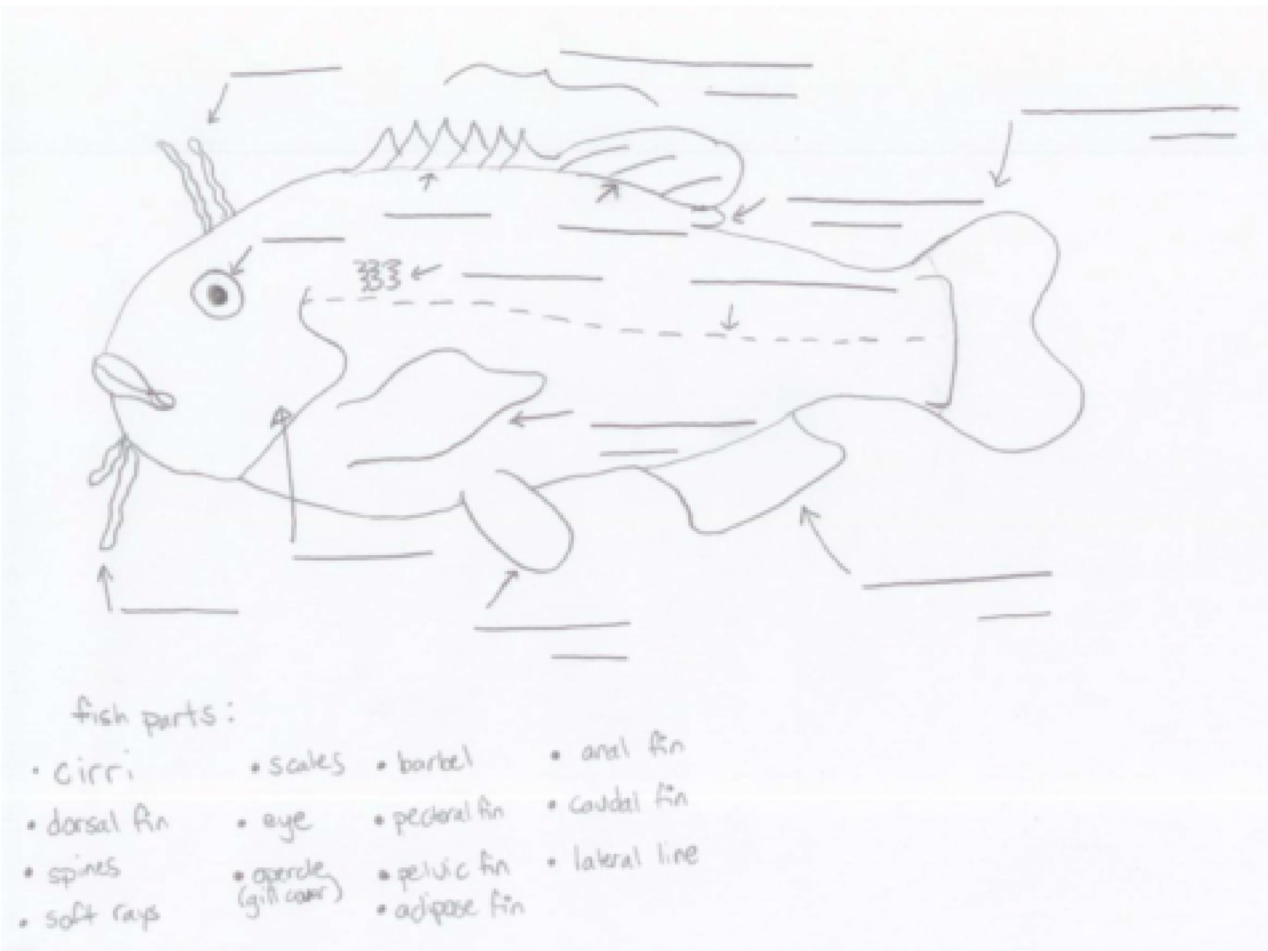
III. Population and Communities

Fish Identification

Estimated Lesson Duration: 45 min

Engage

What makes a fish a fish? Start a discussion of how a student might know a fish is really a fish, and not, for instance, a **mammal**, or an **invertebrate**. (If they say it has fins, point out that many other organisms also have fins, like shrimp and whales. Can be repeated with **gills**, **scales**, **vertebrae**, etc.). Point out that scientists have spent a lot of time trying to classify and categorize exactly this question.



Explore

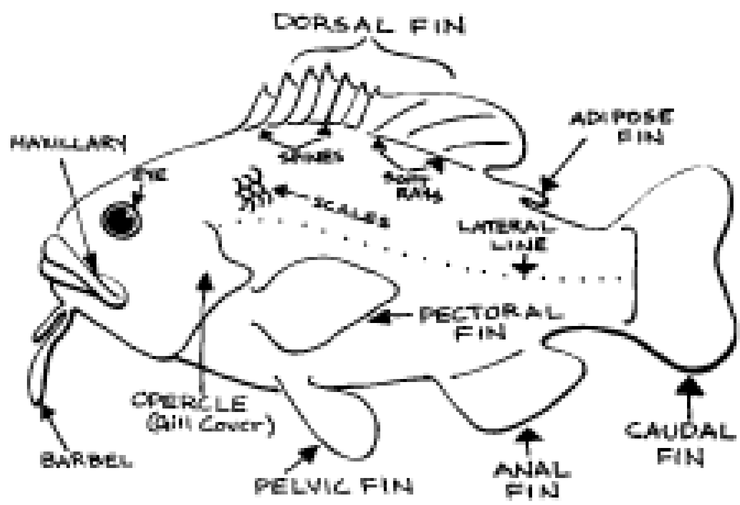
Did you know there are over 25,000 different species of fish in the world, and over 250 alone in the Hudson River? How do we know what lives here? How can we identify fish? We need to know their **anatomy**. Let's try to identify all the parts of a fish. *Draw a fish on the board/ screen like the one above and start to label the parts with the* *students*. Which do you recognize? Which don't you? What do each of these parts do for the organisms? Why is it important for Estuary educators to know these? What happens if we catch a fish that we can't identify? (Answers and additional function definition of parts found below.)

Dorsal Fin: Provides stability against rolling

Maxillary: Aids in capture of prey via mouth

Barbel: Helps in acquisition of food in waters with low visibility and benthic dwelling fish

Opercle: Protective covering for the gills (respiratory system of fish)



Scales: Act as protection from environment and predators

Pectoral Fin: Help steer and control depth in movement

Pelvic Fin: Help balance the fish and keep level and against rolling

Anal Fin: Provides stability, similar to the function of a keel on the bottom of a boat

Lateral Line: This line of highly sensitive sensory nerves can be used as prey detection, spatial orientation, predator avoidance, and schooling behavior

Adipose Fin: Fin used for additional stabilization

Caudal Fin: Provides power to move the fish forward and helps fish steer

Explain

We use a **dichotomous key**! What is a dichotomous key? Write "dichotomous key" on the board and have them break down the words before discussing what it is. For example, di = two, key = guide to a map.

Once this is discussed, bring out the [Clearwater Dichotomous Key] to show how the dichotomous key works and what it is.

Elaborate

Pass out dichotomous keys and practice as a class on one fish that everyone can already identify, like a goldfish in the Fish ID Practice Powerpoint. Keep the fish in a clear bin if possible and go through the dichotomous key steps one by one at each table, until everyone has gotten to help with at least one step. Show how difficult it can be, even when you know what the fish is, because of how well you need to know the anatomy parts.

Then have other fish prepared for students to identify in their small groups. As they finish, have them rotate through the tables to complete identifying all of the fish.

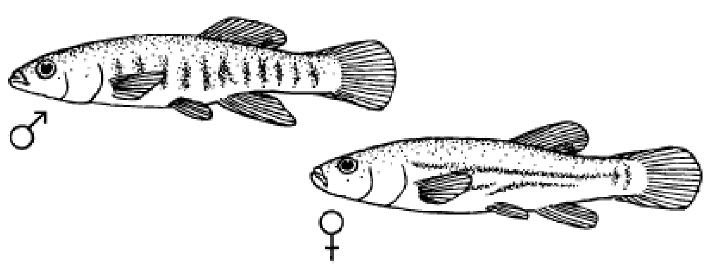
Evaluation

Come back together as a group and discuss the process with everyone. Review what each of the fish were and see if every group correctly identified them. Were some fish harder than others? Why or why not?

Extension

Some students may notice that in identifying some species, there may be some differences within the species' individuals. For example, some striped killifish may be slightly larger than others or have a slight color difference; these are often the effect of sexual dimorphism. When using the recommended Clearwater Dichotomous Key these species' differences in sex are addressed at the end of the key branch as seen in the example of the striped killifish below:

The **striped killifish**, also fairly slender, grows larger than the other two species. Males have dark vertical stripes on their sides; females' stripes are mostly horizontal, more so as they grow older, though there are usually a few vertical stripes near the tail. This species prefers salty water.



Some prompts that can support this conversation are found here:

- Do you know of any organisms where juveniles look different from adults, or males look different from females? (ex. lions, peacock/ foul, ducks)
- Why might males and females look different?
- Genotype vs phenotype - an organism's genes versus its physical appearance. This has to do with evolution and sexual selection, and something we call sexual dimorphism. (What does that mean?)
    - You can break down the word dimorphism as well – di = 2, morphs = changes. Sexual dimorphism can arise in three ways:
        1. Dissimilar sexual functions of males and females
        2. Contests between males
        3. Direct exercise of mate choice

For more on mating, see lesson "Reproduction and Natural Selection".

Classroom Modification Tips

This lesson can be modified in a number of ways to be completed in the classroom. Here are a few ways you can use different medium to conduct the Fish ID lesson:

- Using live fish - if you have the ability to use live fish, this is a great way for students to see the function of each of the different parts they are looking at while identifying. Although this is a great way for students to witness movement of the animals, you can also look at videos online.
- Using photos, videos, and plastic molds/models - this is a great way to conduct this activity with large groups. By using photos and videos, students are able to conduct the identification much easier since they will be able to do things such as counting spines and seeing the shapes of the fins. It is highly recommended to use this method as a way of having students practice.
- Using preserved samples - Although this is a great way of seeing real fish, this method can often become challenging as many specimens begin deteriorating within their medium and it may be difficult to see minor identifying markers.

Vocabulary

Anatomy: A study of the structure or internal workings of something

Dichotomous: Providing two choices

Gills: The respiratory organs of fishes and some amphibians, allowing them to breathe oxygen

Invertebrate: Animal lacking a backbone

Mammal: A warm-blooded vertebrate animal distinguished by the possession of hair or fur, the production of milk by females, and giving birth to live young

Scales: Small bony plates protecting the skin of fish and reptiles and reptiles, typically overlapping one another

Vertebrae: Each of the series of small bones forming the backbone

Standards

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity

HS-LS2-8. Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce

HS-LS4-2. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources,and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment

HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and(3) the extinction of other species.

Materials Needed

- ❏ Paper
- ❏ Clipboards
- ❏ Pencils
- ❏ Dichotomous Keys online version or can be purchased here
- ❏ Different species for identification
- ❏ Live animals will need
  - ❏ Water
  - ❏ Containers and lids
  - ❏ Bubblers
  - ❏ Extra batteries for bubblers

III. Population and Communities

Seining

Estimated Lesson Duration: 90-120 min

Engage

The Hudson River is a habitat for different species and creates a vast ecosystem for different populations. What do you know about the Hudson? What are some creatures you know that live there? How might some of these creatures interact with their environment/ each other?

Explore

Go through properties of the Hudson River. Where does it begin? Where does it end? How long is it? What 3 types of water are present within the river? Estuaries act as nurseries for many species. What lives in the river estuary? (Begins at Lake Tear of the Clouds in the Adirondack Mountains on the shoulder of Mt. Marcy. Ends at the Atlantic Ocean. It's 315 miles long, but the estuary itself is 153 miles of that - where the ocean still influences the river by tidal changes. Tides bring salty water from the ocean at high tide and lower salinity in the estuary at low tide. Within the tidal section of the river at Yonkers some of the organisms we see are American Eel, Mummichogs, Silversides, Striped Bass, Blue Crab, White Perch, Grass Shrimp, Moon Jellies, Comb Jellies.)

Some species are able to move throughout these waters with different salt content and some rely on this movement in order to have offspring. For example, the American Eel generally lives in freshwater rivers for most of its adult life; however, it travels out to the salty Sargasso Sea when they are ready to spawn. The mysterious adult eels never return to the shallow freshwater river, but the babies find their way back to the same freshwater rivers their spawners came from. Because American Eel live in freshwater and travel to saltwater to spawn, they are categorized as **catadromous fish**. Other fish species that live in saltwater throughout their lives and move to freshwaters to spawn are categorized as **anadromous fish**. Do you know of any fish that do either of these aquatic **migrations**? (Think about salmon).

There are also times where we find fish that are technically "freshwater fish" within the brackish areas at CURB. Why do you think this happens? (There are a number of reasons this can happen - fish can become sick and be taken by the tides, large rainfalls can cause rivers to flow at high velocities taking smaller juvenile fish into the **mouth of the river** and out to an estuary, super moons can cause very low tides causing a dilution of the estuary water).

Can do the explore part as a powerpoint or in person at a field trip at CURB.

Explain

There are a lot of ways that we can measure the health of the river. One of the ways we measure the river's health at CURB is by looking at what species are present at different times of the year. Through fishing with a **seine** net, we are able to safely collect animals and information about them. We can compare this information with past data to get a long-term broad picture of river health.

Animals have different characteristics. Some animals are **pollution tolerant** - which means we might see more of them in waters that are not as healthy. Some animals are pollution sensitive, which means they can only survive in healthy water. A lot of times we call these **indicator species**, because their survival (or lack thereof) in an environment can give us insight into how healthy their environment is. Different populations may also be able to live in different conditions better than others through **adaptations**.

As we collect animals from the river, we will look at them carefully within our hands and take note of the different adaptations that help them survive in the Hudson River. What do you anticipate we will see today?

Elaborate

Have students seine with proper adult supervision. Split them into teams of 2 and provide them with waders, if possible. Students can use their skills from the Fish ID lesson to properly identify the organisms they catch. Make sure students document the identified organisms and their accurate population counts on the chart.

Evaluate

Why is it important for us to understand what different species are living within the Hudson River estuary? What can they tell us about the health of the river? Based on the data collected in today's seining, what do you think the water quality conditions of the Hudson River are today?

Extension

Educators leading the groups of students are able to take a copy of their seining data back to their classroom with them (this data will also become available later on our website at www.centerfortheurbanriver.org/research/). This data can be used to complete further analysis and study of the Hudson River's ecology.

Have students work in small groups to look at the way data is represented in four different charts, all taken from the 2019 seining spreadsheet (in the tabs at the bottom of the document): 2019 Running Totals by Month; 2019 % of top 10 Catches; Catch vs Water Parameters; 2019 Salinity and Catch.

Ask the students to try to analyze the chart and come up with some conclusions they might be able to draw from the data. Let them discuss for 8-10 minutes, and then have each group present their data and analysis to the rest of the class. After each presentation, ask the rest of the class to share any questions or ideas about other conclusions they may be able to draw or what additional information may be needed.

Classroom Modification Tips

While the basis of this lesson is doing hands-on seining, it would be best if you can take your students on a field trip either to CURB or to other organizations that do similar fish surveys along the Hudson River. However, even without physically going seining, your class can review historic seining data from CURB's website (www.centerfortheurbanriver.org/research/) to look at trends from previous seines, learn more about the fish and the water quality they prefer, and think about habitat/identification (see lessons on Fish ID and Organism Relationships for more on these topics). The Extension section of this lesson is also a good standalone classroom activity.

Vocabulary

Adaptation: The process of change in a species' behavior, physiology or structure over time

Anadromous Fish: Fish that spend most of their lives in the ocean, but return to rivers to spawn

Catadromous Fish: Fish that spend most of their lives in rivers, but return to the ocean to spawn

Growing Population: a population of a specific species that gets larger over time

Indicator Species: An animal or plant species that can be used to infer conditions in a particular habitat

Migration: Seasonal movement of animals from one region to another

Mouth of the River: The specific place where a river empties out into another body of water

Pollution Tolerant: Organisms that can survive in poor water quality

Seine: A fishing net that sits vertically in the water with floats at the top and weights at the bottom edge, usually attached to poles at each end which are drawn together to ensnare organisms. Generally used on coasts/shorelines.

Shrinking Population: a population of a specific species that is getting smaller over time

Stable Population: a population of a specific species that is neither getting larger, smaller, nor changing the age composition over time

Standards

HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scale

HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem

Materials Needed

- ❏ Seine Net (2)
- ❏ Fish Buckets (lots)
    - ❏ Small plastic buckets or even gallon-sized ziplocs for proper fish ID
- ❏ Bubblers
- ❏ Hand Nets - various sizes
- ❏ Waders - Staff and students
- ❏ Clipboard and pencil
- ❏ Tally Sheet
- ❏ First Aid Kit
- ❏ Fish Measurement Board, if needed

Catch of the Day

School / Group:	Date:	Time of Seine:	Low Tide Time:
Water Temp: Salinity:	pH:	D.O.:	Turbidity:

Name of Species	Tally	Total Number
American eel		
amphipod		
anchovy (bay)		
anchovy (striped)		
Atlantic silverside		
Atlantic tomcod		
banded killifish		
blue crab		
bluefish		
comb jellies		
flounder (summer)		
flounder (winter)		
herring, not shad		
hogchoker		
lion's mane jellyfish		
moon jelly		
mummichog		
naked goby		
northern pipefish		
sand shrimp		
grass shrimp		
soft shell clam		
striped bass		
white perch		
Total Species =		Total Catch =
Hauls		
Pieces of plastic		
Weight of plastic		

IV. Aquatic Systems and Habitats

Water Quality Monitoring

Estimated Lesson Duration: 90 min

Engage

The Hudson River is a dynamic system that changes every day, even hour to hour. What do you know about the Hudson? What changes? Does anything ever stay the same?

Explore

Go through properties of the Hudson River. Where does it begin? Where does it end? How long is it? How do tides influence the river? How might that change some of its properties? What else could influence the river? (Begins at Lake Tear of the Clouds in the Adirondack Mountains on Mt. Marcy. Ends at the Atlantic Ocean. It's 315 miles long, but the estuary itself is 153 miles of that - where the ocean still influences the river by tidal changes. Tides bring salty water from the ocean at high tide and lower salinity in the estuary at low tide. Many tributaries line the Hudson bringing more freshwater in, especially in rainy seasons/ early spring when snow is melting from the mountains. Rain and precipitation also have an impact on the amount of salinity, and other parameters which we'll explore shortly.)

Explain

There are a lot of ways that we can measure the health of the river, and looking at the physical and chemical properties can give us a lot of information. At CURB, we periodically measure the following: temperature, salinity, pH, turbidity, and dissolved oxygen. Which of those do you recognize? Review them all.

Temperature: a measurement of how much heat is in a substance. The tool we use to measure temperature in the river is a thermometer, and the unit is Celsius (scientific temperature measurement) or Fahrenheit (used in the US as general temperature measurement). What do you think the water temperature is right now? Will it be the same as the air temperature, or different? Higher or lower? Why?

Salinity: a measurement of how much salt is dissolved in the water. The tool we use to measure dissolved salt is a hydrometer, and the unit is parts per thousand (ppt), which generally means that if you had a thousand parts of water, how many of those would be dissolved salt ions. For reference, the ocean is generally between 34 and 36 ppt. What do you think the estuary would be? What would that depend on?

pH: a measurement of the acidity of a substance. The tool we use is a chemical test kit, and the unit is a logarithmic scale from 0 to 14. What is neutral? (7). What would you expect the Hudson River to be?

Turbidity: a measurement of the clarity, or really unclarity, of the water. This can also be expressed as a measurement of suspended particles. The tool we use is a turbidity tube, which relies on being able to see a secchi disk at the bottom. The unit of measurement for turbidity from the tube is centimeters, and is a general measurement of how far you could see if you opened your eyes underwater. What causes turbidity? What do you think the Hudson River's turbidity is? Is it low (high visibility) or high (low visibility)?

Dissolved oxygen: a measurement of how much oxygen is dissolved into the water and is available for organisms to breathe. The tool we use is a chemical test kit, using a Winkler titration, and the unit is parts per million, or ppm. Why is dissolved oxygen so important to measure? What might cause DO to go up? Go down?

Elaborate

Have students complete water quality testing of their waterway. Split them into groups and take multiple water samples so each group can have their own bucket, if possible. Use the Water Quality How-to Guide to help students work on their own to complete the testing. Make sure students document their answers in the chart on their worksheet. It is helpful to have the students run through 3 different stations to keep them on time and know what they need to do next. For example, one station can be turbidity, one station temperature and dissolved oxygen, and the last station salinity and pH. They can be at each station for about 10-15 minutes.

Evaluate

Why is it important for us to keep track of these water quality parameters? What can they tell us about the health of the river? Why would long-term monitoring be useful? Use Water Quality Worksheet to have students think about some of the parameters and their fluctuations, uses, and causes. Compare students' readings from their worksheets. Did every group get the same results? Why or why not?

Classroom Modification Tips

Although this lesson requires many different tools of measurement to conduct these water quality tests, a classroom can use the videos provided by CURB via Vimeo to take a closer look at pre-recorded water quality data collection. After taking a look at these videos students can also analyze and look at past data collected by the HRECOS sonde in Yonkers to answer questions on the worksheets.

Vocabulary

pH: a measurement of the acidity of a substance

Salinity: a measurement of how much salt is dissolved in the water

Temperature: a measurement of how much heat is in a substance

Turbidity: a measurement of the clarity, or really unclarity, of the water

Dissolved oxygen: a measurement of the amount of available oxygen dissolved into the water

Standards

HS-LS2-1. Use mathematical and/or computational representations to support explanations of biotic and abiotic factors that affect carrying capacity of ecosystems at different scales

HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and(3) the extinction of other species.

HS-ESS2-5.Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

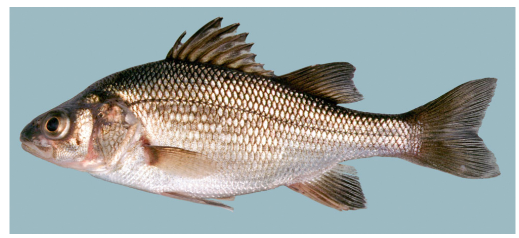
HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Materials Needed

- ❏ Buckets
- ❏ Thermometers
- ❏ Hydrometers
- ❏ pH kits
- ❏ Dissolved Oxygen kits
- ❏ Turbidity Tube
- ❏ Funnel and Small Buckets for Turbidity tube fill
- ❏ Water Quality Data Collection Sheet
- ❏ Clipboards
- ❏ Pencils
- ❏ Towels/Mop
- ❏ Waste Buckets for chemical kits
- ❏ Water Quality How To Cards

Striped bass
Ideal water quality:
8° - 25°C
Marine, freshwater, and brackish water environments
Dissolved oxygen: >5ppm, ideal range is 8 - 10ppm

White perch
Ideal water quality:
Spawning temperatures: between 50° - 60°F
Marine, freshwater and brackish water environments
Dissolved oxygen: >5ppm



Blue crab
Brackish to full saltwater environments
Preferred temperatures between 13° - 20°C
Dissolved oxygen: >2ppm

Bluegill sunfish
Freshwater environments (salinity up to 3.6ppt)
1°C - 36°C
pH range: 6.5 - 8.5
Dissolved oxygen: >5ppm
Turbidity: ≥18cm

IV. Aquatic Systems and Habitats

Sediment and Site Conditions

Duration: 90-120 min

*This lesson has to be done at dead low tide so we can access all parts of the tidal pool and marsh island. Teachers will likely not be able to do this whole lesson in their class, but see note at the end of the lesson for some modification ideas.

Engage

Have you ever thought about what's at the bottom of the Hudson River? What kind of **habitat** do you think it is? Sandy/ rocky/ muddy? We have a **soft-sediment habitat** in the Hudson River, and millions of pounds of **sediment** are washed down from the mountains and **tributaries** every year. In fact, in some places, the sediment is over 150 feet deep before reaching the bedrock that lines the Hudson Valley. What is sediment? (a collection of mud and *detritus* [dead animal and plant matter] that sinks to the bottom of the river). Why might the **benthic** habitat be important for our estuary? (The type of habitat determines what types of organisms are able to live there, and the **ecosystem** it can support). How do the conditions of the water, weather, and air impact the sediment at the bottom of the river?

Explore

How can we delve into the sediment on our shoreline? What timeframe does it represent? Each sediment core shows us a period of time with the items at the bottom being older than the ones on top. How much time does it represent? How could we find that out?

We will also look at the site conditions, to see how our abiotic factors might impact our ecosystem. We will look at things like wind speed, tide, current speed, temperature, and precipitation. How might these factors influence what we find in the sediment?

We're going to set up a series of **quadrats** to take sediment samples from each one, about 2 yards apart, for a total of 5 - 8 sampling areas, or however many quadrats can fit in the marsh/make sense for the number of students in the class. There will be 2 - 3 students working on each quadrant together. Do you think they will all have the same contents?

[Setup for sediment sampling will have the students measure out the whole tide pool section with a long measuring tape, and then split it into 1-meter quadrats an equal distance apart. All students should be in waders and work together to do the measuring - 2 people with the tape measure, and the others dividing up and marking out the quadrant evenly. This will also be good practice for walking in the mud and how tricky it can be. Once the quadrats are set up, educators will go over the worksheet with students to make sure everyone knows how to fill it out, and then demonstrate how to take a proper sediment core sample. Then every group will take a sample and fill out their worksheets, looking at presence, abundance, and absence of materials found in the sediment samples. If there is only one sediment corer, the other groups can work on their site conditions worksheet while waiting to take their core. Make sure the groups measure the core lengths, including the difference between biotic and abiotic sections, and carefully explore the samples so they document everything they find inside.

For site conditions, students will gather on the marsh island to fill out the site conditions worksheet. Put the tide stick into the tidal pool to measure water level changes throughout the program, and make sure to check at the beginning and end of each section to mark the difference. Mark down precipitation and cloud status. Take the air temperature with a thermometer, figure out which direction the wind is blowing and then use the Beaufort scale (also available at end of lesson) to determine wind speed if there is no anemometer. To measure approximate current speed, spread out a tape measure on the ground about 20-30 feet. Have the group try to determine which direction the current is going. Have one student throw a clementine into the water as far as they can, and when it bobs up again, have another student mark on the tape measure where the clementine is. Set a 15 or 30 second timer (depending on how fast the current is moving), and have a second student stand at the point along the tape measure where you see the clementine after the timer goes off. Calculate the distance from point A to point B to get distance traveled per 30 seconds, and then multiply by 2 to get a minute, and multiply by 60 to get the distance traveled per hour.]

Explain

Did every group have the same findings? Which quadrat found the longest biotic sediment section? Which group(s) had any live organisms? Were some more shell- or woody plant-heavy? Were some more sandy than others? Did we all get the same results for site conditions? Was it consistent over time, or did it change from beginning to end?

Elaborate

Have each group take a jar sample in their quadrat to see how they are different/ similar. Set up individual jars with sediment and river water back in the classroom so students can see what happens when sediment sinks to the bottom of the jar of water and when it is mixed/ kicked up again. Let jars settle and look for striation, similarities in samples, differences. Label them so students can match quadrats with location and see what might impact their makeup.

Evaluation

Have students compare their Sediment Data Sheets to try to find the match of contents from the same quadrats if they didn't all sample at the same time. Then, lead a group discussion on findings - how did site conditions impact or influence the sediment findings? What about water quality parameters from earlier? Could they impact the sediment findings? How? Why did different parts of the tidal pool have different findings? What differences might you see if you took samples of the sandy beach? Or the middle of the river? What other things might we be able to measure/ look for if we had different tools? Metals, PCBs, nutrients?

Classroom Modification Tips

It is unlikely that teachers will be able to do this whole lesson unless they bring their students to a field trip at CURB. If that is not possible, teachers can collect sediment samples themselves, whether in small jars or in a larger bucket (making sure there is at least some river water available so the sample doesn't dry out), and have students explore the sediment in small groups in the classroom. You can use hand lenses or microscopes for students to further explore if available. Make sure they are wearing gloves or are able to wash their hands well after the exploration. Once you're done with the sediment, we would recommend returning it to the exact same location you brought it from! They can also do some of the site condition documentation from the classroom window, or if you can bring them to the river they can do most of it from anywhere they can see the water.

Vocabulary

Benthic: Of, relating to, or occurring at the bottom of a body of water

Ecosystem: A biological community of interacting organisms and their physical environment

Habitat: The natural home or environment of an animal, plant, or other organism

Quadrat: a square- or rectangular-shaped area used to study habitats and organisms

Sediment: Matter that settles to the bottom of a liquid

Soft-Sediment Habitat: The mud, silt, and sand that cover a large portion of the world's estuarine benthic environments and provide habitat for many benthic species

Tributary: A river or stream flowing into a larger river or lake

Standards

HS-ESS2-5.Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.

HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem

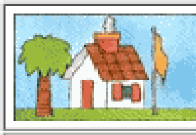
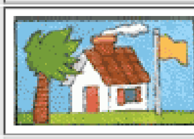
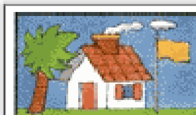
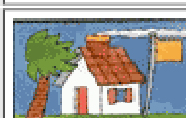
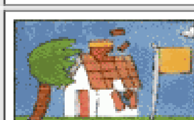
Materials Needed

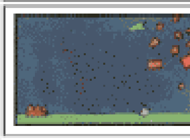
- ❏ Sediment and site conditions worksheet
- ❏ Sediment Reference Sheet
- ❏ Quadrats
- ❏ Sediment Core
- ❏ Dissection Trays
- ❏ Plastic spoons and knives
- ❏ Waders
- ❏ Measure tape
- ❏ Clementines/oranges for tide readings
- ❏ Beaufort scale
- ❏ Thermometers
- ❏ Pencils
- ❏ Clipboards

STORMFAX® WEATHER ALMANAC

Beaufort Wind Scale

Devised by British Rear-Admiral, Sir Francis Beaufort in 1805
based on observations of the effects of the wind

Beaufort number (force)	Wind Speed		Wave height (feet)	WMO* description	Effects observed on the sea	Effects observed on land
	knots	mph				
0	under 1	under 1	-	**Calm**	Sea is like a mirror	
1	1 - 3	1 - 3	0.25	**Light air**	Ripples with appearance of scales; no foam crests	
2	4 - 6	4 - 7	0.5 - 1	**Light breeze**	Small wavelets; crests of glassy appearance, not breaking	
3	7 - 10	8 - 12	2 - 3	**Gentle breeze**	Large wavelets; crests begin to break; scattered whitecaps	
4	11-16	13-18	3½ - 5	**Moderate breeze**	Small waves, becoming longer; numerous whitecaps	
5	17-21	19-24	6 - 8	**Fresh breeze**	Moderate waves, taking longer form; many whitecaps; some spray	
6	22-27	25-31	9½-13	**Strong breeze**	Larger waves forming; whitecaps everywhere; more spray	
7	28-33	32-38	13½-19	**Near gale**	Sea heaps up; white foam from breaking waves begins to be blown in streaks	

8	34-40	39-46	18-25	**Gale**	Moderately high waves of greater length; edges of crests begin to break into spindrift; foam is blown in well-marked streaks	
9	41-47	47-54	23-32	**Strong gale**	High waves; sea begins to roll; dense streaks of foam; spray may begin to reduce visibility	
10	48-55	55-63	29-41	**Storm**	Very high waves with overhanging crests; sea takes white appearance as foam is blown in very dense streaks; rolling is heavy and visibility is reduced	
11	56-63	64-72	37-52	**Violent storm**	Exceptionally high waves; sea covered with white foam patches; visibility further reduced	
12	64 and over	73 and over	45 and over	**Hurricane**	Air filled with foam; sea completely white with driving spray; visibility greatly reduced	
* World Meteorological Organization						

Fujita Scale of Tornado Intensity

HOME

V. Reproduction and Evolution

Reproduction and Natural Selection

Duration: 90 Minutes

Engage

How do aquatic organisms mate and reproduce? Is it different from how land organisms reproduce? What are some methods you know of? Go over **asexual** and **sexual** reproduction - does anyone know of any examples on land or underwater? Do any organisms do both? Why would one method be preferable over another? Go over important words from the vocabulary list at the end of the lesson ahead of time.

Explore

Split the class up into groups to explore different stations around the room - each station will have a set of information cards about one Hudson River species with a specific type of mating process.

Students should have a notebook to write down key ideas they learned using the following outline:

- How it mates: asexual, sexual, or both
- Are males and females different? Are they **hermaphrodites**? Sequential or simultaneous?
- What are the roles of each sex before/ during/ after reproduction?
- Is **fertilization** internal or external?
- Is there **sexual dimorphism**? How is it displayed?
- Do they take care of their youth?
- What are the survival rates of reproduction?

Explain

Students from different groups will pair up to find another classmate whose organism mates in a similar way as theirs. Compare and contrast each organism's methods. If there is time, have them shuffle again to find a classmate whose organism mates in a different way than theirs, and have them compare and contrast again. Do they have any methods in common? What is different? What seems to be better for a species' evolution and adaptations?

Elaborate/Evaluation

Students will play "The Hudson River Dating Game" using the information they gained from the cards in the previous activity, and the questions and answers found in this table: Reproduction Grid.

One student will play the "bachelorx", and three students will represent different species (one species the same as the "bachelorx", and two different ones). The "bachelorx" will also get a copy of their information card for their species to give them a little more information about their organism's reproductive habits. The "bachelorx" will ask each question and try to find his perfect mate from the participant answers. After they guess correctly, a new bachelorx and set of participants will be picked until all the species are covered.

**Additional Instructions and materials are found at the end of this lesson.

Extension

Have students reflect in a group or in a paragraph about reproductive strategies and what seems the best, most difficult, and most complicated. Why do organisms have so many different ways to reproduce? What does that mean about the survival of each species?

Reproduction Vocabulary

(Green vocabulary indicate words associated exclusively to plant reproduction)

Asexual reproduction - the creation of new organisms from only one parent, and therefore does not rely on the fusion (mixing) of *gametes*

Broadcast spawning - the release or deposit of both eggs and sperm from the same species into the water column, where they are fertilized to produce new organisms of that species

Brood - the hatching of a group of eggs from one set of parents

Clones - an identical cell formed through mitosis

Fertilization - the process of combining the female gamete with the male gamete

Gametes - organisms' reproductive cells, usually referring to sperm and/or eggs

Hermaphroditism - Having both male and female sex parts required for reproduction

Incubation - the time needed for any process of development, usually of eggs, to take place

Mitosis - the type of cell division used in asexual reproduction, where one parent splits their cell to make an identical, or clone, cell.

Ovipositor - the body part used by some female organisms to deposit her eggs into a secure location

Pollen - the male gametophyte (the plant version of a gamete)

Pre-copulation - the period of time just before sexual reproduction, usually referring to crustaceans' mating habits

Rhizomes - the underground plant part capable of producing the shoot and root systems of a new plant (one way that plants undergo asexual reproduction)

Sequential hermaphroditism - being able to shift from having male or female sex parts throughout an organism's lifetime as needed

Sexual dimorphism - difference in outward appearance in each sex of the same species. Can show up as body size, ornamentation, coloration, courtship behavior.

Sexual reproduction - the type of creation of new organisms that requires two parents with two different types of *gametes,* sometimes referred to as copulation

Simultaneous hermaphroditism - having both male and female sex parts in an organism's body at the same time

Spawning - the release or deposit of eggs, usually referring to animals living in water that do not give live birth

Sprout - a new small bud, or small growth on a plant

Zygote - a fertilized egg cell that comes from the union of a female gamete with the male gamete

Additional General Vocabulary

Crustacean - an aquatic organism in the arthropod phylum that typically has a hard outer shell, or exoskeleton, i.e. crab, lobster, shrimp, etc. Intertidal zone - the zone on the shore that can be exposed to air at low tide and underwater at high tide

Larvae - the plural of larva, or the first stage in development of many animals occurring after birth or hatching, before the adult form is reached

Mobile organism - an organism that can move around at will, whenever and wherever it wants

Phytoplankton - plants or plantlike organisms that float in the water column

Sessile Organism - an organism that stays in one place and never moves through all or nearly all of its life

Zooplankton - animals that float as plankton in the water column

Standards

HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.
HS-LS2-8. Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce
HS-LS4-2. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment

Materials Needed

- ❏ Notebook/ Clipboard
- ❏ Pencil
- ❏ Information Cards

Blue Crab

Sexual dimorphism: females have a wide triangular-shaped modified tail (telson), and tend to have red claw tips, whereas males have a skinny telson and blue claw tips

Sexual reproduction occurs after a several-day pre-copulation period where the male performs a mating dance, and when chosen, clutches and guards the female until she is ready to shed her hard shell. This molting enables her to mate with the male safely. After several hours, the male pushes his spermatophores into a specialized sperm pouch in the female. After mating, the male will guard the female once more until her shell hardens, and then she swims to saltier waters.

Childcare: the female keeps the males' sperm viable until she is ready to lay her eggs, anywhere from two to nine months later. Females lay on average 2 million eggs in full ocean water, away from males, because males would likely eat their own larvae (babies) if they had the opportunity. Some females can lay up to 8 million eggs at once. The larvae float as zooplankton until they reach the estuary where they start to grow into adulthood. Neither male nor female blue crabs care for their young.

Larval survival: Only one out of every million larvae hatched will live to adulthood

Eastern oyster

Sexual **dimorphism**: You cannot tell the difference between a male and female oyster just by looking at their shells, meaning there is no dimorphism. Oysters are **sequential hermaphrodites**, meaning they can have both male and female sex parts at different stages of their lives. Most oysters start out with male parts, because sperm take less energy to produce than eggs. If an oyster gets enough food and has a good location in the oyster reef, it will likely grow female gonads in order to produce eggs.

Oysters perform **broadcast spawning**, meaning they shoot out their gametes (eggs or sperm) into the water. Though they don't physically connect their bodies, this type of mating is still considered **sexual reproduction**. Once the eggs and sperm meet in the water, they are fertilized. After several weeks of development as free-floating zooplankton, the larvae eventually settle on a hard surface to become adults. They stay in that same place for the rest of their lives, making them sessile species.

Childcare: oyster larvae are on their own after fertilization, which is why so many eggs and sperm are produced each season.

Larval survival: Of the nearly 100 million eggs a female oyster can produce in one season, fewer than 1% of them will become adults.

Lined seahorse

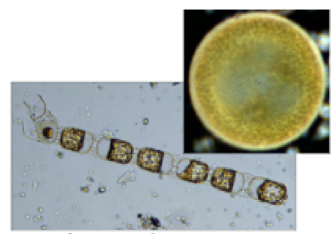
Sexual dimorphism: The main difference between male and female seahorses is that males have an egg pouch and their front anal fin is in a slightly different Location, though it can sometimes be tricky to tell them apart.

Seahorses perform **sexual reproduction**, starting with an elaborate courtship dance. When ready to mate, the female deposits 250-650 eggs through an ovipositor into the male's egg pouch, whereby he fertilizes them and guards them for about three weeks until he gives a live birth.

Childcare: seahorse males guard the eggs in their pouch until hatching, and then care for the young for the first few weeks of their lives. The babies hatch as miniature seahorses; there are no separate larval stages.

Larval survival: For each brood of usually several hundred eggs, only a few will survive into adulthood

Diatoms (phytoplankton)



Diatoms do both **asexual** and **sexual reproduction**, depending on their size.

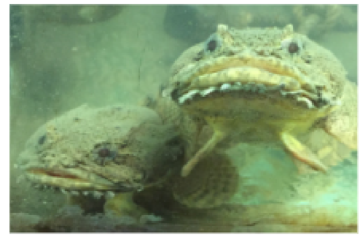
Most diatoms start off with **asexual** cell division by mitosis to split off part of themselves and create a new daughter cell.

Once the size of the daughter cell is less than half of their original size, they undergo **sexual** reproduction because they can't do their life functions being that small. In general, they have sperm that can move around (mobile) and eggs that can't (immobile). Scientists actually don't know why some are male and others are female. Eggs are fertilized inside of the female diatom and once the zygote forms it pushes out of the "mother".

There is no **childcare.** Most diatoms only actually live a few days!

Larval survival: Asexual reproduction has a very high success rate, and scientists are less sure about the success of sexual reproduction in diatoms. However, sexual reproduction is generally healthier for species in the long run because of genetic mutations through evolution.

Oyster toadfish



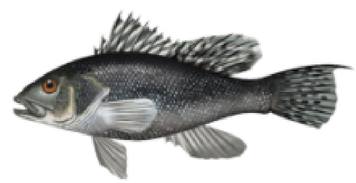
Oyster toadfish don't have any outward differences between males and females, so they don't exhibit any **sexual dimorphism**.

Sexual reproduction occurs in the spring months, when a male makes a nest and practices his foghorn-like mating call to attract a female. She lays her 200-300 unusually large and sticky eggs (for Hudson River fish) in the nest and swims away, leaving the male to fertilize the eggs.

Childcare: Male toadfish guard the fertilized eggs in his nest for about a month until they hatch, fanning them with water regularly to clean off sediment and debris. He continues to care for the young larvae for 3-4 weeks after they're born.

Larval survival: Scientists are unsure how many larvae survive to adulthood. In some labs, 64% of larvae succeed, though that number is likely much lower in the wild, because toadfish are often cannibalistic.

Black sea bass



Black sea bass are **sequential hermaphrodites**, meaning they have both male and female sex parts at different parts of their life. They also exhibit **sexual dimorphism** in each phase: males in mating season turn bright blue colors. Most black sea bass start off as females, and as they mature most (but not all) become male, usually after mating.

Sexual reproduction occurs in late spring-summer, and females can produce 30,000 to 500,000 eggs in a single season.

Childcare: black sea bass eggs hatch in coastal waters, and the larvae live on their own without any parental supervision. Young larvae migrate to estuaries to live for the first few years of their lives

Larval survival: Very few larvae make it to adulthood, which is why females produce so many eggs!

Mummichogs

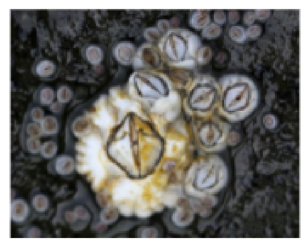
Mummichogs have **sexual dimorphism,** with females growing to be larger than males, and usually with a slightly lower number of stripes along their sides. During mating season, males become aggressive and change the color of some of their fins and/or exhibit a dark dot on the side of their dorsal fin.

Mummichogs engage in **sexual reproduction** during their mating season, usually late spring through summer. Females lay their eggs in little nooks like oyster shells during high tide, and can spawn up to 8 times per season with up to 460 eggs per brood. The male releases his gametes on the eggs to fertilize them. The eggs must be exposed to air before they hatch at the next high tide.

Childcare: Mummichogs do not care for their young, who hatch as small larvae and stay in the intertidal zone for close to 2 months before they begin schooling with adults.

Larval survival: mummichog larvae have a less than 5% success rate into adulthood.

Northern rock barnacle



Barnacles are sessile crustaceans, and are **simultaneous hermaphrodites**, meaning they have both male and female sex parts at the same time. They cannot fertilize themselves, so they still need to find a partner.

Barnacles perform **sexual reproduction** in a very different way than most sessile organisms. Unlike bivalves that do broadcast spawning, barnacles that perform as males have a penis that they use to both find and mate with a partner. Since they cannot move, the penis is often up to 8 times the length of the body, helping the barnacle successfully find a female mate. The eggs are fertilized inside of the female barnacle.

Childcare: barnacles keep their fertilized eggs in their shells until they hatch as free-swimming larvae into the water column. After a few weeks, the barnacle larvae cement themselves onto a hard surface, usually near other barnacles, and settle there for life. There is no childcare for barnacle larvae.

Larval survival: Barnacles lay up to 10,000 eggs per brood and have very low survival rates into adulthood

Eelgrass

As a plant, eelgrass do both **asexual** and **sexual reproduction.** For **asexual** methods, they sprout rhizomes that grow into clones to help form bigger seagrass beds.

Sexual reproduction occurs in the summer when females sprout flowers that get fertilized by pollen passing through the water. The fertilized flowers form buds that break off and send seeds into the water column, where they root and eventually sprout in other places.

Childcare: Plants normally do not have any means to do childcare, though the rhizomes that grow clones near the parent plants make it so that eelgrass grow together in large meadows.

Larval survival: The clones (rhizomes) of eelgrass generally have high success rates, and depending on environmental conditions, seeds often sprout in high numbers after being buried in the sediment.

Wood ducks

Wood ducks demonstrate **sexual dimorphism** by their plumage (feathers): males grow bright-colored feathers on their heads in mating season, whereas females have a duller, brown plumage throughout their bodies.

Wood ducks perform **sexual reproduction** by pairing up in the late winter and spawning in early spring. Females lay 15 eggs on average, fertilized internally by the male before laying them in nests. They usually lay their eggs in empty tree cavities (holes) on the waterfront.

Childcare: Wood duck eggs hatch after about 4 weeks, with females laying on the nest to help incubate them, and the ducklings take to the water soon after they are born. They stay with their mother until they can fly, which is usually around 8 weeks.

Larval survival: Wood ducklings have a high mortality rate, and not many make it to adulthood.

CURB mini lesson: The Hudson River Dating Game

The Hudson River Reproduction Game is modeled after the once popular "*The Dating Game*" showcased on television in the 60s and 70s. These instructions are intended to help you set up the game in your classroom.

Game Objective: Studio audience members (students not participating in the game round) have to carefully listen to the identity clues given by the game participants to determine which contestant matches with the "bachelorx".

Game Setup:
One student will be chosen to be each round's "bachelorx" looking for their match. This student should be given a print out of <u>one</u> of the animals found in the Reproduction Cards for Lesson. This contestant will sit on one side of the room and can inform audience members (students not participating in the game round) of their identity once the game begins. This student will receive and hold onto a copy of the "Bachelorx Card" found on the last page of the Reproduction Game Materials.

Three other students will be chosen to be that round's "contestants" and will sit bunched on another side of the room (to make it fun, an obstruction can be placed between the bachelorx and the contestants. At random, the educator can give these students one of the animal roles found in the Reproduction Game Materials. *THEY MUST KEEP THEIR IDENTITY TO THEMSELVES!* Contestants should take a moment to study their role. Their card will provide them with answers to the questions being presented, but it is the contestant's role to bring the animal personality to life. Each animal is provided with sample personality traits on their cards; however, students are welcome to use their imagination and bring their animal to life.

Either an educator or chosen student (cannot be bachelorx nor contestant) can play the role of gameshow host. The role of the host is to move the game along and ensure the audience has the information they need at hand.

Playing the Game:
The host will begin by welcoming everyone to the "Hudson River Dating Game"! They will introduce the bachelorx and ask the student in this role to tell us a little bit about themselves (here they can disclose their animal and possibly one or two facts they have learned from their card). The host will then introduce the players as "Contestant 1, 2 and 3." The contestants are able to wave and smile but are not allowed to give any information at this time.

The host will then prompt the bachelorx to read aloud the first question.

Once the question is read aloud, the host will ask each of the contestants to provide us with the answers on their card to the best of their ability with their animal personality.

(Note: Audience members are encouraged to take notes, laugh, and applaud, when appropriate.)

The question and answer portion of the game continues until each of the four questions are answered by each of the three contestants.

Ending the Game:
Once we have received all of the information from all playing the game, the bachelor will attempt to pick their matching contestant. The audience members will use the knowledge they received from the reproduction lesson to tell the bachelor if they are correct, and also determine the identity of the other contestants.

Once identities are revealed, all those playing can become audience members for the next round, where new identities are given to students who have not participated yet. It is recommended at least two rounds of the game are played. The provided cards allot for three rounds.

Photo Credit: Vanmark Scenic

Role:	***MAIN PERSONALITY TRAIT***	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***
Blue Crab	Fiery, feisty, fast	A several day pairing where the male holds me until I'm just soft enough for reproducing	The first thing I could get my claws on	I'd have to have some rocks and maybe some salt water...	Generally, I lay my eggs far away from where I mated to protect them from being eaten by their father!

CUT

Role:	***MAIN PERSONALITY TRAIT***	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***
Eastern Oyster	Some would call me lazy, but I like to think it's patience	Well, that would depend on where I'm sitting in my reef. Now I might look for some strong eggs to help fertilize, but in a few years I might be the ones making the eggs	I'm a strict herbivore, so phytoplankton only for both of us!	I need to have a community. Although I am a homebody - I don't mind living in close quarters with others.	The babies are always welcome back home - it's like momma always said - home is where the reef is!

Role:	***MAIN PERSONALITY TRAIT***	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***
Lined Seahorse	I'm not a very good swimmer, but I'm super cute so I like to think that makes up for other lacking traits	Someone I can wrap tails with for a season, at least	At least a thousand or two amphipods sound good, don't you think?	I need a lot of support, so preferably somewhere I can wrap my tail around to help hold me tight	I need my male partner to carry all of the weight of parenting - literally.

CUT

Role:	***MAIN PERSONALITY TRAIT***	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***
Diatoms (Phytoplankton)	I have a split personality, because, get this, I split myself into new selves as often as I need to!	If absolutely necessary, I try to find someone who looks an awful lot like me	I can survive on sunlight, pure and simple	A place to float, gently, in the sunlit-tipped waves	There is no real childcare in my life. I mean - I am my own child so how can I parent myself?!

Role:	***MAIN PERSONALITY TRAIT***	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***
Oyster Toadfish	Very monotone	A deep, booming voice like a foghorn is my number 1 interest	Oh, whatever happened to unknowingly swim by	Something at the bottom of the estuary, with something cozy to nest in!	I depend on my partner to do all of the work - build the nest, watch the eggs, fan them continuously... so if they don't survive - it's all his fault.

CUT

Role:	***MAIN PERSONALITY TRAIT***	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***
Black Sea Bass	Comfortable with change and gender fluidity.	I look for wisdom and age. Right now most of us are female, but I'm more interested in an older and stronger male, with nice blue coloring along his face.	Fish. As many fish as I can find.	I like an open everything concept - no walls, no rocks, nothing. I just need open space.	Well, since we have a high mortality rate at conception it's hard to get emotionally attached. We just try to give them the best chances by finding the quietest coastal waters.

Role:	***MAIN PERSONALITY TRAIT***	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***
Mummichogs	I'm afraid of deeper waters, so I tend to stay in the shallows for as long as I can	A nice aggressive male when the tide is high	Something small in our marsh sounds romantic, don't you think?	I want to be sure we are prepared for winter, so a shallow place with a decent amount of muddy sediment is preferred.	I am not big on babies; but they are welcome to join the school if they must when they're older.

CUT

Role:	***MAIN PERSONALITY TRAIT***	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***
Northern Rock Barnacle	I love rocks.	The bigger the better, and as close as they can be!	Oh, anything I can grab with my feathery tentacles that happens to be floating by	Rock.	I am a hands off parent, whether I'm female or male - I am sure they will pick the right rock that is for them.

Role:	***MAIN PERSONALITY TRAIT***	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***
Eelgrass	Green	I love myself very much, so for a lot of the year I'm enough. When I'm not, I spread my seeds to the surface and see what happens!	Oh, I can literally survive on sunshine and smiles	I need sunshine! So bring on the sunroof!	I say let the child wander and they will eventually find their own way. If not, I'll just shoot out a rhizome and make my own child that looks exactly like me.

CUT

Role:	***MAIN PERSONALITY TRAIT***	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***
Wood Duck	Overprotective helicopter parent	I'm looking for someone who will be as serious about having babies as I am. This season, at least.	I'm an equal opportunity eater, though I generally eat plants and moss, with the occasional bug as a delicacy	For my babies? Give me a little hole in a tree. Me, I just need some wide open space to let me paddle to my heart's content	My babies are my little shadow. They need me and I love every second of it. From swimming in calm water to digging in the mud for some yum grub - I just can't get enough of them!

BACHELORX CARD	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***

CUT

BACHELORX CARD	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***

CUT

BACHELORX CARD	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***

CUT

HOST CARD	***What do you look for on a first date?***	***If you were ordering dinner for the both of us, what would you order?***	***If I could build you the perfect home, what is the one thing you'd HAVE to have?***	***There are many ways species parents their offspring, what kind of parent would you be?***

VI. Human Impacts and Pollution

Enterococcus

Duration: 30-90 Minutes

Engage

Humans have a huge impact on the Hudson River - some impacts have been positive and some have been negative. What are some negative impacts you can think of? What are some specific kinds of pollution you know of?

Explore

What do we think about when we think about the word “Bacteria”? What are some thoughts that come to mind? What do bacteria need in order to survive? How do bacteria enter the natural environment?

Educators can use these videos found here (English/ Spanish) to introduce the concept of the bacteria Enterococcus on the Hudson River.

Explain

There are a lot of different ways we can explore and test the Hudson River’s health. There are some common water quality **parameters** that are looked at such as temperature, salinity, turbidity, pH, and dissolved oxygen. Why are these parameters important in understanding a river’s health? What can cause the water chemistry of a river to change?

Pollution in our watershed can have lasting impacts on the ecosystem, living organisms, and human health. Some pollution types that are common within the Hudson River environment are: *litter/plastic, chemicals, and* **combined sewage overflows** *(CSO’s)*. In many cities throughout the world, CSO’s are a way to address the problem of sewage and the capacity of treatment plants in areas of high populations. As populations in cities grow, it becomes increasingly difficult to address sewage infrastructure and capacity.

Trunk pipes within CSO systems transport waste from general sewage pipes connected to homes and businesses and storm drainage from the street to the treatment plant. On dry weather days, the amount of waste in the pipe is enough to be handled at the treatment facility. When rain enters the connected trunk pipe at a high volume (think of downpour rain events), the treatment plant won’t be able to take in the large volume of rain and sewage without there being backup. To ensure people don't have sewage coming back up their drains, a sensor triggers a release system and the mixture moves into a local waterbody from the trunk pipe (oftentimes it is released into a local river). Sometimes this mixture is partially treated with chlorine and sometimes it is not - this is determined by local law.

At CURB, testing for **enterococcus** is an important way to understand the river's health. Although we are aware of legal releases of sewage in CSO events, there are also other ways sewage enters our local rivers such as leaking pipes and illegal sewage connections. Together we will collect and process river samples together.

The following is the complete process and explanation of the enterococcus determination process. This process can be summarized in the *explain* portion of the lesson and further explained in detail in the *elaboration* portion.

1. Ensure **Quanti-tray** sealer and **incubator** are placed in the on position before the sample collection.
2. Wearing gloves, collect 100mL of our sample water, up to the bottle line. Don't forget to not touch the inside lip of the bottle and place your bottle cap carefully inside upward on a dry surface while filling your bottle. This bottle will need to stay in a cold insulated bag until you get back to the lab - you have up to six hours to get the sample processed. Write down the time you took the sample on the top of the bottle.
3. Before we start processing, the tops of the bench should be sterilized with alcohol or bleach based wipes or solution and allowed to dry. We will then prepare all of our materials - each sample will need one of the following:
    a. **Pipette** and pipette tip (do not remove tip from box until we are moving our 10mL sample)
    b. **Enterolert** packet
    c. Sodium Thiosulfate processing bottle
    d. Deionized water
    e. Quanti-tray
    f. Marker
4. Wearing a new set of gloves, we will prepare to pipette 10mL of our sample into the sodium thiosulfate bottle. The CURB pipette is set to 5mL, so we will need to fill 2 pipettes. Before we move our sample, we need to vigorously shake our sample bottle (make sure the cap is on correctly). When pipetting, press down before placing it into the sample to the point of pressure is felt - keep this held at this point. Place the pipette tip into the shaken sample and release the pipette hold without having the tip touching any part of the bottle - tip should be as close to the middle of the sample as possible. Press down completely with the pipette tip lingering over the sodium thiosulfate bottle. Use one pipette tip per sample bottle.

5. Fill the sodium thiosulfate processing bottle with 10mL of sample with 90mL of deionized water or up to the fill line.
6. We are going to now “feed” our bacteria with the proprietary enterolert. Open the packet away from your face and place the content into our processing bottle.
7. Cap processing bottle and give it a rigorous swirl. If you are processing more than one bottle, be sure your processing bottles are labeled to reduce inaccuracy.
8. Label Quanti-tray backing with name of site, collection date and time, and any other pertinent information needed. Gently pressing on the edges of the Quanti-tray opening without touching the inner of the tray, fill the labeled quanti-tray with shaken contents of the processing bottle. Flick Quanti-tray window to allow bubbles to reduce.
9. Place Quanti-tray into the rubber holder and run through the Quanti-tray sealer.
10. Record time of incubation and place into incubator for 24-28 hours.

The proprietary Enterolert system is used as a way that is consistent with EPA testing standards for primary contact water. The current federal standard for safe interaction with enterococcus in water is less than 35 MPN as the **geometric mean**. The Enterolert results are measured in a statistical system that gives us a measurement in **MPN** or **Most Probable Number**. If bacteria are present, enterococcus specific bacteria will metabolize the Enterolert powder and the enzymes will cause the bacteria to glow a bright blue under a blacklight.

After we have given the sample 24 hours to metabolize the Enterolert, place the processed Quanti-tray into the blacklight cave to read results. You will need to count and record the number of small wells that are glowing and count and record the number of larger wells on a sheet. It is good practice to also record the time you have read the plates. Because this is a statistical test, we will need to compare our results of glowing wells to the IDEXX conversion sheet (conversion sheet and download can be found: https://www.idexx.com/en/water/resources/mpn-generator/).

Elaborate

Have students do enterococcus testing of their waterway. Split them into groups and take multiple water samples so each group can have their own bucket, if possible. Use **Enterolert Procedure Guide** (www.idexx.com/files/enterolert-procedure-en.pdf) to help students work on their own to do the testing. Make sure students document appropriate information on their worksheet.

Evaluate

Activity: Review *MPN worksheet* from summer 2019, and have students find MPNs of all data points to practice finding MPN and thinking about results.

Start by reviewing a photo of a quanti-tray and review the way scientists use the glowing wells to determine the Most Probable Number (MPN) of colonies of bacteria in a sample of water. The large wells number 49 total (don't forget the biggest one on top!) and the smaller wells number 48 total. Count the number of wells that are actually glowing blue for both the large and small wells and mark them down. Then use the MPN chart to find the MPN where the number of glowing large wells meets up with the number of small wells. Because we dilute our sample, we need to multiply any result by 10 (just move the decimal point over one space to the right). For instance: 7 large wells and 4 small wells glowing would give us an MPN of 118.

Now, focus on the *MPN Worksheet* and begin by telling students that these are real data points collected by high school students at CURB. Ask students what they think they're looking at. When was the data analyzed? Where? (On the floating dock at the Yonkers Paddling and Rowing Club, just off the shore of Habirshaw Park/CURB, in the summer of 2019.) Have students work independently or in pairs to find the MPN of each of the samples taken, and make sure they multiply by 10 for the final result (also, remember that any MPN higher than 35 is considered unsafe for swimming, so they can keep that in mind as they work on their results).

When looking at enterococcus data in rivers, we want to compare our results to current local, state and federal government standards. At CURB in Yonkers, we are a few miles north from the sewage treatment center and next door to the sewage pump station, so it is important to take in additional information that can help us look at the whole picture of water quality. Review answers to questions on the back of the worksheet and talk through answers with students. This worksheet will prompt students to think through what additional parameters and information is needed to tell a bigger story of why the entero levels are high/low.

Extension

Enterococcus data is often used by organizations and government officials to create policies that protect, regulate, and advocate for local waterways. Using the Hudson River as a case study, use some of the following prompts as a starting point of how enterococcus in water impact the everyday life of communities along rivers:

- What are the different enterococcus regulations that are in place in the lower river areas compared to northern areas?

- Are there differences in regulations within saltwater v. freshwater?
- What factors are taken into account for these different regulations?
- What are some current projects that are helping reduce the amount of enterococcus present in local waterways?

Classroom Modification Tips

While lots of expensive and specialized materials are needed for the full lesson, you can still do the Engage, Explore, Explain, and Evaluate sections of this lesson in the classroom. Students always love to learn about where their waste goes, and it is possible to review and understand the enterococcus data without doing the actual collection and processing if that is not accessible to your classroom.

Vocabulary

Combined Sewage Overflow (CSO): Sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe

Enterococcus: A type of bacteria that indicates fecal presence

Enterolert: A nutrient indicator designed by the IDEXX company to detect enterococci

Geometric Mean: A mean (or average), which indicates the central tendency by using the product of their values instead of their sums - by doing so we create a better picture of the average including the use of outliers

Incubator: A piece of lab equipment that is enclosed and proves a controlled environment, usually set to a specific temperature

Most Probable Number (MPN): A statistical method used to estimate the viable numbers of bacteria in a sample

Parameter: Chemical, physical, biological properties that are tested

Pipette: Slender graduated tube used in a lab for measuring and transferring specific amounts of liquid from one container to another

Pollution: The introduction of harmful substances or products into the environment

Quanti-Tray: Specialized tray created by the IDEXX company to indicate bacteria numbers based on those that turn a bioluminescent color

Trunk Pipe: A centralized pipe that travels a long distance, often to waste water treatment plants, while collecting the contents of other, usually smaller local pipes

Standards

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity

HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and(3) the extinction of other species.

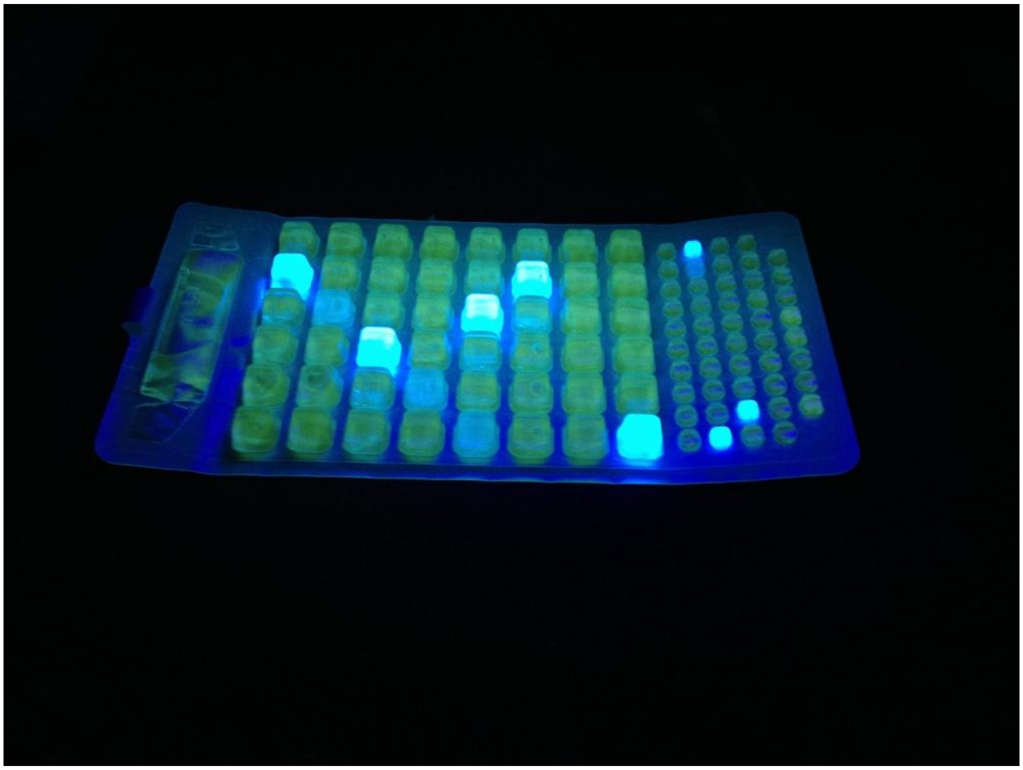
HS-ESS3-4.Evaluate or refine a technological solution that reduces impacts of human activities on natural systems

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Materials Needed

- ❏ Sample collection bottles
- ❏ Sample processing bottles
- ❏ Entero-lert
- ❏ Pipette tips and pipette
- ❏ Deionized water
- ❏ Quanti-tray
- ❏ Sealer
- ❏ Incubator
- ❏ Blacklight Reader and conversion sheet
- ❏ Enterococcus activity data sheet
- ❏ Lab gloves

Sample Quanti-Trays



SARAH LAWRENCE COLLEGE

CENTER FOR THE URBAN RIVER AT BECZAK

Yonkers Paddling and Rowing Club Enterococcus Sampling Data

Date	Time	# small wells	# large wells	MPN
7/8/2019	10:22 AM	0	9	
7/8/2019	12:57 PM	0	7	
7/9/2019	11:08 AM	0	2	
7/10/2019	1:01 PM	1	2	
7/12/2019	10:24 AM	0	4	
7/12/2019	11:08 AM	2	19	
7/15/2019	10:09 AM	0	0	
7/15/2019	11:05 AM	0	1	
7/16/2019	10:37 AM	0	3	
7/16/2019	1:08 PM	0	2	
7/17/2019	1:08 PM	0	1	
7/19/2019	10:28 AM	16	42	
7/19/2019	11:09 AM	2	26	
7/19/2019	1:05 PM	0	6	
7/22/2019	1:05 PM	1	6	
7/23/2019	10:14 AM	41	49	
7/23/2019	11:15 AM	43	48	
7/23/2019	1:07 PM	42	49	
7/24/2019	10:26 AM	3	20	
7/24/2019	1:08 PM	0	1	
7/26/2019	1:20 PM	0	0	
7/29/2019	1:08 PM	1	2	
7/30/2019	11:08 AM	0	1	
7/31/2019	10:20 AM	1	1	
7/31/2019	1:11 PM	0	0	
8/2/2019	10:18 AM	0	8	
8/2/2019	11:11 AM	1	7	
8/5/2019	11:08 AM	2	9	
8/5/2019	1:05 PM	0	1	
8/6/2019	10:16 AM	0	0	
8/6/2019	11:08 AM	1	6	
8/6/2019	1:37 PM	0	4	
8/7/2019	10:07 AM	0	1	
8/7/2019	11:12 AM	0	0	
8/7/2019	1:06 PM	0	1	
8/9/2019	10:18 AM	0	2	
8/9/2019	11:18 AM	1	1	

Entero data questions:

1) Do you notice anything interesting about some of these results? What days in particular stand out?

2) Are there any days where the bacterial counts rise or fall within a few hours? What could be causing this?

3) What other information might you want to see alongside these data in order to tell a fuller story about the Hudson River?

IDEXX Quanti-Tray®/2000 MPN Table *(per 100ml)*

# Large Wells Positive	# Small Wells Positive: 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	<1	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.1	15.1	16.1	17.1	18.1	19.1	20.2	21.2	22.2	23.3	24.3
1	1.0	2.0	3.0	4.0	5.0	6.0	7.1	8.1	9.1	10.1	11.1	12.1	13.2	14.2	15.2	16.2	17.3	18.3	19.3	20.4	21.4	22.4	23.5	24.5	25.6
2	2.0	3.0	4.1	5.1	6.1	7.1	8.1	9.2	10.2	11.2	12.2	13.3	14.3	15.4	16.4	17.4	18.5	19.5	20.6	21.6	22.7	23.7	24.8	25.8	26.9
3	3.1	4.1	5.1	6.1	7.2	8.2	9.2	10.3	11.3	12.4	13.4	14.5	15.5	16.5	17.6	18.6	19.7	20.8	21.8	22.9	23.9	25.0	26.1	27.1	28.2
4	4.1	5.2	6.2	7.2	8.3	9.3	10.4	11.4	12.5	13.5	14.6	15.6	16.7	17.8	18.8	19.9	21.0	22.0	23.1	24.2	25.3	26.3	27.4	28.5	29.6
5	5.2	6.3	7.3	8.4	9.4	10.5	11.5	12.6	13.7	14.7	15.8	16.9	17.9	19.0	20.1	21.2	22.2	23.3	24.4	25.5	26.6	27.7	28.8	29.9	31.0
6	6.3	7.4	8.4	9.5	10.6	11.6	12.7	13.8	14.9	16.0	17.0	18.1	19.2	20.3	21.4	22.5	23.6	24.7	25.8	26.9	28.0	29.1	30.2	31.3	32.4
7	7.5	8.5	9.6	10.7	11.8	12.8	13.9	15.0	16.1	17.2	18.3	19.4	20.5	21.6	22.7	23.8	24.9	26.0	27.1	28.3	29.4	30.5	31.6	32.8	33.9
8	8.6	9.7	10.8	11.9	13.0	14.1	15.2	16.3	17.4	18.5	19.6	20.7	21.8	22.9	24.1	25.2	26.3	27.4	28.6	29.7	30.8	32.0	33.1	34.3	35.4
9	9.8	10.9	12.0	13.1	14.2	15.3	16.4	17.6	18.7	19.8	20.9	22.0	23.2	24.3	25.4	26.6	27.7	28.9	30.0	31.2	32.3	33.5	34.6	35.8	37.0
10	11.0	12.1	13.2	14.4	15.5	16.6	17.7	18.9	20.0	21.1	22.3	23.4	24.6	25.7	26.9	28.0	29.2	30.3	31.5	32.7	33.8	35.0	36.2	37.4	38.6
11	12.2	13.4	14.5	15.6	16.8	17.9	19.1	20.2	21.4	22.5	23.7	24.8	26.0	27.2	28.3	29.5	30.7	31.9	33.0	34.2	35.4	36.6	37.8	39.0	40.2
12	13.5	14.6	15.8	16.9	18.1	19.3	20.4	21.6	22.8	23.9	25.1	26.3	27.5	28.6	29.8	31.0	32.2	33.4	34.6	35.8	37.0	38.2	39.5	40.7	41.9
13	14.8	16.0	17.1	18.3	19.5	20.6	21.8	23.0	24.2	25.4	26.6	27.8	29.0	30.2	31.4	32.6	33.8	35.0	36.2	37.5	38.7	39.9	41.2	42.4	43.6
14	16.1	17.3	18.5	19.7	20.9	22.1	23.3	24.5	25.7	26.9	28.1	29.3	30.5	31.7	33.0	34.2	35.4	36.7	37.9	39.1	40.4	41.6	42.9	44.2	45.4
15	17.5	18.7	19.9	21.1	22.3	23.5	24.7	25.9	27.2	28.4	29.6	30.9	32.1	33.3	34.6	35.8	37.1	38.4	39.6	40.9	42.2	43.4	44.7	46.0	47.3
16	18.9	20.1	21.3	22.6	23.8	25.0	26.2	27.5	28.7	30.0	31.2	32.5	33.7	35.0	36.3	37.5	38.8	40.1	41.4	42.7	44.0	45.3	46.6	47.9	49.2
17	20.3	21.6	22.8	24.1	25.3	26.6	27.8	29.1	30.3	31.6	32.9	34.1	35.4	36.7	38.0	39.3	40.6	41.9	43.2	44.5	45.9	47.2	48.5	49.8	51.2
18	21.8	23.1	24.3	25.6	26.9	28.1	29.4	30.7	32.0	33.3	34.6	35.9	37.2	38.5	39.8	41.1	42.4	43.8	45.1	46.5	47.8	49.2	50.5	51.9	53.2
19	23.3	24.6	25.9	27.2	28.5	29.8	31.1	32.4	33.7	35.0	36.3	37.6	39.0	40.3	41.6	43.0	44.3	45.7	47.1	48.4	49.8	51.2	52.6	54.0	55.4
20	24.9	26.2	27.5	28.8	30.1	31.5	32.8	34.1	35.4	36.8	38.1	39.5	40.8	42.2	43.6	44.9	46.3	47.7	49.1	50.5	51.9	53.3	54.7	56.1	57.6
21	26.5	27.9	29.2	30.5	31.8	33.2	34.5	35.9	37.3	38.6	40.0	41.4	42.8	44.1	45.5	46.9	48.4	49.8	51.2	52.6	54.1	55.5	56.9	58.4	59.9
22	28.2	29.5	30.9	32.3	33.6	35.0	36.4	37.7	39.1	40.5	41.9	43.3	44.8	46.2	47.6	49.0	50.5	51.9	53.4	54.8	56.3	57.8	59.3	60.8	62.3
23	29.9	31.3	32.7	34.1	35.5	36.8	38.3	39.7	41.1	42.5	43.9	45.4	46.8	48.3	49.7	51.2	52.7	54.2	55.6	57.1	58.6	60.2	61.7	63.2	64.7
24	31.7	33.1	34.5	35.9	37.3	38.8	40.2	41.7	43.1	44.6	46.0	47.5	49.0	50.5	52.0	53.5	55.0	56.5	58.0	59.5	61.1	62.6	64.2	65.8	67.3
25	33.6	35.0	36.4	37.9	39.3	40.8	42.2	43.7	45.2	46.7	48.2	49.7	51.2	52.7	54.3	55.8	57.3	58.9	60.5	62.0	63.6	65.2	66.8	68.4	70.0
26	35.5	36.9	38.4	39.9	41.4	42.8	44.3	45.9	47.4	48.9	50.4	52.0	53.5	55.1	56.7	58.2	59.8	61.4	63.0	64.7	66.3	67.9	69.6	71.2	72.9
27	37.4	38.9	40.4	42.0	43.5	45.0	46.5	48.1	49.6	51.2	52.8	54.4	56.0	57.6	59.2	60.8	62.4	64.1	65.7	67.4	69.1	70.8	72.5	74.2	75.9
28	39.5	41.0	42.6	44.1	45.7	47.3	48.8	50.4	52.0	53.6	55.2	56.9	58.5	60.2	61.8	63.5	65.2	66.9	68.6	70.3	72.0	73.7	75.5	77.3	79.0
29	41.7	43.2	44.8	46.4	48.0	49.6	51.2	52.8	54.5	56.1	57.8	59.5	61.2	62.9	64.6	66.3	68.0	69.8	71.5	73.3	75.1	76.9	78.7	80.5	82.4
30	43.9	45.5	47.1	48.7	50.4	52.0	53.7	55.4	57.1	58.8	60.5	62.2	64.0	65.7	67.5	69.3	71.0	72.9	74.7	76.5	78.3	80.2	82.1	84.0	85.9
31	46.2	47.9	49.5	51.2	52.9	54.6	56.3	58.1	59.8	61.6	63.3	65.1	66.9	68.7	70.5	72.4	74.2	76.1	78.0	79.9	81.8	83.7	85.7	87.6	89.6
32	48.7	50.4	52.1	53.8	55.6	57.3	59.1	60.9	62.7	64.5	66.3	68.2	70.0	71.9	73.8	75.7	77.6	79.5	81.5	83.5	85.4	87.5	89.5	91.5	93.6
33	51.2	53.0	54.8	56.5	58.3	60.2	62.0	63.8	65.7	67.6	69.5	71.4	73.3	75.2	77.2	79.2	81.2	83.2	85.2	87.3	89.3	91.4	93.6	95.7	97.8
34	53.9	55.7	57.6	59.4	61.3	63.1	65.0	67.0	68.9	70.8	72.8	74.8	76.8	78.8	80.8	82.9	85.0	87.1	89.2	91.4	93.5	95.7	97.9	100.2	102.4
35	56.8	58.6	60.5	62.4	64.4	66.3	68.3	70.3	72.3	74.3	76.3	78.4	80.5	82.6	84.7	86.9	89.1	91.3	93.5	95.7	98.0	100.3	102.6	105.0	107.3
36	59.8	61.7	63.7	65.7	67.7	69.7	71.7	73.8	75.9	78.0	80.1	82.3	84.5	86.7	88.9	91.2	93.5	95.8	98.1	100.5	102.9	105.3	107.7	110.2	112.7
37	62.9	65.0	67.0	69.1	71.2	73.3	75.4	77.6	79.8	82.0	84.2	86.5	88.8	91.1	93.4	95.8	98.2	100.6	103.1	105.6	108.1	110.7	113.3	115.9	118.6
38	66.3	68.4	70.6	72.7	74.9	77.1	79.4	81.6	83.9	86.2	88.6	91.0	93.4	95.8	98.3	100.8	103.4	105.9	108.6	111.2	113.9	116.6	119.4	122.2	125.0
39	70.0	72.2	74.4	76.7	78.9	81.3	83.6	86.0	88.4	90.9	93.4	95.9	98.4	101.0	103.6	106.3	109.0	111.8	114.6	117.4	120.3	123.2	126.1	129.2	132.2
40	73.8	76.2	78.5	80.9	83.3	85.7	88.2	90.8	93.3	95.9	98.5	101.2	103.9	106.7	109.5	112.4	115.3	118.2	121.2	124.3	127.4	130.5	133.7	137.0	140.3
41	78.0	80.5	83.0	85.5	88.0	90.6	93.3	95.9	98.7	101.4	104.3	107.1	110.0	113.0	116.0	119.1	122.2	125.4	128.7	132.0	135.4	138.8	142.3	145.9	149.5
42	82.6	85.2	87.8	90.5	93.2	96.0	98.8	101.7	104.6	107.6	110.6	113.7	116.9	120.1	123.4	126.7	130.1	133.6	137.2	140.8	144.5	148.3	152.2	156.1	160.2
43	87.6	90.4	93.2	96.0	99.0	101.9	105.0	108.1	111.2	114.5	117.8	121.1	124.6	128.1	131.7	135.4	139.1	143.0	147.0	151.0	155.2	159.4	163.8	168.2	172.8
44	93.1	96.1	99.1	102.2	105.4	108.6	111.9	115.3	118.7	122.3	125.9	129.6	133.4	137.4	141.4	145.5	149.7	154.1	158.5	163.1	167.9	172.7	177.7	182.9	188.2
45	99.3	102.5	105.8	109.2	112.6	116.2	119.8	123.6	127.4	131.4	135.4	139.6	143.9	148.3	152.9	157.6	162.4	167.4	172.6	178.0	183.5	189.2	195.1	201.2	207.5
46	106.3	109.8	113.4	117.2	121.0	125.0	129.1	133.3	137.6	142.1	146.7	151.5	156.5	161.6	167.0	172.5	178.2	184.2	190.4	196.8	203.5	210.5	217.8	225.4	233.3
47	114.3	118.3	122.4	126.6	130.9	135.4	140.1	145.0	150.0	155.3	160.7	166.4	172.3	178.5	185.0	191.8	198.9	206.4	214.2	222.4	231.0	240.0	249.5	259.5	270.0
48	123.9	128.4	133.1	137.9	143.0	148.3	153.9	159.7	165.8	172.2	178.9	186.0	193.5	201.4	209.8	218.7	228.2	238.2	248.9	260.3	272.3	285.1	298.7	313.0	328.2
49	135.5	140.8	146.4	152.3	158.5	165.0	172.0	179.3	187.2	195.6	204.6	214.3	224.7	235.9	248.1	261.3	275.5	290.9	307.6	325.5	344.8	365.4	387.3	410.6	435.2

09-63235-01

IDEXX Quanti-Tray®/2000 MPN Table *(per 100ml)*

# Large Wells Positive	# Small Wells Positive																							
	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
0	25.3	26.4	27.4	28.4	29.5	30.5	31.5	32.6	33.6	34.7	35.7	36.8	37.8	38.9	40.0	41.0	42.1	43.1	44.2	45.3	46.3	47.4	48.5	49.5
1	26.6	27.7	28.7	29.8	30.8	31.9	32.9	34.0	35.0	36.1	37.2	38.2	39.3	40.4	41.4	42.5	43.6	44.7	45.7	46.8	47.9	49.0	50.1	51.2
2	27.9	29.0	30.0	31.1	32.2	33.2	34.3	35.4	36.5	37.5	38.6	39.7	40.8	41.9	43.0	44.0	45.1	46.2	47.3	48.4	49.5	50.6	51.7	52.8
3	29.3	30.4	31.4	32.5	33.6	34.7	35.8	36.8	37.9	39.0	40.1	41.2	42.3	43.4	44.5	45.6	46.7	47.8	48.9	50.0	51.2	52.3	53.4	54.5
4	30.7	31.8	32.8	33.9	35.0	36.1	37.2	38.3	39.4	40.5	41.6	42.8	43.9	45.0	46.1	47.2	48.3	49.5	50.6	51.7	52.9	54.0	55.1	56.3
5	32.1	33.2	34.3	35.4	36.5	37.6	38.7	39.9	41.0	42.1	43.2	44.4	45.5	46.6	47.7	48.9	50.0	51.2	52.3	53.5	54.6	55.8	56.9	58.1
6	33.5	34.7	35.8	36.9	38.0	39.2	40.3	41.4	42.6	43.7	44.8	46.0	47.1	48.3	49.4	50.6	51.7	52.9	54.1	55.2	56.4	57.6	58.7	59.9
7	35.0	36.2	37.3	38.4	39.6	40.7	41.9	43.0	44.2	45.3	46.5	47.7	48.8	50.0	51.2	52.3	53.5	54.7	55.9	57.1	58.3	59.4	60.6	61.8
8	36.6	37.7	38.9	40.0	41.2	42.3	43.5	44.7	45.9	47.0	48.2	49.4	50.6	51.8	53.0	54.1	55.3	56.5	57.7	59.0	60.2	61.4	62.6	63.8
9	38.1	39.3	40.5	41.6	42.8	44.0	45.2	46.4	47.6	48.8	50.0	51.2	52.4	53.6	54.8	56.0	57.2	58.4	59.7	60.9	62.1	63.4	64.6	65.8
10	39.7	40.9	42.1	43.3	44.5	45.7	46.9	48.1	49.3	50.6	51.8	53.0	54.2	55.5	56.7	57.9	59.2	60.4	61.7	62.9	64.2	65.4	66.7	67.9
11	41.4	42.6	43.8	45.0	46.3	47.5	48.7	49.9	51.2	52.4	53.7	54.9	56.1	57.4	58.6	59.9	61.2	62.4	63.7	65.0	66.3	67.5	68.8	70.1
12	43.1	44.3	45.6	46.8	48.1	49.3	50.6	51.8	53.1	54.3	55.6	56.8	58.1	59.4	60.7	62.0	63.2	64.5	65.8	67.1	68.4	69.7	71.0	72.4
13	44.9	46.1	47.4	48.6	49.9	51.2	52.5	53.7	55.0	56.3	57.6	58.9	60.2	61.5	62.8	64.1	65.4	66.7	68.0	69.3	70.7	72.0	73.3	74.7
14	46.7	48.0	49.3	50.5	51.8	53.1	54.4	55.7	57.0	58.3	59.6	60.9	62.3	63.6	64.9	66.3	67.6	68.9	70.3	71.6	73.0	74.4	75.7	77.1
15	48.6	49.9	51.2	52.5	53.8	55.1	56.4	57.8	59.1	60.4	61.8	63.1	64.5	65.8	67.2	68.5	69.9	71.3	72.6	74.0	75.4	76.8	78.2	79.6
16	50.5	51.8	53.2	54.5	55.8	57.2	58.5	59.9	61.2	62.6	64.0	65.3	66.7	68.1	69.5	70.9	72.3	73.7	75.1	76.5	77.9	79.3	80.8	82.2
17	52.5	53.9	55.2	56.6	58.0	59.3	60.7	62.1	63.5	64.9	66.3	67.7	69.1	70.5	71.9	73.3	74.8	76.2	77.6	79.1	80.5	82.0	83.5	84.9
18	54.6	56.0	57.4	58.8	60.2	61.6	63.0	64.4	65.8	67.2	68.6	70.1	71.5	73.0	74.4	75.9	77.3	78.8	80.3	81.8	83.3	84.8	86.3	87.8
19	56.8	58.2	59.6	61.0	62.4	63.9	65.3	66.8	68.2	69.7	71.1	72.6	74.1	75.5	77.0	78.5	80.0	81.5	83.1	84.6	86.1	87.6	89.2	90.7
20	59.0	60.4	61.9	63.3	64.8	66.3	67.7	69.2	70.7	72.2	73.7	75.2	76.7	78.2	79.8	81.3	82.8	84.4	85.9	87.5	89.1	90.7	92.2	93.8
21	61.3	62.8	64.3	65.8	67.3	68.8	70.3	71.8	73.3	74.9	76.4	77.9	79.5	81.1	82.6	84.2	85.8	87.4	89.0	90.6	92.2	93.8	95.4	97.1
22	63.8	65.3	66.8	68.3	69.8	71.4	72.9	74.5	76.1	77.6	79.2	80.8	82.4	84.0	85.6	87.2	88.9	90.5	92.1	93.8	95.5	97.1	98.8	100.5
23	66.3	67.8	69.4	71.0	72.5	74.1	75.7	77.3	78.9	80.5	82.2	83.8	85.4	87.1	88.7	90.4	92.1	93.8	95.5	97.2	98.9	100.6	102.4	104.1
24	68.9	70.5	72.1	73.7	75.3	77.0	78.6	80.3	81.9	83.6	85.2	86.9	88.6	90.3	92.0	93.8	95.5	97.2	99.0	100.7	102.5	104.3	106.1	107.9
25	71.7	73.3	75.0	76.6	78.3	80.0	81.7	83.3	85.1	86.8	88.5	90.2	92.0	93.7	95.5	97.3	99.1	100.9	102.7	104.5	106.3	108.2	110.0	111.9
26	74.6	76.3	78.0	79.7	81.4	83.1	84.8	86.6	88.4	90.1	91.9	93.7	95.5	97.3	99.2	101.0	102.9	104.7	106.6	108.5	110.4	112.3	114.2	116.2
27	77.6	79.4	81.1	82.9	84.6	86.4	88.2	90.0	91.9	93.7	95.5	97.4	99.3	101.2	103.1	105.0	106.9	108.8	110.8	112.7	114.7	116.7	118.7	120.7
28	80.8	82.6	84.4	86.3	88.1	89.9	91.8	93.7	95.6	97.5	99.4	101.3	103.3	105.2	107.2	109.2	111.2	113.2	115.2	117.3	119.3	121.4	123.5	125.6
29	84.2	86.1	87.9	89.8	91.7	93.7	95.6	97.5	99.5	101.5	103.5	105.5	107.5	109.5	111.6	113.7	115.7	117.8	120.0	122.1	124.2	126.4	128.6	130.8
30	87.8	89.7	91.7	93.6	95.6	97.6	99.6	101.6	103.7	105.7	107.8	109.9	112.0	114.2	116.3	118.5	120.6	122.8	125.1	127.3	129.5	131.8	134.1	136.4
31	91.6	93.6	95.6	97.7	99.7	101.8	103.9	106.0	108.2	110.3	112.5	114.7	116.9	119.1	121.4	123.6	125.9	128.2	130.5	132.9	135.3	137.7	140.1	142.5
32	95.7	97.8	99.9	102.0	104.2	106.3	108.5	110.7	113.0	115.2	117.5	119.8	122.1	124.5	126.8	129.2	131.6	134.0	136.5	139.0	141.5	144.0	146.6	149.1
33	100.0	102.2	104.4	106.6	108.9	111.2	113.5	115.8	118.2	120.5	122.9	125.4	127.8	130.3	132.8	135.3	137.8	140.4	143.0	145.6	148.3	150.9	153.7	156.4
34	104.7	107.0	109.3	111.7	114.0	116.4	118.9	121.3	123.8	126.3	128.8	131.4	134.0	136.6	139.2	141.9	144.6	147.4	150.1	152.9	155.7	158.6	161.5	164.4
35	109.7	112.2	114.6	117.1	119.6	122.2	124.7	127.3	129.9	132.6	135.3	138.0	140.8	143.6	146.4	149.2	152.1	155.0	158.0	161.0	164.0	167.1	170.2	173.3
36	115.2	117.8	120.4	123.0	125.7	128.4	131.1	133.9	136.7	139.5	142.4	145.3	148.3	151.3	154.3	157.3	160.5	163.6	166.8	170.0	173.3	176.6	179.9	183.3
37	121.3	124.0	126.8	129.6	132.4	135.3	138.2	141.2	144.2	147.3	150.3	153.5	156.7	159.9	163.1	166.5	169.8	173.2	176.7	180.2	183.7	187.3	191.0	194.7
38	127.9	130.8	133.8	136.8	139.9	143.0	146.2	149.4	152.6	155.9	159.2	162.6	166.1	169.6	173.2	176.8	180.4	184.2	188.0	191.8	195.7	199.7	203.7	207.7
39	135.3	138.5	141.7	145.0	148.3	151.7	155.1	158.6	162.1	165.7	169.4	173.1	176.9	180.7	184.7	188.7	192.7	196.8	201.0	205.3	209.6	214.0	218.5	223.0
40	143.7	147.1	150.6	154.2	157.8	161.5	165.3	169.1	173.0	177.0	181.1	185.2	189.4	193.7	198.1	202.5	207.1	211.7	216.4	221.1	226.0	231.0	236.0	241.1
41	153.2	157.0	160.9	164.8	168.9	173.0	177.2	181.5	185.8	190.3	194.8	199.5	204.2	209.1	214.0	219.1	224.2	229.4	234.8	240.2	245.8	251.5	257.2	263.1
42	164.3	168.6	172.9	177.3	181.9	186.5	191.3	196.1	201.1	206.2	211.4	216.7	222.2	227.7	233.4	239.2	245.2	251.3	257.5	263.8	270.3	276.9	283.6	290.5
43	177.5	182.3	187.3	192.4	197.6	202.9	208.4	214.0	219.8	225.8	231.8	238.1	244.5	251.0	257.7	264.6	271.7	278.9	286.3	293.8	301.5	309.4	317.4	325.7
44	193.6	199.3	205.1	211.0	217.2	223.5	230.0	236.7	243.6	250.8	258.1	265.6	273.3	281.2	289.4	297.8	306.3	315.1	324.1	333.3	342.8	352.4	362.3	372.4
45	214.1	220.9	227.9	235.2	242.7	250.4	258.4	266.7	275.3	284.1	293.3	302.6	312.3	322.3	332.5	343.0	353.8	364.9	376.2	387.9	399.8	412.0	424.5	437.4
46	241.5	250.0	258.9	268.2	277.8	287.8	298.1	308.8	319.9	331.4	343.3	355.5	368.1	381.1	394.5	408.3	422.5	437.1	452.0	467.4	483.3	499.6	516.3	533.5
47	280.9	292.4	304.4	316.9	330.0	343.6	357.8	372.5	387.7	403.4	419.8	436.6	454.1	472.1	490.7	509.9	529.8	550.4	571.7	593.8	616.7	640.5	665.3	691.0
48	344.1	360.9	378.4	396.8	416.0	436.0	456.9	478.6	501.2	524.7	549.3	574.8	601.5	629.4	658.6	689.3	721.5	755.6	791.5	829.7	870.4	913.9	960.6	1011.2
49	461.1	488.4	517.2	547.5	579.4	613.1	648.8	686.7	727.0	770.1	816.4	866.4	920.8	980.4	1046.2	1119.9	1203.3	1299.7	1413.6	1553.1	1732.9	1986.3	2419.6	>2419.6

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VII. Restoration

Ecological Restoration: Oyster Monitoring

Duration Time: 120 Minutes

Engage

What do we think about when we hear the word **restore**? In what context have you heard of the word restore? How might one “restore” a natural place? How would one know what we are restoring it back to?

Explore

We started our week looking at the marsh in Habirshaw Park and identifying plants that grow there. We then combined all of our sample sets of plants and created the marsh on the dry erase board. When professionals are looking to create a plan of ecological restoration, they also need to study the conditions of their site, what it looked like before it was changed, and weigh the pros and cons of changing the site again.

We do not modify a singular item of ecology, as we learned this week - everything in an ecosystem is interconnected and so the modification of anything can impact everything. A prime example of this idea is the impact of overfishing, pollution and waste on the oyster populations of the Hudson River. Many historic records reminisce on the over 9,000 year stretch of time where oysters were in abundance in the river - harvested with care and used by native populations along the river and eventually making their way to inshore kitchens.

In the early 1920’s an influx of NYC’s population after WW1 immediately overwhelmed a barely functioning sewage system and led to the input of over 14 million tons of sewage into the rivers each year. A population increase also led to an increase of imports and use of the harbor for cargo shipping, worsening water quality, and habitat destruction. The oysters, as resilient as they are, were unable to survive in such conditions and their colonies declined rapidly. Oysters, as filter feeders, can take in many impurities from a water column and produce it in waste that falls to the sediment below. Although this does not make the river “cleaner,” it allows **impurities** to be moved into a more digestible format for the ecosystem to process. Without this removal from the water column, and because of continuing pollution being introduced, water quality significantly worsened over time.

There were a lot of things that needed to happen prior to the ecological restoration of the oyster beds in the Hudson. For one, water quality had to improve and the

Clean Water Act of 1972 helped become a catalyst of environmental conservation and preservation, which ultimately led to the reduction of pollution in the Hudson. Non-profit groups were able to start doing research around oyster re-populating and establishing different reefs within the river. In our activity today, we will also become part of this research by looking at oysters and their environment closely.

Ecological restoration is not always successful. It took many years for the oysters in the Hudson River to become established once more. It takes community members like you and me to continue restoring and protecting our local environment - which we will be part of today.

Photo Credit: Billion Oyster Project

Possible short films to Watch:

- The Nature Conservancy: Oyster Reef Restoration
- Wall Street Journal: The Incredible Oyster Reef

Explain

Go over: [Aspects of BOP protocol]

Start by looking at the Oyster Research Station (ORS) Field Manual Introduction for some background on the project. Each protocol has a separate file with detailed instructions and data sheets, that will be very helpful for you. More than anything, we recommend doing an ORS training with Billion Oyster Project to get you more familiarized with the process, or come to a sampling day at CURB on your own or with your students.

(Disclaimer: These protocols are created by a partner organization (Billion Oyster Project) and are subject to change.)

Elaborate

We will go out to the river and conduct the monitoring protocols that look at site conditions, water quality, associated organisms, and oyster health. Depending on student numbers, split into five groups, and each group will focus on one protocol, or split into two groups and run students through stations of different protocols. Use the instructions from each BOP protocol to have students complete the data collection.

Evaluation

What are some other things we can do in our everyday life to support our local ecosystems? How can we as a community influence our ecosystems in a positive way? How do all of the things we learned pertaining to the Hudson River Estuary fit together?

Extension

Students can continue helping their local ecosystem by participating in ecosystem restoration projects within their own neighborhoods or participate in long term studies by becoming interns or volunteers with organizations doing restoration projects. Most data collected by non-profits are considered public knowledge and can be accessed by anyone who is interested.

Classroom Modification Tips

If you are close to an estuarine waterway or have the ability to take your students, you might be able to get involved with the Billion Oyster Project and adopt your own cage. Even if you're not near the water, you can do oyster research in your classroom. Find more information here: https://www.billionoysterproject.org/educators. We also have a cage at CURB and can lead field trips for your students to do oyster monitoring, if you can get to our waterfront in Yonkers.

Whether or not your students can do hands-on work, oysters are a wonderful way to teach about ecological restoration in NYC and beyond. The Engage and Explore sections of this lesson will be useful whether or not you can do live oyster monitoring with your students. We also recommend this paper, Design & Monitoring of Shellfish Restoration Projects, as a good start for some background on restoration projects.

Vocabulary

Clean Water Act: the primary federal law in the United States governing water pollution, passed in 1972

Impurities: Chemical substances inside a confined amount of liquid, gas, or solid, which differ from the chemical composition of the material or compound

Restore: return something to a former condition

Standards

HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and(3) the extinction of other species.

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Materials Needed

- ❏ Clipboards
- ❏ pencils
- ❏ BOP protocols
- ❏ Calipers
- ❏ Rulers
- ❏ Trays
- ❏ Buckets
- ❏ Gloves