

The Good, the Bad, and the Ugly:
**Aquatic Invasive Species of
the Mid-Atlantic
Education Guide**



December 2015

Introduction to the Project

Each year, billions of dollars and millions of hours are spent dealing with invasive species around the globe. **Invasive species**, by definition, are non-native species that cause economic, environmental, and/or human health related harm. Invasive species can be plants, animals, and/or pathogens like West Nile Virus. These species typically grow and reproduce rapidly and often lack predators and pathogens in their introduced environments, allowing their populations to explode. Historic invasive species like Chestnut Blight and Smallpox have shaped our landscapes today while others have just begun to impact our environment.

Invasive species management can be costly and time consuming. However, proper education on invasive species can prevent invasions from occurring in the first place. Strong education and outreach efforts can increase public awareness while also promoting prevention.

Due to the need for comprehensive invasive species education, this toolkit was developed to tell the story of invasive species in the eastern United States through 5 distinct units:

1. History of Invasive Species
2. Introduction and Spread of Invasive Species
3. Impacts to Natural Areas
4. Impacts to Students' Lives
5. Student and Community Action

The goal of this project is to raise awareness about invasive species and to turn that awareness into action to prevent and to manage current and future invasions.

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Larry Hogan, Governor

Mark Belton, Maryland Department of Natural Resources Secretary

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Impacts to Natural Areas

Many aquatic invasive species, while they may have no direct impact on humans, can have drastic impacts on natural areas. Because they are usually very adaptable, grow quickly and reproduce prolifically, they are often able to successfully outcompete native species in an ecosystem.

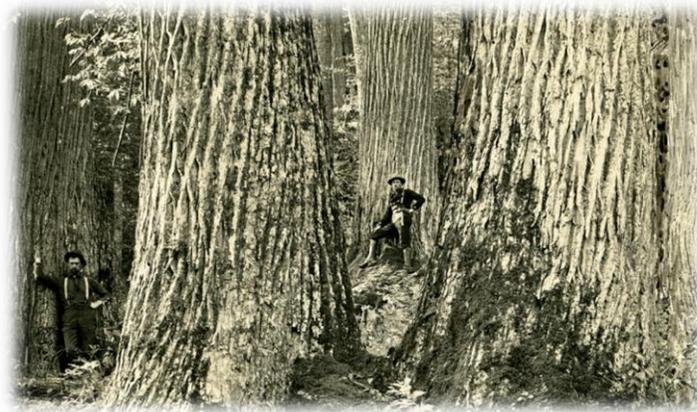
The activities in this module will focus on the impacts of Chestnut Blight, Didymo, Nutria, and Rusty Crayfish on ecosystems. These four organisms have had significant impacts to natural areas. Chestnut Blight dramatically changed eastern forests by destroying one of the most prevalent trees. Today, only a few of the former American Chestnuts stand tall. Didymo alters the underwater landscapes of cold-water streams, disrupting macroinvertebrate communities, which ultimately impacts the food web. The voracious eating habits of Nutria destroy saltwater marshes, reducing food and shelter for other species while allowing for massive erosion to occur. Finally, Rusty Crayfish are underwater aggressors, outcompeting native crayfish, consuming fish eggs and larvae, and even dining on aquatic vegetation. Their rapid expansion is altering aquatic habitats where they have been introduced.



Rusty Crayfish by Wisconsin DNR

To convey the concept of how these invasive species impact natural areas, the lessons in this section include:

- **Boulder Booger Bling -- Grades 3-8; pg**
 - *Students will learn about the microscopic structure of Didymo, explore how structure lends itself to the ability of the diatom to invade, and examine the environmental damage Didymo blooms cause through the use of scientific modeling.*
- **Chestnut Acres -- Grades 9-12; pg**
 - *Students will research different sides of the transgenic American Chestnut tree debate and will decide on whether or not they should plant transgenic American Chestnut trees in a fictional town named Chestnut Acres.*
- **Design an Aquatic Invader -- Grades 3-5; pg**
 - *Students will design their own aquatic invaders in order to learn about how the Rusty Crayfish has adapted to its environment and why it is considered invasive.*
- **Macrophyte Muddle -- Grades 6-12; pg**
 - *Students will investigate the relationship between macrophyte populations and dissolved oxygen concentration as an indicator for aquatic ecosystem health relative to Rusty Crayfish invasion.*
- **Mold, Blight, and Chestnut Strife -- Grades 6-8; pg**
 - *Students will observe the growth and spread of mold to understand how Chestnut Blight grows and spreads in living American Chestnuts.*
- **Nuisance Nutria -- Grades 6-8; pg**
 - *Students will simulate what may happen to a muskrat colony if the invasive Nutria becomes established in a marsh.*
- **Tidal Marsh Web -- Grades 3-5; pg**
 - *Students will simulate what happens to a tidal marsh food web with the introduction of Nutria.*
- **Tree Trouble -- Grades 3-5; pg**
 - *Students will model how the loss of the American Chestnut impacted wildlife.*
- **Water Chestnut vs. SAV-- Grades 3-8; pg**
 - *Students will research the impacts of Water Chestnut on submerged, aquatic vegetation.*



A stand of American Chestnuts before the Blight struck

Boulder Booger Bling

Gr: 3-8

Objectives: At the conclusion of the lesson, students will be able to:

- Describe the microscopic structure of Didymo,
- Understand how the structure lends itself to the ability of the diatom to invade, and
- Describe how Didymo invasions can impact natural areas

Standards:

NGSS	4-LS1-1 - Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. MS-LS1-1 - Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells. MS-LS1-2 - Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function. MS-LS2-4 - Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
Core Idea	LS1.A: Structure and Function All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular).
Practices	<ul style="list-style-type: none">• Developing and using models• Engaging in argument from evidence
Cross-Cutting Theme	<ul style="list-style-type: none">• Patterns• Structure and function
Reading, Writing & Social Studies	CCSS.ELA-Literacy.SL.3-5.1 - Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade-appropriate topics and texts, building on others' ideas and expressing their own clearly. CCSS.ELA-Literacy.SL.6-8.1 - Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade appropriate topics, texts, and issues, building on others' ideas and expressing their own clearly.
Environmental Literacy	4.B.1. Analyze the growth or decline of populations and identify a variety of responsible factors.

Objectives: At the conclusion of the lesson, students will be able to:

- Describe the microscopic structure of Didymo,
- Understand how the structure lends itself to the ability of the diatom to invade, and
- Describe how Didymo invasions can impact natural areas

Materials:

- “Out of Sight” book by Seymour Simon (optional)
- 3.5” x 6” #6 plastic pieces (at least 2 per student are needed, but as many as possible will be most effective – it’s fun to have the students collect this in the days prior to the activity; NOTE: the permanent marker will not stay on if the plastic is not clean)
- Aluminum foil
- Baking sheets
- Computer w/ projector and internet
- Copies of the Boulder Booger Bling Design Template (on CD)
- Electron microscope pictures of common objects and Didymo (in kit & on CD)
- Hole punch
- Oven
- Oven mitt
- Permanent markers
- Scissors
- Wet cottonballs (optional)
- Window



Electron micrograph of Didymo (D. geminata)

Teacher Background: As its common name suggests, Didymo may look like snot, but it’s not. Didymo (*Didymosphenia geminata*) is a microscopic freshwater diatom (type of algae) that secretes a fibrous stalk that it uses to attach itself to rocks and plants in aquatic systems. During blooms, the stalks grow to form thick mats which can completely cover the stream bottom. This diatom may look slimy, but its silica cell walls make it feel more like wet wool. Didymo cells, unlike most other diatoms, grow a yellow-brown or grayish-white, muco-polysaccharide shoot that can extend up to 2 feet long...thus earning it the unflattering nicknames of “rock snot” and “boulder booger”.



Didymo bloom in the Delaware River

The first report of Didymo in the northeastern U.S. came from the northern reaches of the Connecticut River and the White River in Vermont in June 2007. In October 2007, Didymo was discovered in the east and west branches of the upper Delaware River, in New York and Pennsylvania. About five years later, in May 2012, large Didymo blooms were observed over more than 100 miles of the Delaware River, from Hancock NY to near Dingman's Ferry PA. Closer to Maryland, Didymo was first discovered in Virginia in 2006, and is now found in three rivers below dams. Didymo was first reported in West

Virginia in 2008, and currently occurs in at least 3 streams. As of 2011, Didymo has been found in 18 U.S. states and 3 Canadian provinces.

Nuisance Didymo "blooms" are often mistaken for raw sewage spills because trailing stalks look like wet toilet paper in the water. In some situations, Didymo can proliferate rapidly, bloom (for reasons not well understood), and form large, visible clumps or mats of tangled stalks. In worst-case scenarios, these mats can cover the entire bottom of the infested river with a layer of cells and stalks up to 20 cm thick. Although Didymo mats may look slimy, they actually feel gritty and somewhat fibrous (like wet wool) when squeezed between a finger and thumb. Didymo stalks are resistant to biodegradation by bacteria and fungi. They can break off, drift downstream, get snagged on woody debris, and persist for up to two months. Unlike other algae, Didymo has no characteristic odor.

Like many non-native, nuisance aquatic species, Didymo poses myriad ecological threats. From an environmental perspective, the thick mats formed during blooms can completely cover the substrate, trap sediment, and have the potential to disrupt food webs. These extensive mats are a threat to biodiversity because they can smother benthic macroinvertebrates, native diatoms, and aquatic plants, thereby reducing food and habitat for fish.



Electron micrograph showing Didymo stalks

It should be noted that only limited research has been done to elucidate the ecological effects of Didymo in areas where large blooms have occurred. Didymo presence causes shifts in the community composition of macrobenthos toward more midges and worms with fewer caddisflies, stoneflies, and mayflies. Studies have also observed higher macroinvertebrate densities after Didymo becomes established--the average organism size, however, has been recorded as smaller. There is minimal information on the effects of Didymo blooms on fish. Some studies report no impact on fish growth and production, while others have observed declines in native fish populations in Didymo-infested waters.

In this activity, students will learn about the microscopic structure of Didymo, explore how structure lends itself to the ability of the diatom to invade, and examine the environmental damage Didymo blooms cause through the use of scientific modeling.

Procedure:

Engage

1. Begin by showing the class electron microscope photos of common objects (#1-4 in kit and on resource CD). Ask students what they think each might be. See how many students guessed correctly with a show of hands. For those that guessed correctly, what clues did they use to figure out the object? Show students enlarged versions of the objects. What do they notice about the microscope photos compared to the enlarged photos? Be sure to point out object structures.
2. Define **microscopic** and explain that it can be hard to tell what the object is in a photo taken using a microscope. (*NOTE: There are many images that can be used to illustrate this concept; Seymour Simon's book "Out Of Sight" is a great resource.*)
3. Introduce the idea of **invasive" species**. Invite students guess what it means for an organism to "invade" an environment – ask if the students can list examples of invasive species they may have heard about.
4. Explain that some invasive species are microscopic. Show the class photos #5-7 of Didymo. Ask if they can guess what kind of organism is in the photo. Tell them it is a microscope photo of a type of algae called Didymo.
5. Tell your students that Didymo is an example of an invasive aquatic species that is microscopic. Next, show photo #8 of Didymo.
6. Explain that Didymo is sometimes called "rock snot" or "boulder booger". Ask the students why they think Didymo earned these nicknames.
7. Finally, show students photo #9.
8. Use the images to host a discussion about the structure of Didymo. Ask the students to make guesses about structural features that might allow Didymo to form blooms and invade aquatic areas (e.g. the coke-bottle shape allows the cells to fit together well, the hard silica shell makes it an unattractive food source for native organisms, it's large size offers a competition advantage over other algae

and microscopic organisms, the long/branched stalks it produces allow it to stick more easily to the surface of rocks...etc.). Write the ideas on the board. You may want to hand them wet cotton balls to touch and feel as this simulates what a mass of Didymo feels like.

9. Show the students this video short:
<http://www.youtube.com/watch?v=eyqtEM1xQa4>.
10. Given the video, ask students why a Didymo bloom may be bad for a stream. Some examples include:
 - a. completely cover substrate in a river system
 - b. smother aquatic plants, insects, and mollusks to reduce fish habitat and food
 - c. outcompete native species of algae, which serve as food sources for aquatic insects

Explore

1. Tell the students that they are going to model a Didymo bloom using homemade “Boulder Boogers”. Briefly explain the idea of scientific modeling – ask the students why scientific models are used.
2. Hand out copies of the Boulder Booger Bling Design Template and the plastic pieces to each student. Using the design template, allow students to fashion their own boulder boogers using the scissors and permanent markers. Ensure students pay special attention to Didymo shape, color, and internal structure with their designs. This project calls for at least 2 models per student, but would be more successful with a larger number of models – the more models, the more effective the bloom. Students should write their names in small print along the edge of their models.
3. When students are finished with their designs, designate a large window to represent substrate for the modeling activity.
4. Have 1 student adhere a Didymo model to the window-ask the class to imagine the window as the bottom of a stream or river. Ask the students if they think 1 Didymo cell would be enough to cause a problem – discuss the answers provided. Continue inviting students to tape their models to the window. If there are enough models, students can also tape them on top of each other.

Explain

1. Ask the following questions and discuss the answers provided:
 - a. What do you notice about the amount of sunlight that can pass through the window with increasing numbers of Didymo? How do you think this is like the bottom of a river? Why would this be a problem for other organisms?
 - b. Do you think the population of Didymo is enough to cover the substrate at this point? Why/why not?

- c. Do you think the population of Didymo is enough to smother aquatic plants, insects, and/or other microscopic organisms at this point? Why/why not?
 - d. Do you think the population of Didymo is enough to outcompete native species of algae, which serve as food sources for aquatic insects? Why/why not?
 - e. What do you think would happen to the environment if this bloom continued to grow? Over days? Months? Years? Explain.
 - f. Should we be concerned about the effects of invasive species, even when they are microscopic? Why/why not?
 - g. Is this an effective model? Why/why not?
2. *Time-Permitting:* When you are finished with the simulation, punch holes in each of the plastic pieces and bake in an oven using the following directions to fashion the Didymo models into “Boulder Booger Bling” for students to take home:
- a. *Place the plastic pieces on a thin cookie sheet (non-insulated) covered with aluminum foil.*
 - b. *Bake plastic at 350 degrees for 2- 3 minutes. Keep in mind that the plastic shrinks to about 1/3 of the original size – a 2" circle becomes about 3/4" when shrunk (see Appendix 1 below).*
 - c. *Each oven is different, so watch closely. You will see the plastic curl up – the pieces are ready when they flatten back out.*
 - d. **IMPORTANT NOTE: #6 plastic can emit toxic, odorless fumes when subjected to high temperatures – be sure to leave a window open for adequate ventilation!!**
 - e. When the Didymo models are finished baking and are back in the possession of the students, hold a quick review discussion about what they are called, how they are categorized, their significance as invasive species, and their harm to the environment. Send your students off into the world, boasting about their Boulder Booger Bling.

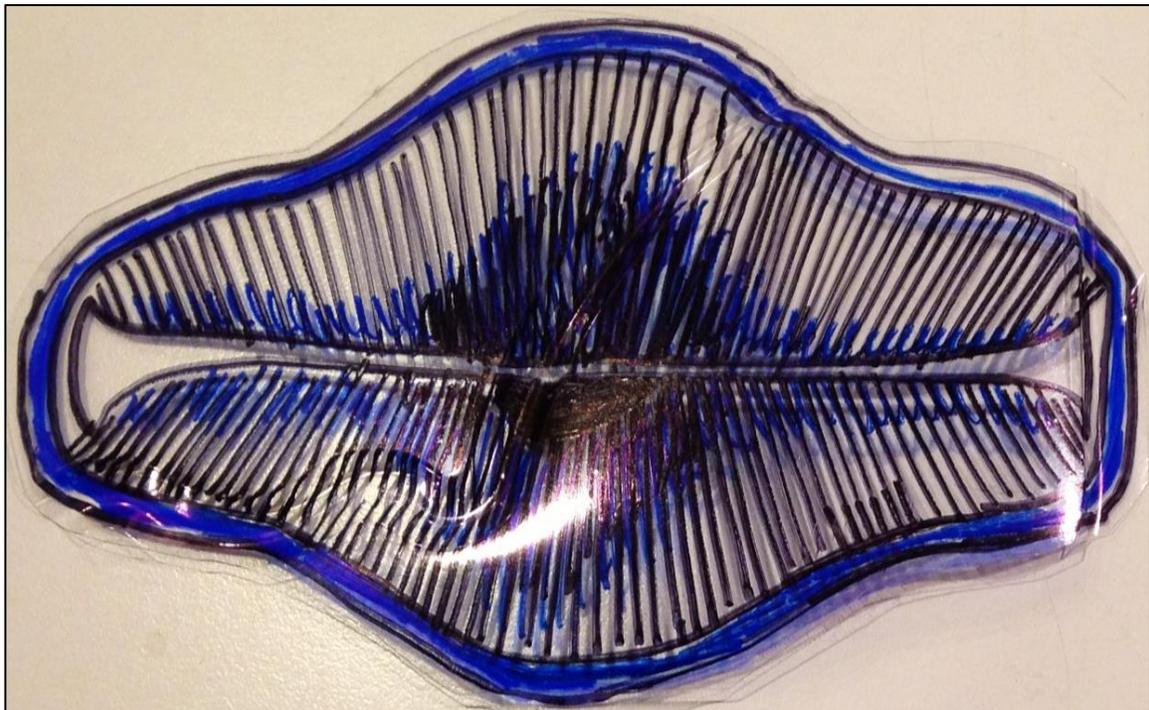
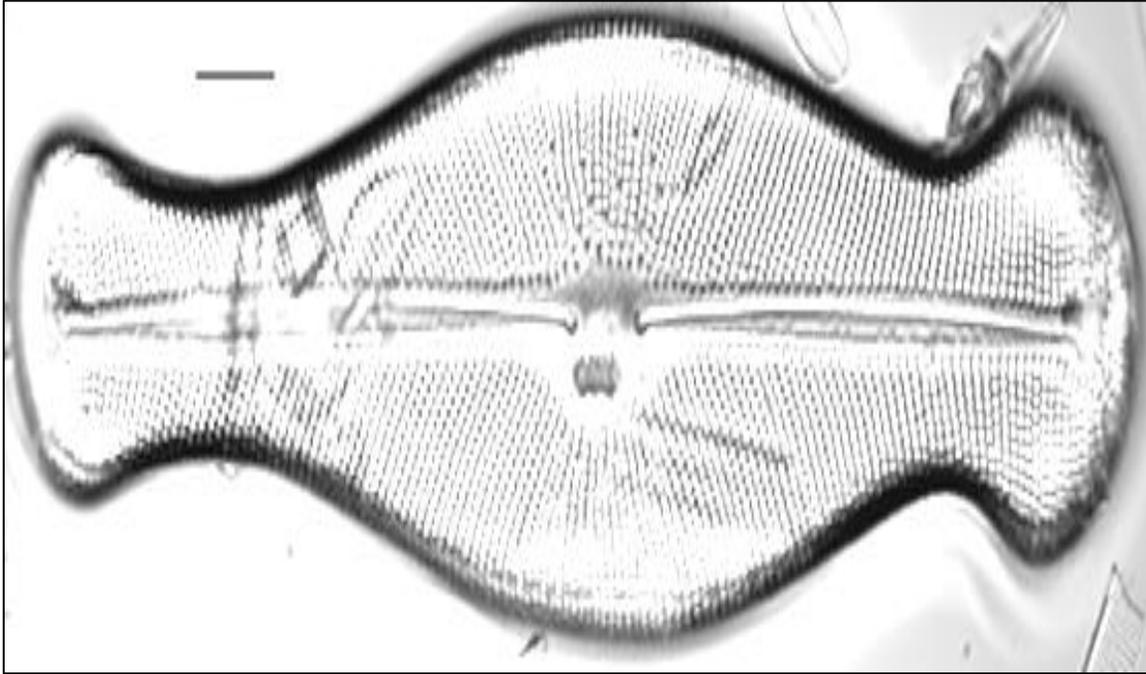
Evaluate

1. Have students explain why the structure of the Didymo makes it successful at creating blooms. Why do native animals not feed on the Didymo?
2. Name 2 impacts of Didymo to natural areas.

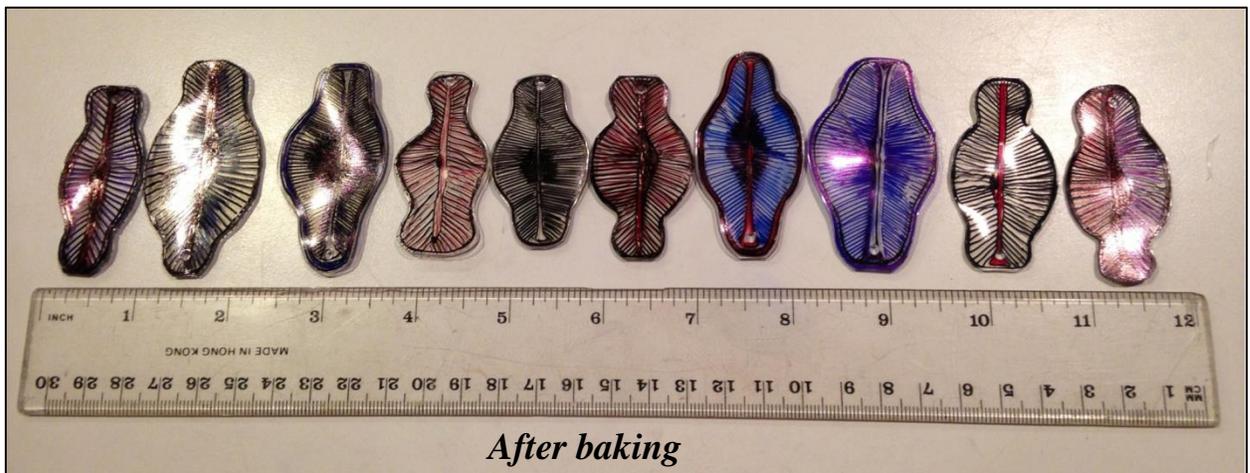
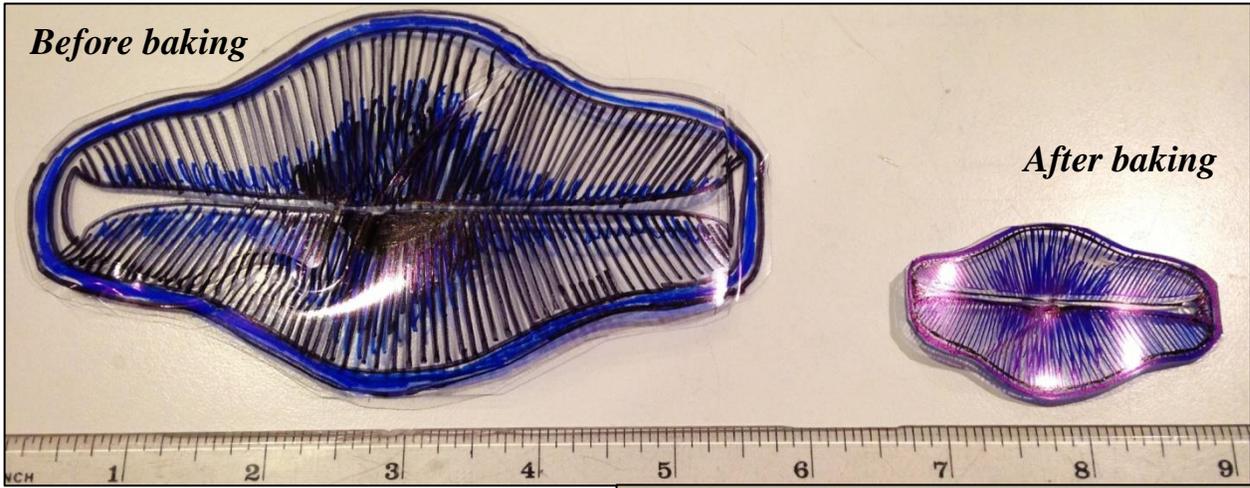
Extend

1. Have students do a research project comparing and contrasting Didymo with native diatoms.
2. Have students create Boulder Booger art in the style of M.C. Escher, focusing on how Didymo cells connect and interlock to form a bloom.
3. Have students research types of organisms that are harmed by Didymo invasion and create advocacy posters for the species in question.

Boulder Booger Bling Design Template



Boulder Booger Bling Photos



Objectives: At the conclusion of the lesson, students will be able to:

- Understand the importance of American Chestnuts to communities and natural areas
- Explain the process of creating transgenic organisms
- Describe the benefits and consequences of introducing transgenic organisms into natural areas

Standards:

<p>NGSS</p>	<p>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.</p> <p>HS-LS2-7 - Design, evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity.</p>
<p>Core Idea</p>	<p>LS2.C: Ecosystem Dynamics, Functioning, and Resilience - A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.</p> <p>LS2.C: Ecosystem Dynamics, Functioning, and Resilience - Moreover, anthropogenic changes (induced by human activity) in the environment – including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change – can disrupt an ecosystem and threaten the survival of some species.</p> <p>LS4.D: Biodiversity and Humans - Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.</p> <p>ETS1.B: Developing Possible Solutions - When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.</p>
<p>Practices</p>	<ul style="list-style-type: none"> • Engaging in Argument from Evidence • Constructing Explanations and Designing Solutions

Cross-Cutting Theme	<ul style="list-style-type: none"> • Stability and change
Reading, Writing & Social Studies	<p>CCSS.ELA-Literacy.RST.9-10.1 - Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.</p> <p>CCSS.ELA-Literacy.RST.9-10.2 - Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.</p> <p>CCSS.ELA-Literacy.RST.9-10.9 - Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.</p> <p>CCSS.ELA-Literacy.RST.11-12.1 - Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.</p> <p>CCSS.ELA-Literacy.RST.11-12.2 - Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.</p> <p>CCSS.ELA-Literacy.RST.11-12.9 - Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.</p> <p>CCSS.ELA-Literacy.RI.9-10.8 - Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning.</p> <p>CCSS.ELA-Literacy.RI.11-12.7 - Integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.</p> <p>CCSS.ELA-Literacy.W.9-10.1 - Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.</p> <p>CCSS.ELA-Literacy.W.11-12.1 - Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.</p>
Environmental Literacy	<p>1.A.1 - Identify an environmental issue.</p> <p>1.A.3 - Given a specific issue, communicate the issue, the stakeholders involved and the stakeholders' beliefs and values.</p> <p>1.A.5 - Use data and references to interpret findings to form conclusions.</p>

Objectives: At the conclusion of the lesson, students will be able to:

- Understand the importance of American Chestnuts to communities and natural areas
- Explain the process of creating transgenic organisms
- Describe the benefits and consequences of introducing transgenic organisms into natural areas

Materials:

- Bushel basket (optional)
- Chestnuts (in kit)
- Internet access
- Nuts (acorns, hickory nuts, walnuts)
- Pictures of American Chestnut trees, healthy and with the Blight (in kit & on CD)
- Student pages (on CD)
- Transgenic organism PPT (on CD)
- Video--Classical vs. Transgenic breeding (optional)
- Video on how GMOs (transgenic organisms) are made:
<https://www.youtube.com/watch?v=2G-yUuiqIZ0>



Large American Chestnut by U.S. Forest Service

Teacher Background: At one time, the American Chestnut (*Castanea dentata*) dominated approximately 200 million acres of land from Maine to Mississippi. In some areas, it is estimated that American Chestnuts covered roughly 20% of the Appalachian forest while other areas contained almost pure stands of trees. Chestnut trees grew up to 100ft tall and often averaged several feet in diameter. The trees were important for wildlife as they produced edible nuts in the fall. One large tree could produce up to 10 bushels or more of nuts! Ruffed grouse, white-tailed deer, black bears, raccoons, squirrels and wild turkeys are just some of the species which foraged on American Chestnuts. The trees were also used in the lumber industry to build fences, caskets and cabins while the bark and inner cordwood were used to tan leather hides.

Unfortunately, during the late 1800s, an **invasive species**, the **Chestnut Blight** (*Cryphonectria parasitica*) was accidentally introduced to the United States from Asia. Invasive species are non-native organisms that create biological, economic and/or human-health related harm. The Blight is an invasive fungus that quickly spread through American Chestnut stands. Just a few decades after the Blight's introduction, over 9 million trees died. By 1950, the American Chestnut was nearly gone from the landscape, and today, only a handful of plants survive.

The fungal spores of Chestnut Blight spread from tree to tree by animals and the wind. The spores infect cuts in the bark and create a rusty-colored **canker** (blister) on the surface of the tree. At the site of the canker, the Blight fungus produces high levels of **oxalate** which lowers the pH of the surrounding tissue and binds to calcium needed for growth. In addition, oxalate inhibits lignin production that is important for compartmentalizing (or sectioning off) infected cells. Below the surface, a network of **hyphae** (fungal strings) grows in the **vascular tissue** (xylem and phloem) which are responsible for food and water transport. As the hyphae plug up the vascular tissue, the tree slowly begins to die due to the lack of food and water reaching its living tissues.

Recently, advances in technology have created **transgenes** that may be used to combat Chestnut Blight. A transgene contains a gene of interest plus extra DNA that encodes for how the gene works. These transgenes then can be inserted into the DNA of another organism. In terms of American Chestnut, the enzyme **oxalate oxidase** has been isolated from wheat tissue. The enzyme breaks down oxalate, which is used by the Chestnut Blight. By inserting the oxalate oxidase transgene into the American Chestnut DNA, researchers can produce Chestnut trees that are more resistant to the Blight. However, there is concern over introducing genetically modified trees into natural areas.

In this activity, students will research different sides of the transgenic American Chestnut tree debate and will decide on whether or not they should plant transgenic American Chestnut trees in a fictional town named Chestnut Acres.

Procedure:

Engage

1. Ask students why trees are important to wildlife. (They provide habitat such as food and shelter). Show students a variety of nuts such as acorns, hickory nuts, walnuts and the like. Ask students what animals may eat those types of nuts. (Squirrels, turkeys, deer, bear, etc). Write down list of animals for future use.
2. Show students pictures of healthy American Chestnut trees and then show them a bushel basket and Chestnuts. Tell the students that those mature Chestnut trees could produce up to 10 bushels (500-600) pounds of nuts!
3. Show students pictures of American Chestnut trees affected by the Blight. Ask students how this may impact wildlife that depend on the trees. (Wildlife will

lose food & shelter). Explain to students that Chestnut Blight is a fungal disease that slowly kills American Chestnut trees. Tell students that the Blight is an invasive species. Define an **invasive species** and describe how they differ from native species.

Explore

1. Tell your students that one option to combat the fungus is to produce transgenic trees. Define **transgenic** and briefly go through the process of gene insertion into the Chestnut DNA. You may want to define what DNA and genes are to your students as well. You can also show students the video on how GMOs (transgenic organisms) are made.
2. Ask students if they are familiar with any transgenic organisms. Use PowerPoint to go through some examples of transgenics. After going through the examples, ask students if the creation of transgenic organisms should be allowed? Why or why not? Should there be limits on experimenting and creating transgenic organisms?
3. Explain to your students that the concept of transgenic organisms is still not fully accepted by everyone. Tell them that they will be representing different sides of the transgenic Chestnut debate.
4. Break students into 4 groups and pass out copies of the Chestnut Acres student page as well as the information on the interest group they represent. The groups are as follows:
 - a. A private landowner
 - b. An ecologist
 - c. A local forester
 - d. A biotech company
5. Have the students read the student page on the fictional Chestnut Acres. Tell them that they will now work in their interest groups to present a proposal on why or why not the transgenic trees should be planted on community property.
6. Allow students at least one class period to research transgenic American Chestnuts and genetically modified organisms (GMOs). Have students write down important points related to their position on the introduction of transgenic trees. Encourage students to print out sources to bring to the discussion.
7. During the next class period, hold a public hearing in which each group presents its proposal. Allow students to spend time debating their proposals. You may want to help prompt their debate.
8. Following the debate, have each student anonymously vote on the best proposal. Tally the votes and tell the students what decision was made for Chestnut Acres. As an alternative, you can use the provided rubric to have students grade each other's debates.

Explain

1. After the vote, discuss the following questions:

- a. Was it easy or difficult to decide what to do? Explain your answers.
- b. What are the most important points raised by each group?
- c. What additional information would you like to know before reaching a final decision?
- d. What impact would the group's decision have on American Chestnuts?

Evaluate

1. Describe a transgenic organism and provide an example of one.
2. List one drawback and one benefit of using transgenic organisms.
3. How could planting transgenic American Chestnuts impact natural areas?

Extend

1. In addition to transgenic Chestnuts to create Blight resistant plants, researchers have also selectively bred and cross bred Chestnut. Define selective breeding and cross breeding. Compare and contrast the pros and cons of selective breeding, cross breeding and transgenics.
 - a. Helpful resource: classical vs transgenic breeding video
<http://www.teachersdomain.org/resource/tdc02.sci.life.gen.breeding/>
2. Have students research information on genetically modified organisms (GMOs) commonly used for food. What are some of the issues with GMO produce and livestock? Are these issues similar to the ones discussed during the debate?
3. Have students create virtual transgenic flies online:
 - a. http://media.hhmi.org/biointeractive/vlabs/transgenic_fly/index.html

Student Page: Chestnut Acres

Chestnut Acres was founded around the trade of American Chestnuts. A local lumber company employed many citizens who harvested the prized Chestnut timber. While most of the wood was exported out of town, the local furniture shop would purchase some of the pieces to craft cribs, chairs and caskets. Scraps of bark and cordwood were also sent to the local tannery that tanned and exported hides from game animals like deer, bear and foxes. These animals were particularly abundant in the fall when the trees would produce Chestnuts. Chestnuts were an important food resource for many wildlife species. Many of the residents collected and sold bushels of Chestnuts, and each year, the town held a Chestnut festival to celebrate the harvest.

In the late 1800s, word passed through town that a disease was killing American Chestnuts to the north. By 1920, the disease, Chestnut Blight, reached Chestnut Acres. Chestnut Blight is a fungal disease that infects trees and produces high levels of oxalate. Oxalate inhibits the tree from sectioning off the disease, lowers the pH of the tree's tissues, and binds to calcium needed for growth. In less than 20 years almost all of the Chestnuts in town died. The local tannery and furniture store shut down. The local lumber company switched to harvesting oaks, hickories, and cherries instead of Chestnuts, but they decreased their factory by half. Many residents left town in search of work.

By 2013, the American Chestnuts of Chestnut Acres were mostly a memory. A few of the older citizens could recall the days when Chestnut trees were plentiful, though one local landowner has three trees that somehow escaped the Blight. Many of the citizens employed in town work at a local biotech company, while the others commute to jobs in distant cities.

Recently, the biotech company has announced that it has successfully inserted a gene produced by wheat into the DNA of American Chestnut. This transgene encodes for an enzyme that breaks down oxalate, an acid produced by the Blight fungus to inhibit lignin production, to lower the pH of the canker wound and to bind to calcium. American Chestnuts with these transgenes are less susceptible to the Blight. In an effort to restore the American Chestnut to the landscape, the biotech company has proposed planting 100 acres of transgenic American Chestnuts on community property outside of town.

A town hall meeting has been scheduled to discuss this proposal. Four interest groups will be presenting at the meeting:

- A private landowner
- An ecologist
- A forester
- The BioTech company

You will be assigned to one of the four interest groups. As a group, you have to decide whether or not your group will support planting the transgenic American Chestnut trees. Be sure to present facts to support your case to the rest of the class. What are some of the advantages of planting the trees? What about the disadvantages? Prepare a proposal with your group's decision to present to the class.

Student Page: Interest Groups

Private landowner-

Your group represents a private landowner who has three remaining American Chestnut trees unaffected by the Blight on your property adjacent to the proposed planting area. You are concerned that the transgenic trees may eventually cross pollinate with your surviving American Chestnuts, producing hybrid seedlings and polluting the gene pool. You also worry that the transgenic trees may produce a strain of Blight that is resistant to the transgenes, which will be harmful to your remaining trees as well as others that have been resistant to the Blight.

Ecologist-

Your group represents an ecologist who is concerned about the long-term impacts of transgenic Chestnut to the ecosystem. While the transgenic trees may be resistant to the Blight, you are concerned that the wheat transgenes will alter the pollen or the fruit of the Chestnuts, which could have unknown impacts on wildlife. In addition, you worry that the transgenic trees may produce a super strain of Chestnut Blight.

Forester-

Your group represents a forester who is tasked with managing forested lands for economic, recreational, and conservation purposes. You are interested in the idea of restoring the American Chestnut as its wood was highly valued in the lumber industry. In addition, the Chestnuts supported many species of wildlife.

BioTech Company-

Your group represents a biotech company that has patented the transgenic gene that has been inserted into the American Chestnuts. You are eager to sell your product and market it as a way to restore the mighty Chestnut to its former glory. If this project is successful, then it can pave the way for future restoration projects to save native trees against diseases such as Sudden Oak Death and Dutch Elm Disease. Your company employs many of the local residents of Chestnut Acres.

Debate Rubric

Criteria	Levels of Performance				Grade
	1	2	3	4	
<p>1. Organization and Clarity:</p> <p>Viewpoints and responses are outlined both clearly and orderly.</p>	Unclear in most parts	Clear in some parts but not over all	Most clear and orderly in all parts	Completely clear and orderly presentation	
<p>2. Use of Arguments:</p> <p>Reasons are given to support viewpoint.</p>	Few or no relevant reasons given	Some relevant reasons given	Most reasons given: most relevant	Most relevant reasons given in support	
<p>3. Use of Examples and Facts:</p> <p>Examples and facts are given to support reasons.</p>	Few or no relevant supporting examples/facts. Little to no use of valid resources.	Some relevant examples/facts given. Few valid resources used.	Many examples/facts given: most relevant. Valid resources used.	All supporting examples and facts given. Valid resources used.	
<p>4. Use of Rebuttal:</p> <p>Arguments made by the other teams are responded to and dealt with effectively.</p>	No effective counter-arguments made	Few effective counter-arguments made	Some effective counter-arguments made	Many effective counter-arguments made	
<p>5. Presentation Style:</p> <p>Tone of voice, use of gestures, and level of enthusiasm are convincing to audience.</p>	Few style features were used; not convincingly	Few style features were used convincingly	All style features were used, most convincingly	All style features were used convincingly	

Design Your Own Aquatic Invader

Gr: 3-5

Objectives: At the conclusion of the lesson, students will be able to:

- Describe adaptations of aquatic organisms,
- Describe adaptations of Rusty Crayfish
- Understand the threat the Rusty Crayfish poses to native species as the result of its adaptations

Standards:

NGSS	3-LS4-2 - Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing. 3-LS4-3 - Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all. 4-LS1-1 - Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.
Core Idea	3.LS3.B: Variation of Traits - Different organisms vary in how they look and function because they have different inherited information. 3.LS4.C: Adaptation - For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.
Practices	<ul style="list-style-type: none">• Engaging in Argument from Evidence
Cross-Cutting Theme	<ul style="list-style-type: none">• Structure and Function
Reading, Writing & Social Studies	CCSS.ELA-Literacy.SL.3-5.1 - Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade-appropriate topics and texts, building on others' ideas and expressing their own clearly.
Environmental Literacy	4.B.1. Analyze the growth or decline of populations and identify a variety of responsible factors.

Objectives: At the conclusion of the lesson, students will be able to:

- Describe adaptations of aquatic organisms
- Describe adaptations of Rusty Crayfish
- Understand the threat the Rusty Crayfish poses to native species as the result of its adaptations.

Materials:

- Art supplies
- Computer w/ internet
- Rusty Crayfish pictures (on CD)
- Student pages (on CD)

Teacher Background: While most aquatic invaders come from other countries, the Rusty Crayfish (*Orconectes rusticus*) has its origin in streams of the Ohio River Basin states. Today, “rusties” are found in 19 U.S. states and in Ontario, Canada. The introduction of the Rusty Crayfish has been widespread in the Mid-Atlantic region. Its introduction to Susquehanna River drainage is rumored to have occurred as early as the mid-1970s. It is now established in portions of New York, New Jersey, Pennsylvania, Maryland, West Virginia, Virginia, and North Carolina. Rusties were probably accidentally introduced into many aquatic systems by anglers who used them as live bait or by students and teachers who purchased and released them after studying them in the classroom.

Similar to lobster, the Rusty Crayfish can be identified by a set of robust, smooth claws and dark, rusty (hence the name) spots on each side of its carapace. The spots are located on the carapace as though you picked the crayfish up with paint on your forefinger and thumb. The spots may not always be present or well developed on Rusty Crayfish from certain waters. Adults reach a maximum of 3-5 inches in length.

When introduced, Rusty Crayfish graze on and reduce aquatic plant species, thereby decreasing aquatic biodiversity. This is especially damaging in unproductive lakes, where beds of aquatic plants are not as abundant and unable to survive such dramatic population declines. Submerged aquatic plants are important in these systems as habitat for consumers such as snails, insects, and other crustaceans (which provide food for fish and waterfowl), critical nursery habitat for juvenile fish and other animals, nesting areas for fish, and erosion control (by minimizing waves).

Rusty Crayfish are very aggressive, competing with and displacing native crayfish that are keystone species in invaded areas. Once a water body is invaded, native crayfishes

usually decline and, in some cases, are eliminated entirely. This can occur through competition, increased predation, or hybridization. Rusties can attain incredibly high densities, far higher than any native species. These high densities affect not only native crayfishes but also many other aspects of the ecosystem.

Rusties are also better able to avoid fish predation and can harm native fish populations by eating their eggs and young. Ultimately, this can result in reduced food availability for native fish. Rusties can be eaten by fish, but their thick shell-to-soft tissue ratio means that the food quality they provide is not as high as some of the invertebrates they replace. Less food or lower food quality means slower growth for the consumer, a trend which has also been shown to reduce survival of fish species such as Bluegill, Walleye, Northern Pike, and Pumpkinseed.

In this activity, students will design their own aquatic invaders in order to learn about how the Rusty Crayfish has adapted to its environment and why it is considered invasive.

Procedure:

Engage

1. Ask the students to define **adaptation**. Host a discussion about adaptations. Ask the class for examples of adaptations and discuss the value of these adaptations in the environments of the organisms that possess them.
2. Ask the students to research and bring in pictures of organisms with special adaptations (this can be done in a computer lab during class or for homework).
3. Invite several students to share the organism they chose. Ask the students to make inferences about the type of habitat in which the organisms live and adaptations the organisms have that help them survive.
4. Ask the class what it means for an organism to be **aquatic**. Explain that when animals live in water, they need special adaptations that help them survive. Explain that the more time an animal spends in the water, the more adaptations the animal will have for an aquatic life. Use the following list of “needs” to conduct a discussion about the kinds of adaptations aquatic organisms may have. You can state the need to the class and invite students to guess what the related adaptation would be and what it might look like:
 - a. Movement through the water.
 - b. Staying warm in cold water.
 - c. Keeping cold water away from skin.
 - d. Preventing feathers from getting wet.
 - e. Swimming fast.
 - f. Keeping the head of the organism out of the water.
 - g. Straining food particles from the water.

- h. Staying underwater while being able to detect predators/prey above the water.
 - i. Not being seen by predators in the water.
 - j. Breathing under the water.
 - k. Seeing underwater.
 - l. Eating different kinds of food in the water.
5. Introduce the idea of “**invasive**” species to the class. Invite the students to make guesses about what it means for an organism to “invade” an environment.
 6. Define “**native**” species and ask the students how the adaptations for an invasive species could be different from a native species (examples could include more feathers, bigger mouth, larger body size, camouflage...etc.). Explain that invasive aquatic species are considered invaders because of special adaptations they have that allow them to survive better than native species in their environment.
 7. Tell your students that the Rusty Crayfish is an example of an invasive aquatic species. Show students pictures of Rusty Crayfish (in kit and on CD). Have the students watch this video short: <http://www.youtube.com/watch?v=WAgNXFeGxQw>. Explain why it is called “Rusty”.
 8. Explain that the Rusty Crayfish (1) grazes on and reduces numbers of aquatic plants and other consumers, (2) is negatively affecting native fish populations, and (3) is outcompeting native crayfish species.
 9. Ask the students to observe the body of the crayfish in the photo/video for adaptations that might give it advantages in its aquatic environment. Invite students to raise their hands to share some of the adaptations they find – ask the students to explain the advantages they think the adaptations provide that make the Rusty Crayfish an aquatic invader.
 10. Have the students complete the Student Worksheet and discuss answers to Thought Questions.

Explore

1. Break the class into groups of 2-3 students each and give them an assortment of craft supplies. Tell your students that they will have the opportunity to “design their own aquatic invader”. Each group should
 - a. Include at least 3 adaptations for its aquatic invader.
 - b. Be able to explain what each adaptation is used for.
 - c. Be able to explain how its aquatic invader would be harmful to the environment.
 - d. Provide a name for its invader.
 - e. Describe the habitat its organism invades.

Explain

1. When the students are finished, have each group present their aquatic invader. Invite each group to highlight the adaptations that make their invader the most successful.

Evaluate

1. Have students list the structure and function of at least 2 of their invader's adaptations. How do these adaptations help the invader survive and compete against native species? How do these adaptations compare to the Rusty Crayfish's adaptations?

Extend

1. Host a gallery walk with the student posters. Create aquatic invader superlatives and have students cast a vote for their top choices.
2. Have student groups research other invasive species in Maryland and give a presentation on adaptations and related impact on the environment.
3. Have students go on an invasive species hunt in their backyard or schoolyard. What did they find? What adaptations do their different invaders have? Compare and contrast the different adaptations.

Rusty Crayfish Worksheet



Photo By: USGS

Rusty Crayfish (<i>Orconectes rusticus</i>)	
Size Range	Up to 4 inches in length, not including claws
Habitat	Found in streams, lakes, and ponds; feed on what is available (opportunistic)
Diet	Aquatic insects, snails, small crustaceans, juvenile fish and eggs, macrophytes (plants & algae)
Reproduction	Can lay 80-500 eggs when water temperatures reach 39° F
Other Comments	Aggressive towards other crayfish, and predators (like fish) tend to consume less Rusty Crayfish than native crayfish.

Thought Questions:

1. Describe 3 adaptations the Rusty Crayfish possesses that make it a successful invasive species. What is each adaptation used for?
 - a. Adaptation #1:
 - b. Adaptation #2:
 - c. Adaptation #3:

2. What impact does the Rusty Crayfish have on natural areas it has been introduced to? How do its adaptations help it invade?

Macrophyte Muddle

Gr: 6-12

Objectives: At the conclusion of the lesson, students will be able to:

- Describe the importance of macrophytes for aquatic systems
- Describe the impacts of Rusty Crayfish to aquatic systems

Standards:

<p>NGSS</p>	<p>MS-LS2-4 - Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.</p> <p>HS-LS2-2 - Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.</p>
<p>Core Idea</p>	<p>LS2.C: Ecosystem Dynamics, Functioning, and Resilience- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.</p> <p>LS2.C: Ecosystem Dynamics, Functioning, and Resilience- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.</p>
<p>Practices</p>	<ul style="list-style-type: none"> • Developing and using models • Planning and carrying out investigations • Analyzing and interpreting data • Constructing explanations and designing solutions
<p>Cross-Cutting Theme</p>	<ul style="list-style-type: none"> • Cause and effect • Systems and system models • Energy and matter
<p>Reading, Writing & Social Studies</p>	<p>CCSS.ELA-Literacy.W.6-8.7 - Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and refocusing the inquiry when appropriate.</p> <p>CCSS.ELA-Literacy.SL.9-12.1 - Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.</p> <p>CCSS.ELA-Literacy.W.9-12.7 - Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem.</p> <p>CCSS.ELA-Literacy.RST.6-8.3 - Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.</p>
<p>Environmental</p>	<p>1.A.1 - Identify an environmental issue</p>

Literacy	1.A.4 - Design and conduct the research 4.B.1 - Analyze the growth or decline of populations and identify a variety of responsible factors
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Macrophyte Muddle

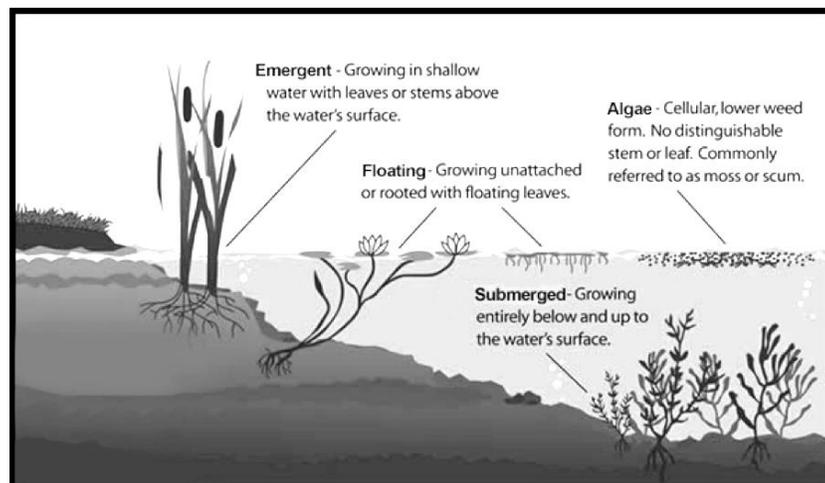
Gr: 6-12

Objectives: At the conclusion of the lesson, students will be able to:

- Describe the importance of macrophytes for aquatic systems
- Describe the impacts of Rusty Crayfish to aquatic systems

Materials:

- 2-2L plastic bottles/group
- 8 Elodea strands per group (or a different aquatic plant from an aquarium supply store)
- Board
- Dissolved oxygen test kit
- Graph paper
- Gravel (1 c per group)
- Rusty Crayfish pictures (on CD)
- Scissors
- Sharpies or labels
- Student pages (on CD)
- Tap water
- Thermometer



Types of aquatic plants (macrophytes)

Teacher Background: Dense stands of diverse aquatic plants thrive in the shallows of many healthy aquatic systems, providing habitat to an abundance of life at or below the surface and helping improve the quality of the water. These aquatic plants are collectively referred to as **macrophytes**, and are considered either emergent, floating, submerged, or algae.

Rusty Crayfish, an aggressive invasive species, can cause a variety of negative environmental impacts when introduced to new aquatic systems. “Rusties” prefer nutrient-rich streams and lakes--once established, they displace native crayfish species through competition and increased fish predation.

Perhaps the most serious impact of the rusty, however, is the destruction of submerged aquatic plant beds. Rusty Crayfish graze on and subsequently reduce aquatic plant abundance and, as a result, species biodiversity. This can be especially damaging in unproductive streams and lakes, where beds of aquatic plants are already in low abundance.

While submerged aquatic plants provide shelter, habitat, and food for many organisms, they also benefit aquatic species by helping maintain the viability of the ecosystem. Their roots help prevent erosion and leaves add essential concentrations of dissolved oxygen (DO) to the water. In an aquatic environment, oxygen must be in solution in a free state (O_2) before it is available for use by organisms. Its concentration in the aquatic environment depends on chemical and physical factors and is greatly affected by biological processes such as photosynthesis and respiration. Photosynthesis usually increases the DO concentration in water. Aerobic respiration requires oxygen and will usually decrease DO concentration. In an aquatic environment, there are about 5-10 mL O_2 /1 L water.

The **primary productivity** of an ecosystem is defined as the rate at which organic materials are stored. Only those organisms possessing photosynthetic pigments can utilize sunlight to create organic compounds from simple inorganic substances. Aquatic plants obtain carbon for carbohydrate synthesis from the carbon dioxide in the water or the air according to the basic equation for photosynthesis ($6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$). The rate of carbon dioxide utilization, the rate of formation of organic compounds, or the rate of oxygen production can be used as a basis for measuring primary productivity. A measure of oxygen production over time provides a means of assessing the amount of carbon that has been bound (taken up by photosynthesis) over a period of time. For each mL of oxygen produced, approximately 0.536 mg of carbon has been assimilated.

Since photosynthesis and respiration occur simultaneously in aquatic systems, the DO concentration is a measure of net productivity and can be used to determine whether the biological activities requiring oxygen are occurring. Over the past several decades, aquatic plants have fared poorly at the hand of invasive species such as the Rusty Crayfish. Areas once covered by thick beds of these plants may have little or no vegetation remaining. In areas that can support them, the plants often serve as a barometer of aquatic ecosystem health. By monitoring the status of these macrophyte populations and related rate of DO concentration change over time, we can better gauge the impact of invasive species such as the Rusty Crayfish and determine the aquatic system's vitality.

In this activity, students will investigate the relationship between macrophyte populations and DO concentration as an indicator for aquatic ecosystem health relative to Rusty Crayfish invasion.

Procedure:

Engage

1. Ask students to list reasons why plants are important for aquatic systems. (Plants provide habitat, oxygen, food for waterfowl, soil stabilization, and filter runoff.)
2. Define **macrophyte** and explain differences between plants that are submerged, emergent, floating and algae. Have students explain importance of different types of macrophytes.
3. Tell students that despite their importance, macrophytes are declining in many aquatic systems. Ask students to explain reasons for decline. (Development, sedimentation, invasive species)
4. Write 'invasive species' on the board. Ask students to make guesses on what it means for the environment. Ask if they can provide examples of invasive species.
5. Show picture of Rusty Crayfish and ask students if they know what it is. How might a crayfish affect macrophytes? (Consumes and destroys macrophytes while foraging.)
6. Hand students student worksheet with graph of macrophyte biomass and Rusty Crayfish catch. Have students answer questions on the worksheet then go over findings.
7. Introduce the importance of water quality and DO concentrations from a metabolic perspective (e.g. photosynthesis and respiration, carbon assimilation...etc.) Tell the students that healthy aquatic systems should have 5-10 mL O₂/1 L water.

Explore

1. Tell the students that they will be investigating the relationship between macrophyte populations and DO concentration as it relates to Rusty Crayfish invasion. Tell them that they will be growing two aquatic plant "communities" – one with a small macrophyte population due to Rusty Crayfish herbivory and one with a normal macrophyte population without Rusty Crayfish. Have them brainstorm the relative effects of each on the DO concentration in each system over time and record their hypotheses on the Student Observation Sheet provided.
2. Divide the students into groups of 2-3 students each. Have them cut the tops off their plastic bottles using scissors, label their bottles #1 and #2, add 1 cup of aquarium gravel to each bottle, and fill each bottle $\frac{3}{4}$ full with tap water. If time allows, the bottles should sit overnight in order to properly dechlorinate.
3. Students should "plant" 2 Elodea strands in Bottle 1 and 6 strands in Bottle 2.
4. Using a dissolved oxygen test kit, the students should take an "initial" DO reading and record their results in the Data Tables provided for each bottle under Week 1. The two bottles should be placed in well-lit areas for the duration of the project. Be sure to discuss the importance of controlled variables at this

point in the activity. Stress the importance of recording the data at the same time each day.

5. For 8 weeks, students should record the temperature and DO concentration in each bottle, as well as calculate and record class averages for each (NOTE: the water in each bottle may need to be occasionally restored due to evaporation).

Explain

1. At the end of the 8-week period, students should create Microsoft Excel graphs showing the change in DO concentration over time relative to their macrophyte populations.
2. Discuss the classes' findings.
3. Ask students what other impacts, besides the decreased DO, would the loss of macrophytes have on aquatic systems.
4. Ask students, given what they know about DO, would the impact of Rusty Crayfish vary by season. Why or why not?
5. It would vary. In the summer, DO concentrations are lower than in the winter due to the temperature of the water. So, the impact of Rusty Crayfish would be higher in summer months than in winter months.

Evaluate

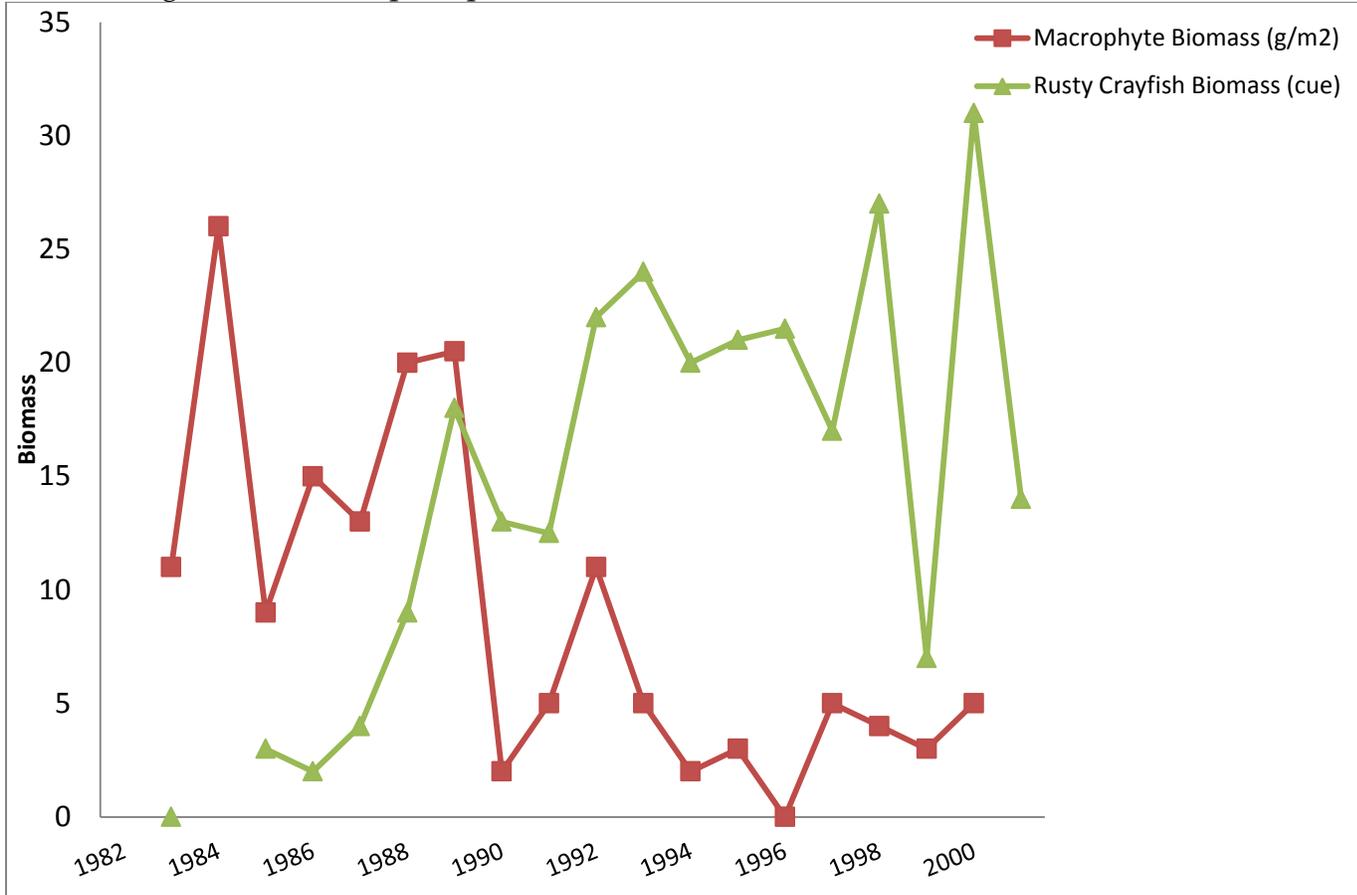
1. Have students explain why Rusty Crayfish invasions are problematic for aquatic systems.
2. In addition to decreased DO levels, what are other ways aquatic species may be impacted by the loss of macrophytes? (Loss of habitat, increased sedimentation, etc)

Extend

1. Have students take DO measurements for a longer period of time and include oxygen saturation measurements (using a nomograph).
2. Have students design an inquiry-based extension project to further assess DO concentration relative to Rusty Crayfish invasion via macrophyte population (e.g. introduction of other experimental variables/dimensions – different type/number of aquatic plant species, addition of secondary consumers such as snails or small fish, temperature, pH, depth of DO measurement...etc).
3. Have students review Rusty Crayfish distribution data and research aquatic plants native to the areas affected. The students could do a research project on an aquatic plant species of their choice, investigating the benefit of that particular species and examining the extended environment impact of species loss due to rusty invasion.

Macrophyte Muddle

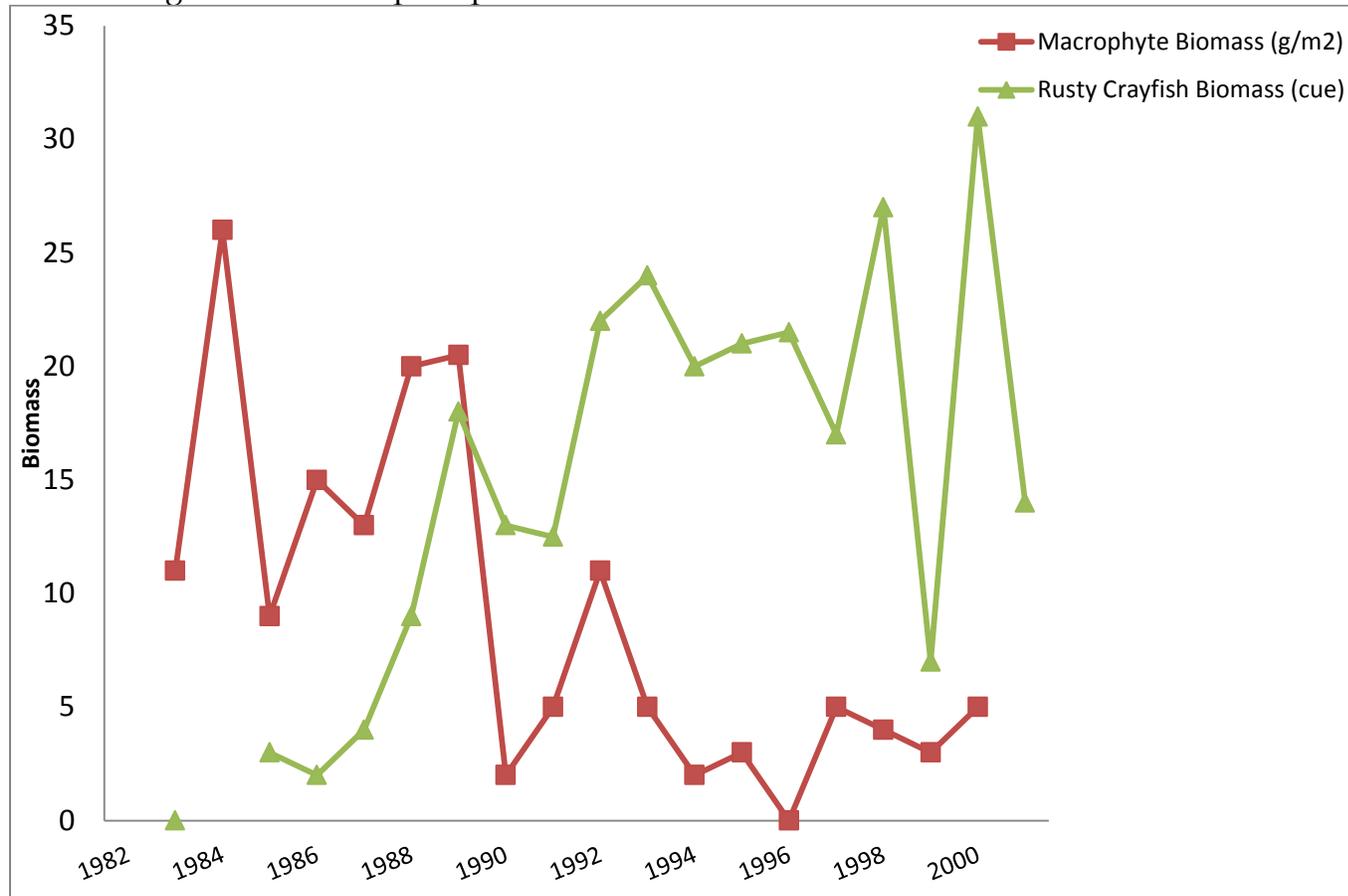
The graph below depicts the biomass of macrophytes and the number of Rusty Crayfish collected from Trout Lake, Michigan from 1982-2000. Rusty Crayfish biomass is represented by the catch per unit of effort (cue) while macrophyte biomass refers to the number of grams collected per square meter.



1. What is the relationship between macrophyte biomass and Rusty Crayfish population sizes?
2. What is the reason for this relationship?
3. What impact may this relationship have on aquatic systems?

Macrophyte Muddle Answers

The graph below depicts the biomass of macrophytes and the number of Rusty Crayfish collected from Trout Lake, Michigan from 1982-2000. Rusty Crayfish biomass is represented by the catch per unit of effort (cue) while macrophyte biomass refers to the number of grams collected per square meter.



1. What is the relationship between macrophyte biomass and Rusty Crayfish population sizes?

Macrophyte biomass decreases as Rusty Crayfish populations increase.

2. What is the reason for this relationship?

Rusty Crayfish feed upon macrophytes and destroy macrophytes while foraging for food.

3. What impact may this relationship have on aquatic systems?

The loss of macrophytes can decrease dissolved oxygen levels in aquatic systems, can decrease biodiversity, etc.

Student Observation Sheet – Macrophytes and Dissolved Oxygen

Hypothesis: _____

Data Table – Bottle 1

Week	Date	Time	Temperature (°F)	Average Class Temperature (°F)	Group DO	Average Class DO
1						
2						
3						
4						
5						
6						
7						
8						

Observations:

Data Table – Bottle 2

Week	Date	Time	Temperature (°F)	Average Class Temperature (°F)	Group DO	Average Class DO
1						
2						
3						
4						
5						
6						
7						
8						

Observations:

Note:

For mg/L:

0-2 mg/L: not enough oxygen to support most animals

2-4 mg/L: only a few kinds of fish and insects can survive

4-7 mg/L: good for most kinds of pond animals

7-11 mg/L: very good for most stream fish

Mold, Blight, & Chestnut Strife

Gr: 6-8

Objectives: At the conclusion of the lesson, students will be able to:

- Understand what mold is and how it grows
- Explain how Chestnut Blight impacts American Chestnut
- Describe how the loss of American Chestnut impacted wildlife

Standards:

NGSS	MS-LS1-4 - Use argument based on empirical evidence and scientific reasoning to support an explanation for how...specialized plant structures affect the probability of successful reproduction. MS-LS2-4 - Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
Core Idea	LS1.B: Growth and Development of Organisms - Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. LS2.C: Ecosystem Dynamics, Functioning, and Resilience - Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.
Practices	<ul style="list-style-type: none">• Engaging in argument from evidence• Asking questions and defining problems• Planning and carrying out investigations• Analyzing and interpreting data• Obtaining, evaluating, and communicating information
Cross-Cutting Theme	<ul style="list-style-type: none">• Cause and Effect• Stability and Change
Reading, Writing & Social Studies	CCSS.ELA-LIT.RST.6-8.2 - Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. CCSS.ELA-LIT.RST.6-8.3 - Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. CCSS.ELA-LIT.RST.6-8.9 - Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.
Environmental Literacy	1.A.1 - Identify an environmental issue. 5.A.2 - Analyze the effects of human activities that deliberately or inadvertently alter the equilibrium of natural processes.

Objectives: At the conclusion of the lesson, students will be able to:

- Understand what mold is and how it grows
- Explain how Chestnut Blight impacts American Chestnut
- Describe how the loss of American Chestnut impacted wildlife

Materials:

- Bread (1 slice/group)
- Bushel basket
- Chestnuts (in kit)
- Diagrams of mold
- Digital camera (optional)
- Dissecting scopes and/or magnifying glasses (in kit)
- Markers
- Nuts (acorns, hickory nuts, walnuts)
- Observation sheets (on CD)
- Pictures of American Chestnut trees (healthy) and with the Blight (in kit)
- Plastic baggies
- Thermometer
- “American Chestnut Blight: - greatest forest loss in history” video (on CD)
- Water spray bottle

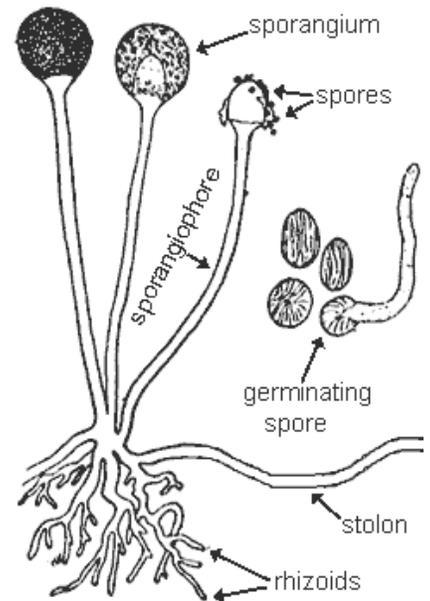


Large American Chestnut by U.S. Forest Service

Teacher Background: At one time, the **American Chestnut** (*Castanea dentata*) dominated approximately 200 million acres of land from Maine to Mississippi. In some areas, it is estimated that American Chestnuts covered roughly 20% of the Appalachian forest while other areas contained almost pure stands of trees. Chestnut trees grew up to 100ft tall and often averaged several feet in diameter. The trees were important for wildlife as they produced edible nuts in the fall. One large tree could produce up to 10 bushels or more of nuts! Ruffed grouse, white-tailed deer, black bears, raccoons, squirrels, and wild turkeys are just some of the species which foraged on American Chestnuts. The trees were also used in the lumber industry to build fences, caskets, and cabins while the bark and inner cordwood were used to tan leather hides.

Unfortunately, during the late 1800s, an **invasive species**, the **Chestnut Blight** (*Cryphonectria parasitica*) was accidentally introduced to the United States from Asia. Invasive species are non-native organisms that create biological, economic and/or human-health related harm. The Blight is an invasive fungus that quickly spread through American Chestnut stands. A few decades after the Blight's introduction, over 9 million trees died. By 1950, the American Chestnut was nearly gone from the landscape, and today, only a handful of plants survive.

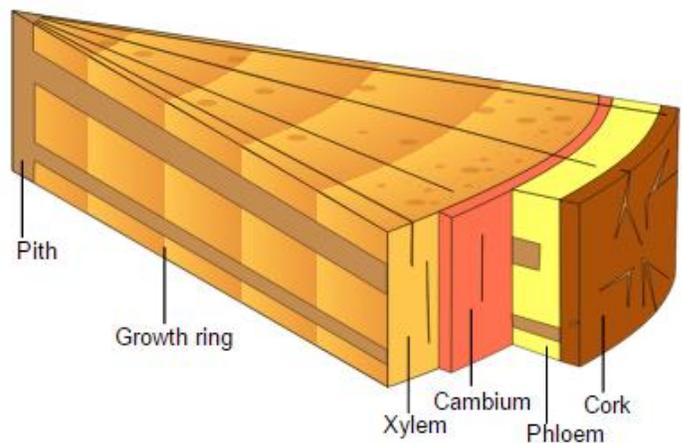
Currently, the American Chestnut Foundation has been working to produce a Blight resistant strain of American Chestnut. The fungal spores of Chestnut Blight spread from tree to tree by animals and the wind. The spores infect cuts in the bark and create a rusty-colored **canker** (blister) on the surface of the tree. Below the surface, however, is a network of **hyphae** (fungal strings) that grow in the **vascular tissue** (xylem and phloem) which are responsible for food and water transport. As the hyphae plug up the vascular tissue, the plant slowly begins to die due to the lack of food and water reaching its living tissues.



Anatomy of bread mold

Mold is a common name for certain species of fungi. Different molds grow on a variety of surfaces--from parasitizing living organisms to growing on surfaces such as wood, fabric and food. Molds are important in the process of decay. One of the most common molds in the world is bread mold fungus (*Rhizopus stolonifer*). The spores are released into the air from mature fruiting bodies known as **sporangia**. The mature fruiting bodies in bread mold fungus are black while those that are still developing are white or translucent. The fungus consists of a network of hyphae that connect to the bread surface and absorb nutrients. The network of hyphae is also known as the **mycelium**.

In this activity, students will observe the growth and spread of mold to understand how Chestnut Blight grows and spreads in living American Chestnuts.



Anatomy of a tree By Thomas Steiner [GFDL or CC-BY-SA-3.0], via Wikimedia Commons

Procedure:

Engage

1. Ask students why trees are important to wildlife. (They provide habitat such as food and shelter). Show students a variety of nuts such as acorns, hickory nuts, walnuts and the like. Ask students what animals may eat those types of nuts. (Squirrels, turkeys, deer, bear, etc). Write down list of animals for future use.
2. Show students pictures of healthy American Chestnut trees and then show them a bushel basket and Chestnuts. Tell the students that those mature Chestnut trees could produce up to 10 bushels (500-600 pounds) of nuts!
3. Show students pictures of American Chestnut trees affected by the Blight. Ask students how this may impact wildlife that depend on the trees. (Wildlife will lose food & shelter). Explain to students that Chestnut Blight is a fungal disease that slowly kills American Chestnut trees.
4. Have students watch the video “American Chestnut Blight: - greatest forest loss in history” provided in kit.

Explore

1. Tell your students they will now be experimenting to see how fungus grows and spreads through surfaces. Go through basic fungi anatomy including key terms such as **hyphae**, **mycelium** and **sporangia**. You may want to show students pictures of the different structures.
2. Break students up into small groups and hand each group an observation sheet, sealable plastic bag, marker and slice of bread. The best bread to use is a multigrain with seeds and without preservatives like propionic acid, which inhibit the growth of mold. Have students label their bag with a group name and date in the top corner and then place their bread in the bag.
3. Tell students that their slice of bread represents a cross section of a tree. The crust represents the **bark** and underneath it is the living tissues such as the **xylem** and the **phloem**, which transport water and food from the roots to the leaves and back.
4. Pass around a plastic spray bottle and have students spray their bread with two sprays of water.
5. Next, have the students seal their bag and then record their initial observations on the worksheet. *Note: you may want students to take pictures to document their bread.*
6. Inform the students that they will be documenting the spread and growth of mold (fungi) on their bread. Have students write down predictions on the sheet. Place bags on a shelf where they will be warm but not too hot. Have students record the air temperature of the space where the bags are placed.
7. Over the next two weeks, students should observe and record their observations. Allow students to use magnifying glasses or dissecting scopes to observe the

network of **hyphae** (branching, white, fuzzy structures) as it grows on the bread. Tell students to look for spore-bearing structures known as **sporangia**. Have students record how many days it takes until sporangia form and then when mature (black) sporangia develop. Be sure to remind students to keep the bags sealed during each observation due to health problems associated with mold spores.

8. At the end of the experiment, go over the student's observations. How did their observations compare with their predictions? Did the mold form slower or faster than their predictions?
9. Create graphs of the time it took for mold formation, sporangia formation and mature sporangia formation. Have students calculate an average time for each event.
10. Tell students that the Chestnut Blight is also a fungus like their bread mold. Ask them where they think the bread mold spores came from. (The air). Tell them the Chestnut Blight is also spread in a similar manner. Ask how else the spores may spread. (From animals)

Explain

1. Now that the students have had a chance to examine the growth and spread of hyphae, tell them that the Chestnut Blight hyphae spread under the bark of the tree and into the living tissue. Why might it be an issue if hyphae grows in the xylem and phloem of American Chestnut trees? (It clogs the tubes, and the trees starve). If the trees are unable to grow, then how will that impact wildlife?
2. Ask the students if they have ever seen a Chestnut tree in the wild. Few to no students will say yes. Tell them that the Chestnut tree was once one of the most abundant trees in the eastern United States and that people also depended on the trees as much as wildlife.
3. Review the list of wildlife species that depend on nuts for food. Ask students if they think any of those species may have been impacted by the Chestnut Blight. Most of the species likely were affected in some way or another. Ask students if they know why species like deer and turkey, which relied heavily on Chestnuts, are still around, unlike our animals in the activity. (They found other food sources from trees such as oaks and hickories).

Evaluate

1. Have students draw and label parts of mold including the sporangia, mycelium, and hyphae.
2. Have students explain how Chestnut Blight affected American Chestnut trees.
3. Have students research the history of the American Chestnut and its importance.

Extend

1. Landscapers have found that Chinese Chestnut (*Castanea mollissima*) is not affected by the Blight. Have students research why this species is not impacted like the American Chestnut.
2. Place half of the bread samples in a warm location and the other half in a cool location. Have students make predictions which bread will develop mold faster and why. Compare and contrast predictions to final results.

Student Observation Sheet

Name: _____

Group: _____

Day 1

Date: _____

Temperature: _____

Draw a picture of your bread below.

Predictions:

1. How many days will it take until mold forms? _____
2. How many days will it take until sporangia forms? _____
3. How many days will it take until mature sporangia forms? _____

Day _____

Date: _____

Draw a picture of your bread below.

Is mold growing? Yes No

What color is the mold? _____

What texture is the mold? _____

Has sporangia formed? Yes No

Is the sporangia mature? Yes No

Other observations:

Nuisance Nutria

Gr: 6-8

**Modified from the Deadly Plant Invaders Game by Karen Bacula and Dave Kronk*

Objectives: At the conclusion of the lesson, students will be able to:

- Understand the impacts of Nutria on natural areas and native species
- Understand ways to control Nutria

Standards:

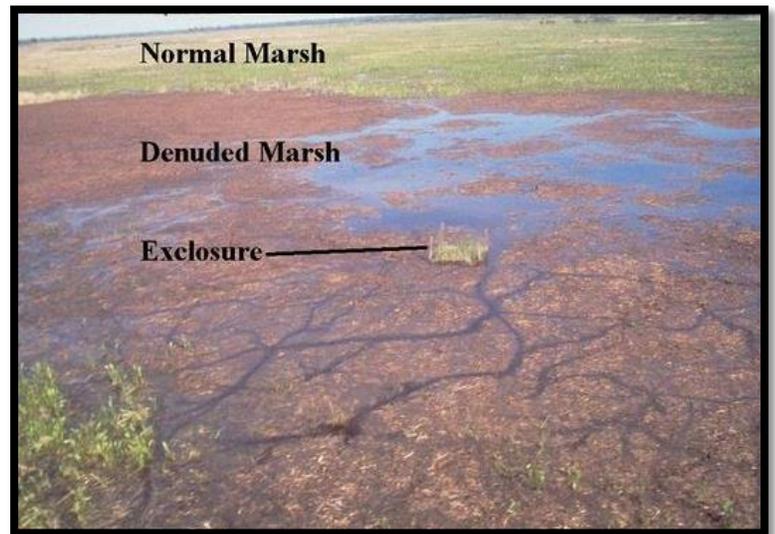
NGSS	MS-LS2-1 - Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. MS-LS2-4 - Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. MS-LS2-5 - Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
Core Idea	LS2.A: Interdependent Relationships in Ecosystems- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. LS2.C: Ecosystem Dynamics, Functioning, and Resilience- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.
Practices	<ul style="list-style-type: none">• Developing and using models• Analyzing and interpreting data
Cross-Cutting Theme	<ul style="list-style-type: none">• Cause and effect• Systems and system models stability and change
Reading, Writing & Social Studies	CCSS.ELA-Literacy.SL.6-8.1 - Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade appropriate topics, texts, and issues, building on others' ideas and expressing their own clearly.
Environmental Literacy	4.B.1 - Analyze the growth or decline of populations and identify a variety of responsible factors.

Objectives: At the conclusion of the lesson, students will be able to:

- Understand the impacts of Nutria on natural areas and native species
- Understand ways to control Nutria

Materials:

- 3 different colored playing pieces (1 of each color/student; 25 of each in kit)
- 3 soft balls (Nerf type, in kit)
- 4 cones or other markers (in kit)
- Arm bands, at least 2 different colors
- Board
- Nutria pelt (in kit)
- Pictures of muskrat and Nutria (on CD)
- Whistle to signal the end of each round



Tidal marsh destroyed by Nutria

Teacher Background: One of the most serious threats to native plants and animals today is the introduction of invasive species. **Invasive species** are non-native species that cause biological, economic or human-health related harm. When a certain invasive species is allowed to invade an ecosystem, the results can be devastating for the native species. Often, natural diseases or predators that normally keep these populations in check are not brought with the invasive species to their new homes, thus causing a great growth in population size. This can lead to a decrease in native plant and animal diversity in a region as these invasive species increase in number. The invasive species often out-compete natives in obtaining the essential requirements for growth.

This decrease in native species' diversity affects many different food chains and may lead to a mono-culture of species and animals where once there was variety. Loss of endemic or native plant and animal species may mean loss of valuable genetic material which could someday provide important medicines or foods.

One invasive mammal is the Nutria. Nutria are large rodents that look like beavers with long, thin tails. Nutria may weigh up to 20 lbs and reach about 24 inches from tip of

nose to tip of tail. Nutria have thick brown fur and orange front teeth. They are designed for aquatic life, with webbed feet and eyes, nostrils and ears located high on their heads to enable them to expose as little of their bodies as possible when breathing at the surface of the water. Nutria were introduced to many wetland habitats in the United States through the fur trade. Nutria are native to South America and can be found in 22 states, including Delaware and the Eastern Shore of Maryland. Nutria eat wetland plants and prefer the roots, rhizomes and tubers. Nutria will eat entire plants and will exploit wetlands in fresh, brackish and salt water.

In the Chesapeake Bay, Nutria currently pose the greatest threat to salt marshes in the lower eastern portion of Maryland and are specifically impacting three-square bulrush. When Nutria remove entire sections of bulrush from the marsh, the sediment supporting the plants erodes away and the level of sediment falls, preventing establishment of new native plant colonies. Nutria also fragment the marsh by creating deep swimming channels, preventing less mobile, marsh-dependant species from using all available habitat.

In contrast to Nutria, muskrats are native, semi-aquatic rodents that feed on marsh vegetation such as cattails. In addition to feeding on marsh plants, muskrats also construct lodges and feeding platforms out of the plants. Muskrat lodges are used by a variety of wildlife including snakes, turtles, frogs, toads and Canada geese. Muskrats also provide an important food resource for predators such as owls, hawks, Bald Eagles, foxes and raccoons.

In this activity, students will simulate what may happen to a muskrat colony if the invasive Nutria becomes established in a marsh.

Procedure:

Engage

1. Ask students what are the main components of habitat (Food, water, shelter, space). What happens if there is not enough habitat to support an animal's needs? What are some reasons for habitat loss? List reasons on the board.
2. Ask students what animals may live in a tidal marsh. List animals on the board.
3. Tell the students that they will be simulating muskrats that live in a tidal marsh. What do they know about muskrats? What do muskrats eat? Where do they live? Review this material with students before beginning simulation or have students research muskrats and their habitat.

Explore

1. Before the activity begins, designate a playing area by placing cones at edges/corners of the playing field. (A 30 foot by 60 foot area works well for 20 students). Scatter playing chips throughout the area. Be sure to provide enough

chips so each player may collect 1 chip of each color during the first round. Each color represents a different need for the species.

- a. Color 1 - shelter
 - b. Color 2 - food
 - c. Color 3 - space
2. Round 1: All players will be muskrats (or another native animal that lives in marshes) that populate a specific area. Everyone will line up along edges of the playing field at the start of each round. Explain to the students that they will be simulating muskrats and will get to forage a tidal marsh for food, water, and shelter resources. Tell students that they need to collect 1 chip of each color to survive, but they can only collect chips one at a time. Record the initial number of muskrats on a board or piece of paper.
 3. At the sound of the whistle, players will enter the field, collect one chip and return to the edge of the playing field. After they reach the sideline, they return to the playing field and collect another chip of a different color. Once again they go to the sideline and then return for a chip of the third color.
 4. After all 3 colors have been collected by a player, he/she moves to the sideline to wait for the signal to end the round, all players should survive.
 5. At the conclusion of round 1, reinforce the fact that the "habitat" had ample food, water, and shelter for everyone to survive.
 6. Round 2: Inform students that this round will now include the invasive Nutria. Ask the students to define an invasive species and then tell them how the Nutria impacts wetland habitats by destroying vegetation and causing extensive erosion in the marsh. Two players will wear an arm band to show that they are Nutria. The Nutria are more aggressive and will be allowed to collect two chips (of any color) per trip into the playing field. The Nutria will also be allowed to return to the field as often as they are able, but must collect three different colors in order to survive. Native muskrats will be considered a survivor if he/she has collected three chips of different colors as done in round 1.
 7. At the end of round 2, identify the survivors and record the number on a board or a piece of paper. Record the number of Nutria in this round as well. Compare population sizes of the two species. What happened to the muskrat population? The muskrat population should have decreased due to competition from the Nutria.
 8. Round 3: Native species that did not survive round 2 become Nutria for this round. Give each new Nutria an arm band. Continue play as in round 2. At the end of this round, most - if not all - of the natives should no longer be surviving. Record the number of muskrats that survived as well as the number of Nutria that survived.
 9. Evaluate as in round 2. Ask the students if there are ways to control invasive species. (Invasive animals can be hunted, trapped, removed, etc).
 10. Round 4: Choose 2-3 players to be population controls for the Nutria: aka "trappers" to remove Nutria. Give each an arm band (different color than the

Nutria). The population controls will join this round and begin removing Nutria with a ball, which is gently tossed and aimed below the waist. After a non-native is hit, he/she returns the gathered chips to the playing area then moves to the sideline to remove the arm band. The player immediately returns to the game as a native species. Native species are NOT to be tagged by the population controllers. After all chips have been collected identify the survivors and record the muskrat and Nutria population numbers.

11. Round 5, if needed introduce more population controls and repeat round 4. Record population sizes.

Explain

1. Create a chart of the muskrat and Nutria populations.
2. What impact did the introduction of the Nutria have on muskrat populations?
3. What impact did the addition of trappers have on the populations?
4. Why were the trappers needed? (*population control, like predators*)
5. Aside from trapping Nutria, what else can be done to control invasive species?
6. Discuss the effects trappers may have on the biodiversity of an area if used to eliminate invasive species like Nutria.

Evaluate

1. What resources do invasive species compete with native species for? Do you think only muskrats will be affected by Nutria in tidal marshes? Refer to the original list of animals on the board. How many may be impacted by the introduction of the Nutria?

Extend

1. Have students research and write a paper on invasive species in their area. What effects are they having on local ecosystems, and why are they a problem? What ways can these invasive species be controlled?

Objectives: At the conclusion of the lesson, students will be able to:

- Show how plants and animals get energy, by telling other students which plants and animals are eaten by other animals
- Explain how all living things depend directly or indirectly on plants for food
- Explain how Nutria impact tidal marsh food webs

Standards:

NGSS	5-LS2-1 - Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.
Core Idea	<p>3.LS4.C: Adaptation - For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.</p> <p>3.LS2.C: Ecosystem Dynamics, Functioning, and Resilience - When the environment changes in ways that affect a place’s physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die.(secondary)</p> <p>3.LS4.D: Biodiversity and Humans - Populations live in a variety of habitats, and change in those habitats affects the organisms living there.</p> <p>5.LS2.A: Interdependent Relationships in Ecosystems - The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants.</p>
Practices	<ul style="list-style-type: none"> • Engaging in Argument from Evidence • Developing and Using Models
Cross-Cutting Theme	<ul style="list-style-type: none"> • Patterns • Cause and Effect • Systems and Systems Models
Reading, Writing & Social Studies	CCSS.ELA-Literacy.SL.3-5.1 - Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade-appropriate topics and texts, building on others' ideas and expressing their own clearly.
Environmental Literacy	None

Objectives: At the conclusion of the lesson, students will be able to:

- Show how plants and animals get energy, by telling other students which plants and animals are eaten by other animals
- Explain how all living things depend directly or indirectly on plants for food
- Explain how Nutria impact tidal marsh food webs

Materials:

- Art supplies
- Board
- Nutria pelt (in kit)
- Paper
- Pictures of tidal marshes
- Spool of yarn or string
- Tidal Marsh Cards (in kit or make your own)



Tidal marsh destroyed by nutria

Teacher Background: A **food chain** is a model that shows how energy is passed, in the form of food, from one organism to another. A series of connected food chains make up a **food web**. Food chains and webs are organized by **trophic levels**, which are feeding positions in the web. The lowest trophic level contains the **producers** (autotrophs), which manufacture their own food, and the decomposers, which break down existing organic material. Plants generally fall into producer category while fungi are typically **decomposers**. The organisms that feed on plants and other producers are then considered to be **primary consumers**. Anything that eats a primary consumer is then considered to be a **secondary consumer**. Animals that eat secondary consumers are known as **tertiary consumers**. Food chains and food webs are, therefore, composed of multiple predator and prey relationships.

Tidal marshes are very important coastal wetland systems. These areas serve as a place where fresh and tidal water come together to form a unique habitat. The constant change with the rise and fall of the tides creates a complex system that supports many different species. The main producers for this ecosystem are tidal marsh grasses such as cordgrass and saltgrass. These producers not only provide habitat for a variety of organisms but also they provide food. Even dead and decaying matter (**detritus**) from the grasses and marsh inhabitants provide food for fiddler crabs, snails and small fish. Oysters and clams also filter detritus while also serving as food for wading birds, crabs

and large fish. Tidal marshes are extremely important habitats that provide erosion and sediment control, provide nursery habitat and are some of the most productive ecosystems in the world.

Unfortunately, tidal marshes around the world have been declining due to factors such as habitat destruction, pollution and introduction of invasive species. **Invasive species** are non-native species that cause biological, economic or human-health related harm. One invasive species that threatens tidal marshes is the Nutria, a large, semi-aquatic rodent from South America. In many areas, Nutria were introduced into wetlands through the fur trade. Unlike many of the other tidal marsh inhabitants, Nutria consume the roots of wetland vegetation, causing the soil normally held in by the roots to become unstable and wash away. In some areas, thousands of acres of tidal marsh have been destroyed by Nutria.

In this activity, students will simulate what happens to a tidal marsh food web with the introduction of Nutria.

Procedure:

Engage

1. Ask students to define a **food web**. What is at the bottom of a food web? Where do plants get their energy? Define terms such as **producer, primary consumer, and secondary consumer**.
2. Ask the students if they have ever been to a tidal marsh. What did it look like? What did it smell like? What kinds of animals and plants did they see? Make a list of animals and plants on the board. Have students try to label the different animals and plants as either producers, primary, or secondary consumers. You may want to show pictures of tidal marshes to students, so they get an idea of what the marshes look like.
3. Ask students why tidal marshes are important for the animals and plants listed. What are other reasons why these habitats are important? (For example, they provide nursery habitat and sediment control).

Explore

1. Hand out one tidal marsh card to each student and then have students stand in a large circle. You can either use the provided tidal marsh cards, or you can have the students research organisms and create their own cards. With younger students, you may want to go over some of the cards and talk to the students about the organisms they represent.
2. Tell the students that they will be making a web that connects the tidal marsh organisms using yarn. Tell them that when they get the yarn, they have to announce who they are and how they contribute to the web. For example, the student with the wild rice card may say "I am wild rice, and I provide food for

animals.” Any other students that consume that resource should raise their hands and explain why they need that resource. The student with the yarn should toss the yarn to one of the students that needed their resource while holding on to a section of the yard.

3. Have one of the ‘plants’ start the activity. Let the student announce who they are and then have other students figure out how they may be connected. You may need to help prompt some of the students if they get stuck on their connections.
4. When all students are connected by yarn, tell them that Nutria have been introduced to their tidal marsh. Nutria is a mammal that is not native to their marsh. It eats the roots of wetland plants, and there are no natural predators for Nutria in their tidal marsh. Tell the ‘plants’ that now that the Nutria are in the marsh, they will not survive. Ask the students how they think this will affect the marsh web.
5. Have students who are plants tug on their yarn strings or step backwards to create tension. How many other students felt the pull or tension? Those are the primary consumers that directly depended on the plants. Next, have the primary consumers tug on their yarn strings. Who else felt the impact? Those students are the secondary consumers. Continue until everyone in the web becomes impacted.

Explain

1. What were the most important organisms in the marsh and why? (Plants because they were at the bottom of the food web).
2. Discuss with your students why the arrival of the Nutria was bad for their marsh. Did they expect the predators like the osprey to be impacted by the Nutria?
3. Besides losing food resources, what other ways can Nutria impact marshes? (Lose nursery habitat, increased erosion from loss of plants, etc).

Evaluate

1. Ask the students to give 2 examples of predators and 2 examples of prey that live in tidal marshes.
2. Ask students why Nutria are bad for tidal marshes while species like muskrats and marsh rice rats are not?

Extend

1. Have students use craft materials to create their tidal marsh web without the Nutria, emphasizing the different connections between the plants and animals. Have students label the producers, primary consumers, and secondary consumers.
2. Have students research the Nutria and areas where they are found. What states have Nutria and what is being done to stop their spread?

Objectives: At the conclusion of the lesson, students will be able to:

- Explain the importance of American Chestnut trees to wildlife
- Describe how Chestnut Blight spread to trees
- Understand the impact of Chestnut Blight to wildlife

Standards:

<p>NGSS</p>	<p>3-LS3-1 - Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.</p> <p>3-LS4-3 - Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.</p> <p>3-LS4-4 - Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.</p> <p>5-LS2-1 - Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.</p>
<p>Core Idea</p>	<p>3.LS3.A: Inheritance of Traits - Many characteristics of organisms are inherited from their parents.</p> <p>3.LS3.B: Variation of Traits - Different organisms vary in how they look and function because they have different inherited information.</p> <p>3.LS4.C: Adaptation - For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.</p> <p>3.LS2.C: Ecosystem Dynamics, Functioning, and Resilience - When the environment changes in ways that affect a place’s physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die.(secondary)</p> <p>3.LS4.D: Biodiversity and Humans - Populations live in a variety of habitats, and change in those habitats affects the organisms living there.</p> <p>5.LS2.A: Interdependent Relationships in Ecosystems - The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants.</p>
<p>Practices</p>	<ul style="list-style-type: none"> • Analyzing and Interpreting Data • Engaging in Argument from Evidence • Developing and Using Models

Cross-Cutting Theme	<ul style="list-style-type: none"> • Patterns • Cause and Effect • Systems and Systems Models • Interdependence of Engineering, Technology, and Science on Society and the Natural World
Reading, Writing & Social Studies	<p>CCSS.ELA-Literacy.RI.3.1 - Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers.</p> <p>CCSS.ELA-Literacy.RI.3.7 - Use information gained from illustrations (e.g., maps, photographs) and the words in a text to demonstrate understanding of the text (e.g., where, when, why, and how key events occur).</p> <p>CCSS.ELA-Literacy.RI.3.8 - Describe the logical connection between particular sentences and paragraphs in a text (e.g., comparison, cause/effect, first/second/third in a sequence).</p> <p>CCSS.ELA-Literacy.RI.4.1 - Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.</p> <p>CCSS.ELA-Literacy.RI.4.3 - Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.</p> <p>CCSS.ELA-Literacy.RI.4.5 - Describe the overall structure (e.g., chronology, comparison, cause/effect, problem/solution) of events, ideas, concepts, or information in a text or part of a text.</p> <p>CCSS.ELA-Literacy.RI.5.1 - Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.</p> <p>CCSS.ELA-Literacy.RI.5.3 - Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.</p>
Environmental Literacy	<p>1.A.1: Identify an environmental issue</p> <p>4.C.1: Explain how the interrelationships and interdependencies of organisms and populations contribute to the dynamics of communities and ecosystems.</p> <p>5.B.1: Analyze, from local to global levels, the relationship between human activities and the earth's resources.</p>

Objectives: At the conclusion of the lesson, students will be able to:

- Explain the importance of American Chestnut trees to wildlife
- Describe how Chestnut Blight spread to trees
- Understand the impact of Chestnut Blight to wildlife

Materials:

- Board
- Bushel basket
- Chestnut cards (4 per “tree”, in kit)
- Chestnuts (in kit)
- Glitter
- Nuts (acorns, hickory nuts, walnuts)
- Pictures of Chestnut trees (on CD)
- The Legend of the American Chestnut Tree book (in kit & on CD)
- Water (optional)



Canker sores on American Chestnut by U.S. Forest Service

Teacher Background: At one time, the American Chestnut (*Castanea dentata*) dominated approximately 200 million acres of land from Maine to Mississippi. In some areas, it is estimated that American Chestnuts covered roughly 20% of the Appalachian forest while other areas contained almost pure stands of trees. Chestnut trees grew up to 100ft tall and often averaged several feet in diameter. The trees were important for wildlife as they produced edible nuts in the fall. One large tree could produce up to 10 bushels or more of nuts (~500-600 pounds)! Ruffed grouse, white-tailed deer, black bears, raccoons, squirrels, and wild turkeys are just some of the species that foraged on American Chestnuts. The trees were also used in the lumber industry to build fences, caskets, and cabins while the bark and inner cordwood were used to tan leather hides.

Unfortunately, during the late 1800s, Chestnut Blight (*Cryphonectria parasitica*), a fungal disease of Chestnut was accidentally introduced to the United States from Asia. It is believed that it entered the United States on imported Japanese Chestnut trees. The disease is an **invasive species**, or a non-native species that causes biological, economic, or human-health related harm. The Blight quickly spread through the American Chestnut stands. The fungal spores of Chestnut Blight spread from tree to tree by wildlife and the wind. The spores infect cuts in the bark and create a rusty-colored **canker** (blister) on the surface of the tree. A few decades after the Blight’s introduction,

over 9 million trees died. By 1950, the American Chestnut was nearly gone from the landscape. Today, only a handful of these trees survive.

In this activity, students will model how the loss of the American Chestnut impacted wildlife.

Procedure:

Engage

1. Ask students why trees are important to wildlife. (They provide habitat such as food and shelter). Show students a variety of nuts such as acorns, hickory nuts, walnuts and the like. Ask students what animals may eat those types of nuts. (Squirrels, turkeys, deer, bear, etc).
2. Read through the student-created story, *The Legend of the American Chestnut Tree*, either as a class or in small groups in order to introduce the topic and the history of the American Chestnut tree. Ask students clarifying questions about the text to check for comprehension: How can you identify an American Chestnut tree? Why was the American Chestnut so important to the east coast? When did the Chestnut Blight start to have an impact? What is being done to restore the American Chestnut?
3. Show students pictures of Chestnut trees and then show them a bushel basket of chestnuts. Tell the students that those mature Chestnut trees could produce up to 10 bushels (500-600) pounds of nuts!
4. Have students write down a list of local wildlife that may have eaten Chestnuts.

Explore

1. Tell students they are going to simulate a forest with woodland wildlife and Chestnut trees.
2. Divide students into two groups: Chestnut trees and wildlife. For every 20 students, 4-5 should be designated as woodland wildlife (like a black bear, woodpecker, squirrel or raccoon). Encourage the "wildlife" to get into character by making the sounds of their respective animal.
3. Give each "Chestnut tree" 4 Chestnut cards and have them disperse around the room.
4. Randomly select 1 of the "woodland wildlife" and sprinkle glitter in the palm of their hand. Sometimes, wetting the student's hand with water before adding the glitter helps it stick better. Don't tell the student what the glitter represents at this time.
5. Instruct the "woodland wildlife" that it's Fall and they have to gather enough Chestnuts to survive the winter. Each "woodland wildlife" has to collect at least 4 Chestnut cards to survive. To collect Chestnuts, they have to visit the "trees" and take a card. After they take a card, the students then have to shake the "tree's" hand. The students should then find another 'tree'.

6. At the end of the first round, ask which “woodland wildlife” were able to collect enough food to survive. All should have been able to find enough food.
7. Point out that one “woodland animal” had glitter in their hand at the start of the round. Unfortunately, the glitter represents Chestnut Blight, an invasive disease introduced from Asia. The Chestnut Blight kills Chestnut trees, and it spreads between trees through wind, water, and wildlife.
8. Ask “trees” to look at the palms of their hands. How many trees were exposed to the “Blight” (aka glitter)? Were any of the “woodland wildlife” also exposed? Tell the students that fortunately, the wildlife are not affected by the disease. However, all Chestnut trees who were exposed to the “Blight” have died.
9. Repeat the activity with the remaining trees and the original band of “woodland wildlife”. Be sure that all “trees” begin round with 4 Chestnut cards. You may also need to replenish glitter on the “infected animal’s” hand.
10. At the end of the second round, ask the “wildlife” who was able to get 4 Chestnut cards. What happens if they are unable to get enough food? (They do not survive the winter). Besides food, what other resources may have been lost with the trees?
11. Have the remaining “trees” look at their hands and see who was infected during the second round. Have the “infected trees” sit down on the side of the classroom.
12. If any “trees” remain, then go through one final round with the remaining “wildlife” and “trees”.

Explain

1. After the final round with the remaining “trees”, discuss the overall impact of the Chestnut Blight with the students. Ask the students if they have ever seen a Chestnut tree in the wild. Few to no students will say yes. Tell them that the Chestnut tree was once one of the most abundant trees in the eastern United States and that people also depended on the trees as much as wildlife.
2. Review the list of wildlife species on the board. Ask students if they think any of those species may have been impacted by the Chestnut Blight. Most of the species likely were affected in some way or another. Ask students if they know why species like deer and turkey, which relied heavily on Chestnuts, are still around, unlike our animals in the activity. (They found other food sources from trees such as oaks and hickories.)

Evaluate

1. Have students write down why American Chestnuts were important to wildlife.
2. Besides wildlife, what other ways can the Blight spread from tree to tree?

Extend

1. Most forests were not pure stands of American Chestnut. As a variation on the activity, you can create a mixed “forest” with Chestnuts, oaks and hickories. Create food cards for the different species and run through the activity a couple times. Since Chestnuts were the most important food source for most wildlife species, have the Chestnuts be a higher value than acorns or hickories. For example, the “wildlife” would need a total of 8 points to survive. Each Chestnut card can be worth 2 points while acorns and hickories will be worth 1 point.
2. Have students watch the video “American Chestnut Blight: - greatest forest loss in history”. <http://www.youtube.com/watch?v=-xgbedXnbfw> Video also provided on CD in kit.
3. Currently, several other invasive diseases impact our native trees like Sudden Oak Death and Dutch Elm Disease. Have students research the importance of Oaks and Elms and write reports on the invasive species that impact them.
4. Have students write a letter to a Chestnut tree from one of the animals. Have the students tell the tree how much he/she misses the tree and why.

Water Chestnut vs. SAV

Gr: 3-8

Objectives: At the conclusion of the lesson, students will be able to:

- Explain how Water Chestnut, an invasive aquatic plant, has an impact on native submerged aquatic vegetation (SAV)

Standards:

NGSS	3-LS4-3 – Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well and some cannot survive at all. 4-LS1-1 – Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. MS-LS2-4 – Construct an argument based on empirical evidence that changes to physical or biological components of an ecosystem affect populations.
Core Idea	LS2.C: Ecosystem Dynamics, Functioning, and Resilience Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.
Practices	<ul style="list-style-type: none">• Asking questions and defining problems• Developing and using models• Planning and carrying out investigations• Analyzing and interpreting data• Constructing explanations• Obtaining, evaluating and communicating information
Cross-Cutting Theme	<ul style="list-style-type: none">• Cause and effect• Systems and system models• Stability and change
Reading, Writing & Social Studies	CCSS.ELA/Lit.RI.3-8.1 - Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text CCSS.ELA/Lit.SL.3-8.1 - Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively. CCSS.ELA/Lit.W.3-8.7 - Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.
Environmental Literacy	1.A.1 – Identify an environmental problem. 1.A.4 – Design and conduct the research. 4.B.1 – Analyze the growth or decline of populations and identify a variety of responsible factors. 5.A.2 – Analyze the effects of human activities that deliberately or inadvertently alter the equilibrium of natural processes.

Objectives: At the conclusion of the lesson, students will be able to:

- Explain how Water Chestnut, an invasive aquatic plant, has an impact on native submerged aquatic vegetation (SAV)

Materials:

- Water Chestnut background (for students; on CD)
- Six 5 gallon buckets without lids
- Green craft foam - 8 sheets
- Tacky craft glue, stapler or other art supplies for students to create a rosette
- One bunch of *Elodea canadensis* (also known as common waterweed) - this will probably have to be ordered online; do not substitute *Elodea densa* (Brazilian waterweed) as this is an invasive species.
 - Carolina Scientific (www.carolina.com)
 - Ward Scientific (www.wardsci.com)
 - Pond Plants Online (<http://pondplantsonline.com>)
- Pictures of Water Chestnut (on CD)

Teacher Background: The invasive, aquatic plant known as Water Chestnut (*Trapa natans*) is not to be confused with the Water Chestnut used in Chinese cooking. Water Chestnut is found in fresh water up to 15 feet deep and consists of a long submerged stem with fine roots that anchor the plant in the mud. The leaves are triangular or diamond shaped, about 1 ½ - 2 inches wide, with saw-toothed edges. The leaves form a rosette, as wide as 12 inches, which float on the surface of the water. If a rosette breaks off, then it can drift away and re-establish itself somewhere else. The seed is a hard nut with four ½ inch spines which can remain viable for as long as 12 years. The nuts can spread by floating to new areas or by clinging to birds or floating objects. Each seed can produce 10-15 rosettes, and each rosette in turn can produce 15-20 more seeds.

Water Chestnut is native to Europe, Asia, and Africa and was first found in this country near Concord, Massachusetts in 1859. How it was introduced is unknown, but it obviously was introduced by humans, possibly as an ornamental aquatic plant. In the late 1870s, Water Chestnut was being grown in the Harvard Botanical Garden, where it later escaped into nearby lakes and ponds. It is now found in most of New England and Mid-Atlantic states as far south as Virginia.

The presence of this invasive species has had major impacts on the water bodies where it is found. The rosettes can grow so dense that they form a continuous mat of vegetation across the water that can shut out as much as 95% of the sunlight.

The lack of sunlight kills the native submerged aquatic vegetation (SAV), which is important food for waterfowl and is important nursery habitat for a variety of species. In contrast, the leaves of the Water Chestnut have very little nutritional value and are not readily consumed. Furthermore, the seeds are mostly inedible because of the hard shell and sharp spines. The dense biomass of Water Chestnut in invaded areas can result in lower levels of dissolved oxygen, which reduces the amount of habitat for invertebrates and fish. Water Chestnut also makes swimming and boating impossible, and the seeds can cause injury if stepped upon.



*Water Chestnut invasion by Krzysztof Ziarnik, Kenraiz
Wikimedia Commons*

In this activity, students will research the impacts of Water Chestnut on submerged, aquatic vegetation.

Procedure:

Engage

1. *Before beginning the activity:*
 - a. This activity should be done either in the fall or spring so the weather is warm enough to put the buckets outside.
 - b. Purchase the live aquatic plants ahead of time. They will be fine in a bucket of water until you need them.
2. Ask the students what they know about submerged aquatic vegetation (SAV). If they do not know, they may need to do some research.
 - a. What is it?
 - b. Why is SAV important?
3. Discuss the definition of an **invasive species** -- a non-native plant or animal whose introduction causes or is likely to cause economic or environmental harm or harm to human health
4. Have students read the Student Background. After reading, ask the following questions:
 - a. Why is Water Chestnut considered an invasive species?
 - b. Based on the reading, what impact does it have on SAV?

Explore

1. Ask students - How could they test the impacts of Water Chestnut on SAV? Have students construct a hypothesis.

2. Explain that you have some SAV plants, but you cannot get Water Chestnut because it is invasive, so they will have to use the craft foam, which floats, to represent it. Show students pictures of Water Chestnut so they are familiar with its design.
3. Show students what you have – 6 buckets, craft foam, glue, stapler, and *Elodea*.
4. Have students work in groups to design an experiment to test their hypothesis.
5. Remind students that they need replicate tests and controls.
6. Once the groups have designed their experiment, bring them together and as a class discuss the pros and cons of each group's design.
7. Have students come to consensus about the design. They may incorporate parts of each group's ideas in the final design. You may want to make the suggestion that the buckets not be placed where they get full sunlight all day because that might affect the temperature of the water.
8. Once a design is finalized, have students decide how often they will monitor the buckets – twice a week for 4-6 weeks is probably adequate.
9. Have students devise a data sheet to record their results that will help them test their hypothesis.
10. Evaluate students based on their contribution to designing and setting up the experiment.
11. If students are familiar with writing lab reports, then have them write this experiment up with a hypothesis, method, data, results, and conclusion.

Explain

1. Analyze the student's results as a group. Did their results support or reject their hypothesis? Why or why not?
2. Were there any differences between the *Elodea* in the control buckets and the experimental buckets? If so, what differences did they see? How soon did they begin to see differences? If they did not see any differences, why not?

Evaluate

1. How does Water Chestnut affect SAV?
2. Why are biologists concerned about the presence and spread of Water Chestnut?

Extend

1. For older students, have them measure the area of the Water Chestnut "plants" and calculate how much surface area in the bucket it takes up in order to correlate to a percentage of light being blocked by the Water Chestnut.
2. Have students research the impacts of Water Chestnut on humans.
3. Have students research the history of Water Chestnut in their state, whether it is present, and if so, when and where it first appeared, where it is found now and attempts at control.

Water Chestnut

The invasive plant known as Water Chestnut (*Trapa natans*) is found in fresh water up to 15 feet deep. It has a long underwater stem with roots that hold the plant in the mud. The leaves are triangular or diamond shaped, about 1 ½ - 2 inches wide, with saw-toothed edges. The leaves form a “rosette” as wide as 12 inches across, which floats on the surface of the water. If a rosette breaks off, then it can drift away and start a new plant somewhere else. The seed has a hard shell with four ½ inch spines and can remain alive for as long as 12 years. The seeds can spread by floating to new areas or by sticking to birds or floating objects.

Water Chestnut is native to Europe, Asia, and Africa and was first found in this country near Concord, Massachusetts in 1859. No one knows for sure how it was introduced, but it likely was introduced by humans. Water Chestnut is now found in most New England and Mid-Atlantic states as far south as Virginia.

This invasive plant has had major impacts on the water bodies where it is found. The rosettes can grow so dense that they form a mat of leaves across the water, which can shut out as much as 95% of the sunlight.

The lack of sunlight kills the native submerged aquatic vegetation (SAV), which is important food for ducks and other wildlife. Without underwater pastures of SAV in the water, aquatic invertebrates have no food. Without the invertebrates in the food chain, estuaries no longer serve as nurseries for young fish and crabs that feed on the invertebrates. SAVs also generate dissolved oxygen during the day time.

Unlike SAV, the leaves of the Water Chestnut have very little nutritional value, so many wildlife do not eat them. The seeds, too, are not consumed because of the hard shell and sharp spines. Masses of Water Chestnut in waterways also makes swimming and boating impossible, while the spiny seeds can cause injury if stepped on.



Water Chestnut invasion (left) by Krzysztof Ziarnik, Kenraiz Wikimedia Commons and spiny seeds (right) by Kerry Wixted