The Good, the Bad, and the Ugly:

Aquatic Invasive Species of the Mid-Atlantic

Education Guide

December 2015

Mid-Atlantic Panel AIS on Aquatic Invasive Species

MARYLAND DEPARTMENT OF NATURAL RESOURCES

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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Introduction and Spread

The introduction and spread of invasive aquatic species is almost always attributed to human actions-- either accidentally or deliberately. Some of the deliberate introductions were to meet a need that was apparent at the time. This module will use activities that show students how and why different invasive aquatic species were introduced. Species highlighted in this module include the Asian Grass Carp, Blue Catfish, Northern Snakeheads, Red-eared Sliders, Rusty Crayfish, and Zebra Mussels.

Asian Grass Carp were introduced deliberately to control aquatic vegetation in ponds and lakes. Some locations still release sterile Carp. Similarly, Blue Catfish were intentionally released as sport fish but have now become a nuisance species in many areas they occupy. Northern Snakeheads are large, predatory fish that are also a popular food. It is believed some of the initial Snakehead introductions were intentionally released.

Red-eared Sliders continue to be a popular pet turtle species. However, many unwanted turtles are released into natural areas. The height of the Teenage Mutant Ninja Turtle craze was also the time when many unwanted sliders were introduced into new areas.

Rusty Crayfish were once popular live bait that often were released by anglers. Some states, such as Maryland, have banned the use of live bait to prevent future spread of this invasive species.

Zebra Mussels are the poster children for invasive species. In 1988, Zebra Mussels were discovered in Lake St. Clair in Michigan. It is believed they were accidentally released via ballast water. Since then, Zebra Mussels have hitchhiked far and wide on boats, in canoes, in gear, and via other structures.

Red-eared Slider by Tim the Photographer, Flickr Creative Commons

To convey how invasive species have been introduced and ways that they spread, the lessons in this section include:

- **A Problem with Hitchhikers -- Grades 9-12; pg**
  - *Students will learn about the introduction and spread of Zebra Mussels through a research and mapping exercise.*
- **Blue Catfish: Friend or Foe -- Grades 9-12; pg**
  - *Students will learn about the introduction and spread of Blue Catfish and will determine if further introductions should occur by conducting research.*
- **Blue Catfish- Going Fishing -- Grades 3-8; pg**
  - *Students will learn about the spread and impacts of Blue Catfish through an active simulation.*
- **Crayfish Compete -- Grades 3-8; pg**
  - *Students will learn about the impacts of Rusty Crayfish and will simulate how Rusty Crayfish compete with native Crayfish for food.*
- **Crayfish Release -- Grades 9-12; pg**
  - *Students will learn about the impacts of Rusty Crayfish and will simulate what happens when just a few Rusty Crayfish are released into a lake.*
- **Invaders at Taylors Pond -- Grades 9-12; pg**
  - *Students will learn about the impacts of Asian Grass Carp and will read and discuss a fictional scenario in which Grass Carp are released into a pond.*
- **Invasion of the Snakehead -- Grades 9-12; pg**
  - *Students will learn about the impacts of Northern Snakeheads and will explore the introduction and spread of this species in the Mid-Atlantic.*
- **Is it a Snakehead? -- Grades 3-8; pg**
  - *Students will learn about the problems with Northern Snakeheads, how they are introduced and spread, and will learn how to identify Northern Snakeheads in order to educate others.*
- **Not Wanted: Invasive Ninja Turtles -- Grades 6-12; pg**
  - *Students will learn about the impacts of Red-eared Sliders, how they are introduced, and will simulate the spread of Red-eared Sliders in a pond ecosystem.*
- **The Grass Carp Dilemma -- Grades 6-12; pg**
  - *Students will learn about the impacts of Asian Grass Carp and will role play as different community groups to debate whether or not Grass Carp should be introduced to remove the invasive plant, Hydrilla.*
- **Unlikely Cargo -- Grades 3-5; pg**
  - *Students will simulate the dispersal of Zebra Mussels through ship's "cargo".*
- **Zebra Mussels: Coming to a Water Near You -- Grades 6-12; pg**
  - *Students will learn about the introduction and spread of Zebra Mussels through a research and mapping exercise.*

A Problem with Hitchhikers Gr: 9-12

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

- Explain what invasive species are and how they are introduced and spread
- Map the spread of Zebra Mussels in the United States

Standards:

NGSS	**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
Core Idea	**LS4.C: Adaptation** - Changes in the physical environment, whether naturally occurring or human induced, have contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species.
Practices	• Asking questions • Analyzing and interpreting data • Constructing explanations • Engaging in argument from evidence • Obtaining, evaluating and communicating information
Cross-Cutting Theme	• Cause and effect • Stability and change
Reading, Writing & Social Studies	**CCSS.ELA.Lit.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. **CCSS.ELA/Lit.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. **CCSS.ELA/Lit.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. **CCSS.ELA/Lit.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.
Environmental Literacy	**1.A.5 –** Use data and references to interpret findings to form conclusions. **5.A.2 –** Analyze the effects of human activities that deliberately or inadvertently alter the equilibrium of natural processes. **7.B.1 –** Examine the influence of individual and group actions on the environment and explain how groups and individuals can work to promote and balance interests.

A Problem with Hitchhikers Gr: 9-12

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

- Explain what invasive species are and how they are introduced and spread
- Map the spread of Zebra Mussels in the United States

Materials:

- Board
- Internet access
- Pictures of Zebra Mussels (on CD)
- Student Page (on CD)

Teacher Background: Invasive species are non-native species that cause problems. These problems can include outcompeting native species, spreading disease, harming infrastructures, and/or altering ecological processes. It is estimated that the United States spends over $100 million dollars each year to control aquatic invasive species alone!

One aquatic invasive species found within the Mid-Atlantic is the Zebra Mussel (*Dreissena polymorpha*). Zebra Mussels are small, aquatic mussels native to streams and rivers in Russia. They were officially discovered in the United States in 1988 in Lake St. Clair, Michigan. It is believed that Zebra Mussels were introduced by transoceanic ships that had mussels either attached to the hulls or living in ballast water. From this entry point, Zebra Mussels have spread throughout numerous waterways in the United States.

Zebra Mussels are adept at establishing themselves in new locations. They tolerate a wide-range of water temperatures and flourish in many freshwater aquatic systems. Zebra Mussels have few predators in their introduced range, can survive in poor water quality, and can survive in the absence of water for several days. One female Zebra Mussel can produce up to a million eggs, which develop and mature in less than a year. The juvenile stage (**veligers)** is mobile and can float to new locations before eventually settling down to attach to hard surfaces like boats, buoys, pipes, and even other mollusks. These characteristics allow Zebra Mussels to be successful invaders.

Zebra Mussels have a profound impact on the ecosystems they invade. Their presence causes native mussel and clam populations to plummet. They can also clog pipes, deteriorate dock pilings, sink buoys, and encrust boat hulls. They disrupt aquatic food webs and can alter the flow of nutrients in an environment. Toxins accumulate in the mussels' tissues, which are then transferred to fish and birds when they are consumed.

Zebra Mussels are so destructive that their introduction single handedly prompted a new division of scientific study called invasion ecology.

In this activity, students will learn about the introduction and spread of Zebra Mussels through a research and mapping exercise.

Procedure:

Engage

1. Ask students what they know about invasive species. Go over the definition of invasive species. Ask students if they know of any invasive species. If they do, then ask how these species can get into new ecosystems. List student ideas on the board. Separate introduction ideas into those that were intentional and those that were unintentional.
2. If Zebra Mussel wasn't listed in the brainstorm, then ask students if they have heard about Zebra Mussels. What do they know? Show pictures and specimens to students. Ask students if they think Zebra Mussels were intentionally or unintentionally released.

Explore

1. Tell students they will now research Zebra Mussels and will map their spread.
2. Hand out the Student Page and allow students time to conduct research and write a short report.

Explain

1. Go over answers to Student Page. What was the most interesting information they learned?
2. As a class, view the animation of the Zebra Mussel spread on the United States Geological Survey (USGS) page on Nonindigenous Aquatic Species (http://nas.er.usgs.gov/queries/SpeciesAnimatedMap.aspx?speciesID=5). What do they notice about the spread? Zoom into your state and watch the spread. When were Zebra Mussels found within your state? If Zebra Mussels are not in your state yet, then have students predict when they may be found and in what area they may first appear. Encourage students to support their claims.
3. Zebra Mussels have quickly spread across the United States' waterways. What characteristics of Zebra Mussels have contributed to their rapid spread?
4. What predictions can you reach about the future dispersal of Zebra Mussels in North America?

Evaluate

Evaluate Student Page for completion, sources cited, and accuracy.

Extend

1. Have students research ways that your state tries to prevent the spread (or introduction) of Zebra Mussels. Is there anything more that can be done? How can students spread the word about Zebra Mussels?
2. Have students interview local boaters to see how they handle their equipment when they haul out their boats. Have students share their knowledge about Zebra Mussels with boaters.
3. Continue the lesson using activities from the Virginia Sea Grant Marine Advisory Program on 'Stop the Zebra Mussel!' Lesson plans can be found here: http://web.vims.edu/chessie/zmtxt.html?svr=www

Student Page: A Problem with Hitchhikers

Zebra Mussels are an aquatic, invasive species that have rapidly expanded their range in the United States. Research the following questions and write a short report on Zebra Mussels. Be sure to include citations for your research at the end of the report.

Photo by: Amy Benson, USGS

Questions:

1. Where did Zebra Mussels originate, and how were they introduced to the United States? Was this introduction intentional?
2. What organisms are similar to Zebra Mussels?
3. What characteristics of Zebra Mussels make them so successful?
4. How do Zebra Mussels invade new places? Could they invade a body of water near you?
5. How do Zebra Mussels change ecosystems?
6. Use the information below to map the spread of Zebra Mussels. Be sure to include a title and a legend.

Date	States
1988	Ohio, Michigan
1989-1993	Illinois, Indiana, Wisconsin, New York, Minnesota, Pennsylvania, Kentucky, Alabama, Arkansas, Louisiana, Mississippi, Tennessee, West Virginia, Oklahoma, Iowa
1994-1998	Connecticut, Vermont
1999-2003	Kansas, Virginia, Nebraska
2004-2008	California, Colorado, Maryland, Utah
2009-2013	Massachusetts, Texas, North Dakota
2014	South Dakota

Blue Catfish: Friend or Foe? Gr: 9-12

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

- Explain that a non-native species, Blue Catfish, that was deliberately introduced to provide fishing opportunities, can become an environmental problem
- Explain that there is sometimes controversy or disagreement about the introduction of a non-native species

Standards:

NGSS	**HS-LS2-6:** Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. **HS-LS2-7:** Design, evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity
Core Idea	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience -** Extreme fluctuations in conditions or the size of any population can challenge the functioning of ecosystems in terms of resources and habitat availability. **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.
Practices	• Asking questions • Constructing explanations • Engaging in argument from evidence • Obtaining, evaluating, and communicating information
Cross-Cutting Theme	• Cause and effect • Stability and change
Reading, Writing & Social Studies	**CCSS.ELA/Lit.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. **CCSS.ELA/Lit.W.9-10.1** - Write arguments to support claims in an analysis of topics or texts, using valid reasoning and relevant and sufficient evidence. **CCSS/ELA/Lit.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. **CCSS.ELA/Lit.W.11-12.1** - Write arguments to support claims in an analysis of topics or texts, using valid reasoning and relevant and sufficient evidence.
Environmental Literacy	**1.A.3 –** Given a specific issue, communicate the issue, the stakeholders involved and the stakeholders beliefs and values. **5.A.2 –** Analyze the effects of human activities that deliberately or inadvertently alter the equilibrium of natural processes. **7.B.1 –** Examine the influence of individual and group actions on the environment and explain how they can work to promote and balance interests.

Blue Catfish: Friend or Foe? Gr: 9-12

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

- Explain that a non-native species, Blue Catfish, that was deliberately introduced to provide fishing opportunities, can become an environmental problem
- Explain that there is sometimes controversy or disagreement about the introduction of a non-native species

Materials:

- Board
- Fish print (in kit)
- Internet access

Teacher Background: Blue Catfish (*Ictalurus furcatus*) are one of the largest species of North American catfish. They can grow to enormous sizes and can take over the biomass of an entire area of water. For example, one study found that as much as 75% of the total fish biomass in the James and Rappahannock tributaries was composed of Blue and Flathead Catfish! Adults can consume large quantities of native fish and shellfish.

Blue Catfish were deliberately introduced into the Mid-Atlantic from the Mississippi River watershed, their native range. In the mid-1970s, Blue Catfish were introduced into the James and Rappahannock Rivers by the Virginia Department of Game and Inland Fisheries to provide trophy sport fishing opportunities. Since then, they have expanded their range to all western shore rivers in Virginia, as well as the Potomac, Patuxent, Elk, and Nanticoke Rivers in Maryland, and as far north as the Susquehanna Flats in the Upper Chesapeake Bay. Blue Catfish also have been found in the Delaware River. Blue Catfish have been intentionally introduced to some areas by anglers.

Unfortunately, growing numbers and rapid expansion of Blue Catfish throughout introduced ranges have raised concern about the potential impact on menhaden, blue crabs, and other native species that play an important role in aquatic ecosystems and the economy. Because of this, Blue Catfish in many areas have been deemed as invasive. **Invasive species** are non-native species that cause problems in their introduced ranges.

In this activity, students will learn about the introduction and spread of Blue Catfish and will determine if further introductions should occur by conducting research.

Procedure:

Engage

1. Show students fish print (in kit) of Blue Catfish. Explain that both the Blue Catfish and Northern Snakehead are non-native to the Mid-Atlantic. Ask students what they notice just by looking at the picture,
2. Ask students to guess what Blue Catfish might eat.

Explore

1. Explain that some states have deliberately introduced Blue Catfish to provide fishing opportunities while other states consider them an invasive species.
2. Have students work in pairs to research to answer the question, "Do the economic benefits of the Blue Catfish trophy fishery, commercial fishery, and subsistence fishery (fishing that is carried out primarily to feed the family and relatives of the person doing the fishing) justify introducing Blue Catfish outside of their native range?"
3. Remind students that they must read articles on both sides of the question.
4. Have students create a 5 minute presentation on their research.

Explain

1. Allow students class time to present their arguments.
2. After each presentation, mark on the board whether or not students supported or rejected the introduction of Blue Catfish. Write down the main conclusions for each side of the argument.
3. As a class, tally the students' decisions. What was the verdict?

Evaluate

Evaluate presentations based on content, delivery, accuracy, and presentation.

Extend

1. Have students interview local anglers to see what precautions they take to prevent the spread of aquatic, invasive species. Have students poll anglers to see if they would support introduction of Blue Catfish into new systems. Have students share their knowledge about Blue Catfish with anglers.
2. Have students graph and predict the size of the next trophy Blue Catfish in Virginia using data. http://www.dgif.virginia.gov/education/how-big-will-they-get.pdf
3. Blue Catfish are becoming a popular food to serve in restaurants. Have students research the pros and cons of creating a market for an invasive species.

Blue Catfish - Going Fishing Gr: 3-8

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

- Explain how Blue Catfish spread from one environment to another
- Explain the impacts that this non-native fish has on new environments

Standards:

NGSS	**5-ESS3-1** - Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment. **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-LS2-2** - Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
Core Idea	**ESS3.C**: Human Impacts on Earth Systems **-** …Individuals and communities are doing things to help protect Earth's resources and environments **LS2.A**: Interdependent Relationships in Ecosystems - In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
Practices	• Developing and using models • Analyzing and interpreting data
Cross-Cutting Theme	• Patterns • Cause and effect • Stability and change
Reading, Writing & Social Studies	**CCSS.ELA/Lit.RI.3-5.1 -** 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.W.3-5.1** - Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **CCSS.ELA/Lit.WHST.6-8.1** - Write arguments to support claims in an analysis of substantive topics or texts using valid reasoning and relevant and sufficient evidence. **CCSS.ELA/Lit.SL2.6-8.** - Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.
Environmental Literacy	**1.A.1 –** Identify an environmental issue. **4.B.1** - Analyze the growth or decline of populations and identify a variety of responsible factors.

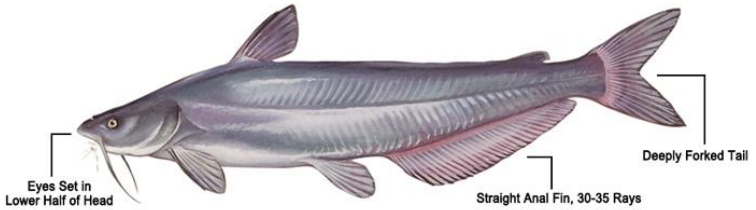
Blue Catfish- Going Fishing Gr: 3-8

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

- Explain how Blue Catfish spread from one environment to another
- Explain the impacts that this non-native fish has on new environments

Materials:

- Board
- Colored armbands (2 different colors)
- Cones (in kit)
- Fish poster (in kit)
- Internet access
- Large playing field
- Paper bags
- Poker chips (in kit)
- Rope
- Student Page (on CD)



Teacher Background: Blue Catfish (*Ictalurus furcatus*) are one of the largest species of North American catfish. They can grow to enormous sizes and can take over the biomass of an entire area of water. For example, one study found that as much as 75% of the total fish biomass in the James and Rappahannock tributaries was composed of Blue and Flathead Catfish! Adults can consume large quantities of native fish and shellfish.

Blue Catfish were deliberately introduced into the mid-Atlantic from the Mississippi River watershed, their native range. In the mid-1970s, Blue Catfish were introduced into the James and Rappahannock Rivers by the Virginia Department of Game and Inland Fisheries to provide trophy sport fishing opportunities. Since then, they have expanded their range to all western shore rivers in Virginia, as well as the Potomac, Patuxent, Elk, and Nanticoke Rivers in Maryland, and as far north as the Susquehanna Flats in the Upper Chesapeake Bay. Blue Catfish also have been found in the Delaware River. Blue Catfish have been intentionally introduced to some areas by anglers.

Unfortunately, growing numbers and rapid expansion of Blue Catfish throughout introduced ranges have raised concern about the potential impact on menhaden, blue crabs, and other native species that play an important role in aquatic ecosystems and the economy. Because of this, Blue Catfish in many areas have been deemed as invasive. **Invasive species** are non-native species that cause problems in their introduced ranges.

In this activity, students will learn about the spread and impacts of Blue Catfish through an active simulation.

Procedure:

Engage

1. Show students fish poster representing the Blue Catfish and sizes of other fish species found within the Mid-Atlantic. What do they notice?
2. Tell students they will now research the Blue Catfish to find out more information about them. Have students answer the following questions:
    a. Where are Blue Catfish native?
    b. Where can Blue Catfish be found?
    c. What do Blue Catfish eat, and what preys on Blue Catfish?
    d. Where do Blue Catfish live?
    e. How many young can they have?
3. Discuss the answers to the questions above with the class.
4. Hand out the Student Page or project maps on a screen. Have students examine the 3 maps showing the different stages of spread of Blue Catfish in Virginia. What conclusions can they draw? What impact could their spread have?
5. Go over the definition of an invasive species. Ask students: could the Blue Catfish be invasive? Tell students they are now going to explore that question.

Explore

1. Set up the room or an outside area to have designated spaces for a river leading into a bay. Use a rope to divide the river from the bay and randomly spread poker chips throughout the area. The chips represent "food" for native species. Explain the set-up to the students.
2. Designate 1 person to be a Blue Catfish and the other members of the group to be yellow perch, rockfish (striped bass), and blue crabs. Explain that these native species are important food fish for people and for Blue Catfish. Give the Blue Catfish an armband to distinguish it. Give the native species paper bags to serve as 'stomachs'.
3. **Round 1:** In the first round, have the Blue Catfish stand off to the side while the rest of the group is lined up on one side of the area designated as the bay. Give a signal and allow the native species to gather as much food as they can. All native species that gather at least 1 poker chip survive. Tally the number of survivors in Round 1.
4. **Round 2:** Tell the students that a fisherman who loves to catch Blue Catfish decided to move one into his favorite river. In this round, we will now have a Blue Catfish feeding. Tell the catfish that it cannot leave the river but do not tell the native species. The catfish can only stay in the river during this round as it has not migrated to the bay yet.

5. Begin the round and allow the native species to feed and the Blue Catfish to tag any species in the river that it can catch. If students are tagged by the catfish, then they will become catfish in the next round. Have them dump out their "stomachs" and discard the bag. Give students 1 minute for the round. At the end of the round, tally the number of native species and the number of Blue Catfish.
6. **Round 3:** Ask students if they noticed the Blue Catfish could not move out of the river. Ask why that might be (*it had not yet migrated to the bay*). Hand the new Blue Catfish armbands and tell them that in this round, they can forage anywhere in the river and the bay. Give students 1 minute for the round.
7. If a catfish fails to catch any food, then it will "die" and become one of the native species. Remember to keep a record of numbers of catfish and native species.
8. **Round 4:** Tell students that fishermen have noticed all of the Blue Catfish in the river and now will be fishing for them. Choose 2 students and tell them that in this round, they are fishermen and can catch catfish by tagging them. Give the fisherman armbands. Any tagged catfish become fisherman. At the end of the round, tally the number of native species, fisherman, and Blue Catfish. Repeat Round 4 and tally numbers.

Explain

1. Have students graph the numbers of catfish, native species, and fishermen. Using the graph, have students write a paragraph explaining:
    a. The impact of Blue Catfish on the population of native species
    b. The impact of fishermen on the population of catfish and native species
    c. Whether or not the Blue Catfish is invasive (provide evidence)
2. Have students explain how the Blue Catfish got into the river in the first place (*by the angler*). What other ways could Blue Catfish be introduced?

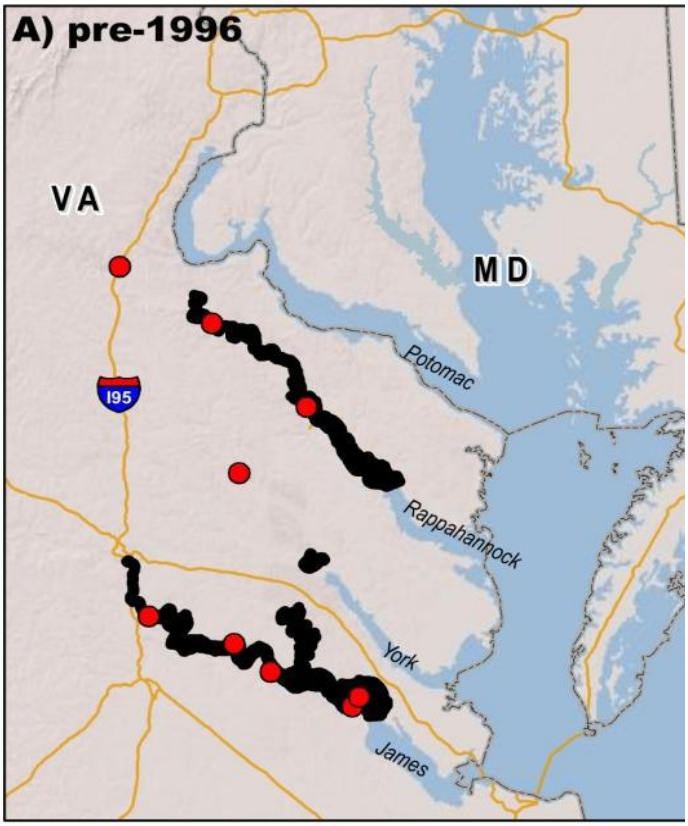
Evaluate

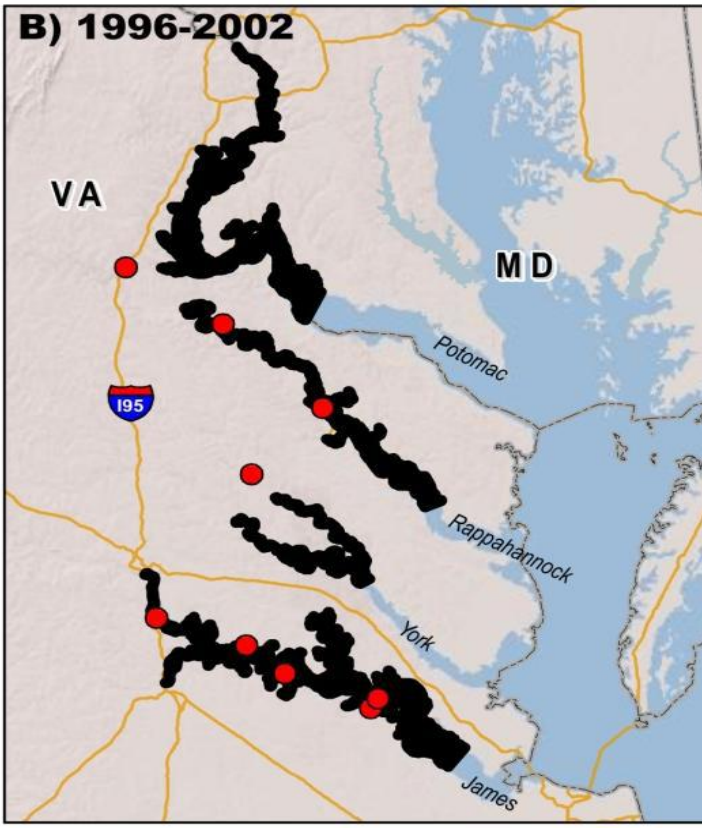
Evaluate students based on accuracy of their graph, and on the validity of their reasoning and use of evidence in their written paragraph.

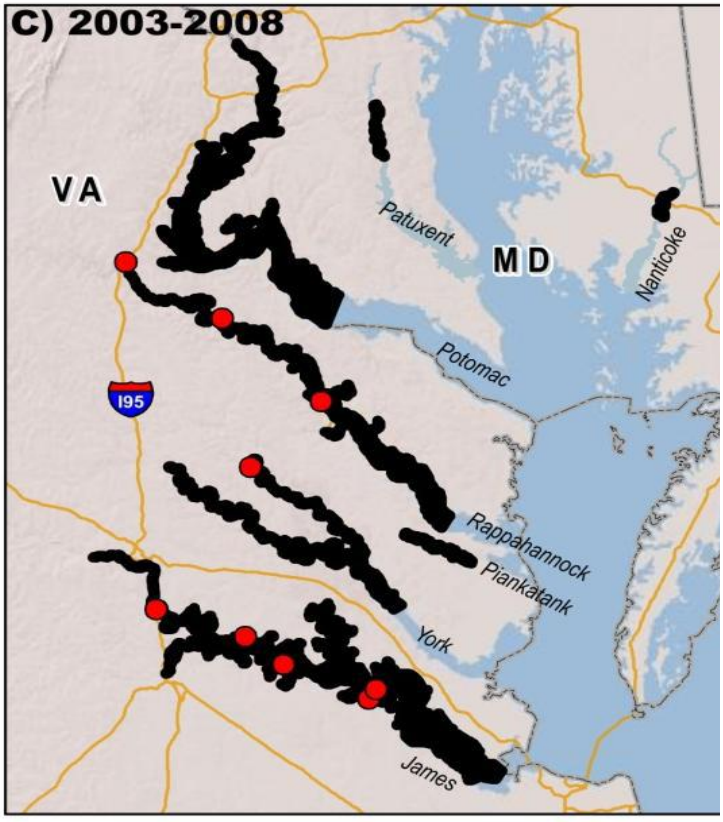
Extend

1. Have students conduct additional research on Blue Catfish and develop a brochure or poster describing the Blue Catfish, what its impacts are, and how to prevent its spread.
2. Have students investigate the sale of Blue Catfish for food. Have students list the pros and cons of creating a food market for an invasive species like the Blue Catfish?

Student Page: Blue Catfish Maps







The black portion represents the range of the Blue Catfish and the red dots represent areas where the catfish have been stocked by Virginia.

Crayfish Compete Gr: 3-8

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

- Explain how Rusty Crayfish spread from their native range in the United States
- Describe how the Rusty Crayfish is able to outcompete native crayfish species

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. **5-LS2-1.** Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment. **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.
Core Idea	**LS2.A: Interdependent Relationships in Ecosystems -** A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.
Practices	• Developing and using models • Analyzing and interpreting data • Engaging in argument from evidence
Cross-Cutting Theme	• Patterns • Cause and effect • Systems and system models • Stability and change
Reading, Writing & Social Studies	**CCSS.ELA/Lit.RST.6-8.7** - Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually. **CCSS.MP.2** - Reason abstractly and quantitatively.
Environmental Literacy	**1.A.1-** Identity an environmental issue. **4.B.1** - Analyze the growth or decline of populations and identify a variety of responsible factors.

Crayfish Compete Gr: 3-8

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

- Explain how Rusty Crayfish spread from their native range in the United States
- Describe how the Rusty Crayfish is able to outcompete native crayfish species

Materials:

- Armbands for Rusty Crayfish
- Board
- Cones (in kit)
- Internet access
- Student Page(on CD)

Teacher Background: Rusty Crayfish (*Orconectes rusticus*) are crayfish native to the Ohio River Valley. Unfortunately, they have been introduced to new areas within the United States, likely due to the use of live bait for fishing.

Rusty Crayfish grow large compared to other species of crayfish and are relatively aggressive when defending territory or food sources. In their introduced range, Rusty Crayfish often outcompete native species of crayfish and feed upon native plants, small fish, invertebrates, and fish eggs. The loss of aquatic plants can impact wildlife in aquatic systems. Because of this, Rusty Crayfish are labeled as invasive in much of their introduced range. A species is **invasive** when it is both non-native to the ecosystem in which it is found and capable of causing environmental, economic, or human harm.

Rusty Crayfish inhabit fresh water streams, rivers, and lakes. They frequently shelter under rocks and submerged vegetation to avoid predators. They begin their life cycle as an egg. Females produce up to 350 eggs at a time. The eggs remain with the female, attached to the underside of her abdomen for up to 6 weeks. At this point, the eggs hatch and juvenile crayfish cling to the mother. The young molt several times and increase in size for up to 3 more weeks. They then detach from the mother to live as individuals. Rusty Crayfish can live up to 3 or 4 years in the wild.

In this activity, students will learn about the impacts of Rusty Crayfish and will simulate how Rusty Crayfish compete with native Crayfish for food.

Procedure:

Engage

1. Show students the video "Cosmo's World: Invasive Species" https://www.youtube.com/watch?v=UyvPxU6LUu0
2. Discuss the concept of an invasive species – a plant or animal that is brought into an area, either accidently or on purpose, that can cause harm to the environment. Ask how might an invasive animal cause harm?
3. Have students read the Student Page: Rusty Crayfish Fact Sheet.
4. Based on the information in the video and the reading, have the students write a paragraph answering the question, "Does the Rusty Crayfish meet the definition of an invasive species? Why or why not?"
5. Have the students go back to the reading and look at the first 2 reasons that Rusty Crayfish are a problem. What impact might these characteristics have on native crayfish?
6. Tell the students that they are going to perform an activity to see what happens when rusty and native crayfish compete for food.

Explore

1. Set up a large playing field in a gym or outside.
2. Divide the students into 2 equal groups – native crayfish and food. (If there are an uneven number of students, then the extra student should be food.) Record the number of each.
3. Tell "crayfish" that they should pretend to have claws and use this signal throughout the activity; food should not make any hand signals.
4. Have the "food" spread throughout the field and "crayfish" line up on the edges.
5. Tell "crayfish" that they have to try to catch "food" by tagging it. (You might want to have students walk rather than run). Tell "crayfish" that in the first round, they have to catch 1 piece of "food" to survive.
6. **Round 1**: Give a signal to start the round. Once a "crayfish" has caught "food", the two stay together and the crayfish stops hunting. Give them a few minutes to catch "food". Record the number of "crayfish" that were able to get "food".
7. **Round 2**: Tell students that an angler recently decided to dump their extra Rusty Crayfish into the stream after fishing. Because of this, we now will have Rusty Crayfish and native crayfish in the stream. Start over with 3 groups- 2 groups of "crayfish" and 1 group of "food". Explain that Rusty Crayfish have large claws and can catch 2 foods each round; native crayfish have small claws and can only catch 1 food. Have the "crayfish" practice the hand signals. Give students a few minutes to catch food. When there are no students left as food, end the round.
8. After Round 2, ask "crayfish" to raise their hands if they were unable to get food. Ask students what happens to crayfish that do not get food. Explain that these crayfish are recycled back into the environment and become food during Round 3.

9. What happens to crayfish that get enough food? Explain that crayfish which got ample food are now able to reproduce. The caught "food" now becomes a crayfish of the species that caught them.
10. Have students group by crayfish type and food. Dead crayfish students should now be in the food group, caught food should now be in the crayfish group, becoming whatever type of crayfish caught them. Record the numbers of each group - food, rusties, and natives.
11. What happened to the crayfish populations?
12. What type of crayfish has a bigger population and why?
13. **Round 3**: Again, start over with 3 groups of crayfish and food. Divide the "crayfish" into 2 equal groups of rusties and natives
14. Remind students that Rusty Crayfish are more aggressive than native crayfish.
15. *New rule* – the Rusty Crayfish cannot only catch 2 foods, but it can steal food from the native crayfish. To do this, the rusty can tag food that was caught by a native crayfish, but not food that was tagged by another rusty.
16. Give students a few minutes to catch food. When there are no students left pretending to be food, end the round.
17. Have students group by crayfish type and food. Dead crayfish students should now be in the food group, caught food should now be in the crayfish group, becoming whatever type of crayfish caught them. Record the numbers of each group-food, rusties, and natives.

Explain

1. Have students graph the number of native crayfish, Rusty Crayfish, and food left at the end of each round.
2. Ask students what happened to the native crayfish population? What happened to the Rusty Crayfish population?
3. What type of crayfish has a bigger population and why?
4. Ask students how the Rusty Crayfish originally got into the stream.
5. Based on what they know about Rusty Crayfish, was the simulation accurate? Why or why not?

Evaluate

1. Based on the activity, have students write a paragraph explaining what happens when Rusty Crayfish and native crayfish compete for food. Why does this happen?

Extend

1. Have students research native species of crayfish in their area. Have them compare the native species with Rusty Crayfish in terms of size, aggression, and food preferences. What species are most at risk?
2. Have students create posters to educate anglers on the impact of Rusty Crayfish and why they shouldn't release live bait.

Student Page: Rusty Crayfish

(*Orconectes rusticus***)**
SeaGrant Uni. of Wisconsin Fact Sheet

Credit: Jeff Gunderson/Minnesota Sea Grant

Where did the Rusty Crayfish come from?

- The Rusty Crayfish is actually native to the Ohio River Valley.
- It is believed that they were probably introduced to new areas by fishermen using them as bait.

Why are Rusty Crayfish a problem?

- They are an opportunistic feeder, which means they eat almost anything, including plants and small fish.
- They are a very aggressive species that often displace native crayfish.
- They also reduce the aquatic plant abundance and diversity by destroying the plants as they feed.
- Rusty Crayfish mate in the late summer, early fall, or early spring, but the females wait until spring to lay their eggs. Each female can lay 80-575 eggs that will hatch in 3-6 weeks depending on the water temperature.

What do Rusty Crayfish look like?

- Rusty Crayfish have dark rusty-colored spots on each side of their back, about where you would grab them to pick them up.
- They also have large, smooth claws that vary in color from grayish-green to reddish brown.
- The Rusty Crayfish also have black bands at the claw tips.

How do we control Rusty Crayfish?

- The best way to control Rusty Crayfish is to slow the spread of them to other lakes.
- Do not use them as bait.
- Inspect your boat and trailer for any exotic species and plants.
- Drain water from motor, boat, live well and bait bucket.
- Never transport them from one body of water to another.
- Learn how to identify the Rusty Crayfish.

Crayfish Release Simulation Gr: 9-12

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

- Explain how Rusty Crayfish are introduced into new ecosystems
- Understand how Rusty Crayfish rapidly reproduce to take over new ecosystems

Standards:

NGSS	**HS-LS4-6.** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
Core Idea	**LS4.C: Adaptation -** Changes in the physical environment, whether naturally occurring or human induced, have contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species.
Practices	• Developing and using models • Analyzing and interpreting data • Using mathematics and computational thinking • Constructing explanations
Cross-Cutting Theme	• Patterns • Cause and effect • Stability and change
Reading, Writing & Social Studies	**CCSS.ELA/Lit.WHST.9-12.5** - Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. **CCSS.ELA/Lit.WHST.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; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
Environmental Literacy	**1.A.1-** Identify an environmental issue. **4.B.1** - Analyze the growth or decline of populations and identify a variety of responsible factors.

Crayfish Release Simulation Gr: 9-12

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

- Explain how Rusty Crayfish are introduced into new ecosystems
- Understand how Rusty Crayfish rapidly reproduce to take over new ecosystems

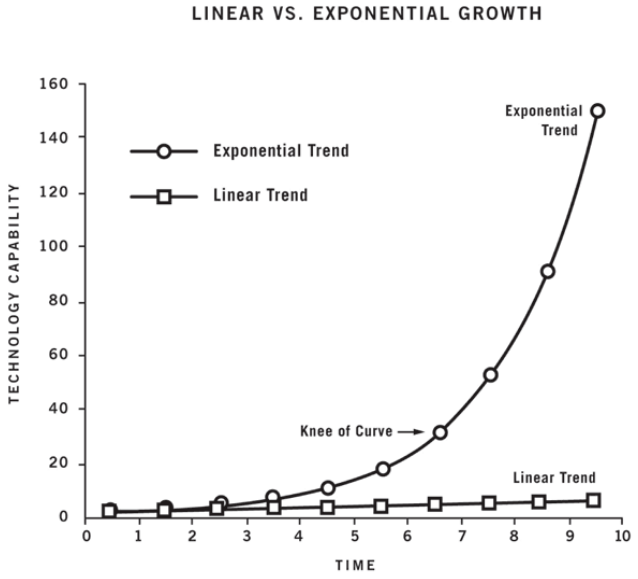
Materials:

- Board
- Dice (in kit)
- Student Pages (on CD)

Teacher Background: Rusty Crayfish (*Orconectes rusticus*) are crayfish native to the Ohio River Valley. Unfortunately, they have been introduced to new areas within the United States, likely due to the use of live bait for fishing.

Rusty Crayfish grow large compared to other species of crayfish and are relatively aggressive when defending territory or food sources. In their introduced range, Rusty Crayfish often outcompete native species of crayfish and feed upon native plants, small fish, invertebrates and fish eggs. The loss of aquatic plants can impact wildlife in aquatic systems. Because of this, Rusty Crayfish are labeled as invasive in much of their introduced range. A species is **invasive** when it is both non-native to the ecosystem in which it is found and capable of causing environmental, economic, or human harm.

Rusty Crayfish inhabit fresh water streams, rivers, and lakes. They frequently shelter under rocks and submerged vegetation to avoid predators. They begin their life cycle as an egg. Females produce up to 350 eggs at a time. The eggs remain with the female, attached to the underside of her abdomen for up to 6 weeks. At this point, the eggs hatch and juvenile crayfish cling to the mother. The young molt several times and increase in size for up to 3 more weeks. They then detach from the mother to live as individuals. Rusty Crayfish can live up to 3 or 4 years in the wild.



Growth rates can be characterized by two different growth curves: linear and

exponential. **Linear growth** occurs at a constant rate. Many increases or decreases occur at a linear rate. An example of this would be having your salary increase by $1,000 a year. **Exponential growth** occurs at an increasing rate through time. An example would be having your salary increase by 5% per year.

Since all populations have the reproductive potential to increase exponentially, it is difficult to comprehend the gravity of problems associated with population growth. Population size is limited by many factors including water, food, shelter, and space, as well as natural and human made changes in habitat. However, for some populations of invasive species, there are few limiting factors that allows populations to grow uncontrollably.

In this activity, students will learn about the impacts of Rusty Crayfish and will simulate what happens when just a few Rusty Crayfish are released into a lake.

Procedure:

Engage

1. Ask students if they have ever gone fishing. Did they ever use live bait (worms, crayfish, minnows, etc)?
2. What did they do with the leftover bait? Ask students if they have ever witnessed anyone dumping out live bait like a package of worms after fishing. What do they think happens with the bait? Do they think any can survive?
3. Talk to students about types of population growth. What is the difference between linear and exponential growth? Draw examples of the 2 types of growth curves on the board. Ask students if wildlife populations tend to increase either linearly or exponentially. (*They can increase both ways*). What might be some problems associated with exponential population growth? (*Lack of habitat resources, competition for food, disease, etc*.)
4. Ask students what they think would happen to released bait that is able to survive in an introduced aquatic system. Do they think the bait will have linear or exponential growth? Why or why not?

Explore

1. If students aren't familiar with the term 'invasive', then define it for them. Explain to students that the Rusty Crayfish is a popular live bait species that has been introduced to the Mid-Atlantic through discarded bait. Tell students that unfortunately, Rusty Crayfish outcompete native crayfish species and devour aquatic plants. Ask students if they would consider Rusty Crayfish invasive. Why or why not?
2. Tell students they are now going to simulate the spread of Rusty Crayfish in a lake after being discarded as bait.

3. Divide students into small groups of 3-5, and then pass out the "Student Page: Crayfish Release Simulation." Go over the basic rules for the activity, hand out a die to each group, and let them go through the simulation.
4. Following their simulation, have each group write down their population numbers for Round 1, Round 2, and their estimated Round 3 numbers on the Board. Average the class numbers and create a small line graph on the board.
5. Ask students if what they are observing is linear or exponential population growth. Why or why not?

Explain

1. Ask students what can happen when Rusty Crayfish enter a new area. How does their data support that conclusion? Ask students what they think may happen to the lake ecosystem following the invasion.
2. Tell students that all populations have the potential to increase at an exponential rate. Ask students what factors limit this potential. Why is it important to have limiting factors that restrict population growth?
   Disease, predation and habitat loss all can limit population growth. In some cases, populations will exceed the amount of resources (such as food). The maximum number of individuals that the environment can sustain indefinitely without harm is known as carrying capacity. Factors that limit population growth are important to ensure that populations don't exceed their carrying capacity and cause harm to the environment.

Evaluate

Evaluate student's understanding based on participation in the simulation and class discussion.

Extend

1. Challenge students to examine the simulation premises and design. Instruct them to develop 3 ideas that alter the simulation's design to make it a more accurate model of Rusty Crayfish introduction and spread. For example, Rusty Crayfish birth rates are much higher than the simulation. Give students ample time to brainstorm and record their ideas. Groups should be able to explain why their changes would make the simulation more accurate. Have students present their ideas to the rest of the class.
   a. Key questions:
      i. What did you feel was not accurate about the simulation?
      ii. What changes did you make to improve the simulation?
      iii. Have students try out each other's simulations.
2. Have students research their state's live bait regulations. What are the regulations? Do the regulations address ways to prevent the introduction of Rusty Crayfish?

Student Page: Crayfish Release Simulation

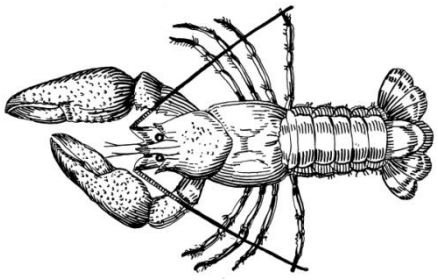
Crayfish are often a popular live bait item for anglers. Unfortunately, after fishing, some anglers discard their live bait into the area they are fishing. Within your group, you will simulate what happens to 5 Rusty Crayfish that begin in a bait bucket. Will their population establish in the river? If so, what will happen after 3 years? Roll to find out!

Directions: For each round, roll the die to determine the fate of your Rusty Crayfish. Tally the results in the tables below.

Year 1:

- Roll 1, 2, or 3= Your Crayfish will be used as bait, resulting in its death. Record '0' in the boxes for survived and birth.
- Roll 4, 5, or 6= Your Crayfish is released and can reproduce. Roll the die again to determine the # of young produced. Record '1' in the survival box and the # of young in the births box. Add the 2 numbers together to get the sum.

Crayfish #	1	2	3	4	5
Survived? (+ 1)					
# births					
Sum					



Total # of Crayfish after Year 1: _____

Year 2:

- Roll 1 or 2= Your Crayfish is consumed by a large fish and dies. Record '0' in the boxes.
- Roll 3= Turf battle! Your Crayfish decides to fight another. Roll again to decide its fate.
    - Roll 1 or 2= Your Crayfish dies.
    - Roll 3, 4, 5, or 6= Your Crayfish survives and reproduces. Roll again to determine the # of births.
- Roll 4, 5, or 6= Your Crayfish lives and can reproduce. Roll again to determine the # of births.

Crayfish #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Survived? (+1)															
# births															
Sum															

Crayfish #	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Survived? (+1)															
# births															
Sum															

Total # of Crayfish after Year 2: _____

Based on the results you have seen so far, what do you expect will happen with the Rusty Crayfish population at the end of Year 3? Provide reasoning in the space below.

Estimate the size of your Rusty Crayfish population after Year 3:_____

Invaders at Taylor's Pond Gr: 3-5

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

- Explain that sometimes non-native species, such as Grass Carp, can become invasive and can cause damage to an ecosystem
- Explain that the introduction of an invasive species, although done on purpose, is sometimes done through ignorance

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. **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.
Core Idea	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** http://www.nap.edu/openbook.php?record_id=13165&page=154 - 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.
Practices	• Asking questions and defining problems • Constructing explanations and designing solutions • Obtaining, evaluating, and communicating information
Cross-Cutting Theme	• Cause and Effect • Stability and Change
Reading, Writing & Social Studies	**CCSS.ELA/Lit.SL.3.1 -** Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher led) with diverse partners on grade 3 topics and texts, building on others' ideas and expressing their own clearly. **CCSS.ELA/Lit.SL3.2 -** Determine the main ideas and supporting details of a text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally. **CCSS.ELA/Lit.SL.3.3 -** Ask and answer questions about information from a speaker, offering appropriate elaboration and detail.
Environmental Literacy	**1.A.1 -** Identify and describe an environmental issue. **1.A.3 –** Given a specific issue, communicate the issue, the stakeholders involved and the stakeholders beliefs and values. **5.A.2 –** Analyze the effects of human activities that deliberately or inadvertently alter the equilibrium of natural processes. **7.B.1 –** Examine the influence of individual and group actions on the environment and explain how groups and individuals can work to promote and balance interests.

Invaders at Taylor's Pond Gr: 3-5

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

- Explain that sometimes non-native species, such as Grass Carp, can become invasive and can cause damage to an ecosystem
- Explain that the introduction of an invasive species, although done on purpose, is sometimes done through ignorance

Materials:

- Board
- Internet Access
- Pictures of Grass Carp (in kit)
- Student Page: Invaders at Taylor's Pond (on CD)

Teacher Background: Many non-native species, whether plants or animals, become invasive when introduced into a new ecosystem. Invasive species often are quick to adapt to new food sources and can out-compete native species for food. In some cases, they can alter the habitat to the point that native species can no longer use it. Invasive species sometimes are able to reproduce more rapidly than native species. Also, in their new range, there are often no natural predators to keep the populations in check. As a result, they often have a negative effect on native plant and animal species.

One such non-native species is the Asian Grass Carp (*Ctenopharyngodon idella*), also called white amur (ah-MOORE). They can reach a length of over 40 inches and can weigh 60 pounds (up to 399 pounds in their native range!). The very young fry eat phytoplankton and zooplankton. Once they grow slightly older, they become strict herbivores and can eat up to 10 times their body weight in plants each day.

Grass Carp are native to rivers in eastern China and Siberia. In 1963, the U.S. Fish and Wildlife Service, in cooperation with Auburn University, brought them into the US to test their usefulness in controlling aquatic vegetation in aquaculture facilities in Alabama and Arkansas. Grass Carp are now found in 45 states where they either spread naturally or were introduced (legally or illegally) as biological controls for aquatic plants in freshwater lakes and ponds.

Unfortunately, Grass Carp can be too efficient with their eating habits and can consume large quantities of aquatic vegetation, which includes native plants. Aquatic vegetation is important as food and shelter for many species, so its loss can have ecosystem level impacts.

In this activity, students will learn about the impacts of Asian Grass Carp and will read and discuss a fictional scenario in which Grass Carp are released into a pond.

Procedure:

Engage

1. Ask students how they travel. Can animals or plants travel the same ways we travel? What are other ways that animals travel that we cannot? List ideas on the board.
2. Show students the video "Cosmo's World: Invasive Species" https://www.youtube.com/watch?v=UyvPxU6LUu0
3. Discuss the concept of an invasive species – a plant or animal that is brought into an area, either accidently or on purpose, that can cause harm to the environment
4. Ask students, "How might an invasive plant or animal cause harm?"
5. How do invasive species get into new areas? Compare students' answers to the list created earlier.

Explore

1. Show students pictures of Grass Carp and discuss their size and feeding habits.
2. Ask students what they think may happen if Grass Carp are introduced into new areas.
3. Have students read the story, "Invaders at Taylor's Pond".

Explain

1. Following the reading, have a class discussion on the following questions:
    a. What 2 invasive species are in the story? Where did they originally come from?
    b. How did the waterweed get into the pond?
    c. What happened once it got there? Why was it a problem?
    d. How did Mr. Taylor try to get rid of waterweed?
    e. Why do you think he put A LOT of carp in the pond?
    f. What happened?
    g. Once all the plants were gone, what happened?
    h. In the end, what was left in the pond? *Nothing*
    i. What do you think the Taylors should have done differently?
    j. What do you think the Taylors should do now?

Evaluate

1. Evaluate understanding based on participation in the class discussion.
2. Have students write a paragraph answering the question "How do Brazilian waterweed and Asian Grass Carp fit the definition of an invasive species?"

Extend

1. Have the students fold an 11x14 inch piece of paper into 3 columns. Have students use each column to draw a representation of Taylor's Pond before, during and after the introduction of the waterweed and Grass Carp. Have students share their pictures with the class.
2. Have students research native submerged aquatic vegetation (SAVs) and their importance for aquatic ecosystems in your state. What would happen if Grass Carp were introduced and the SAVs disappeared?

Student Page: Invaders at Taylor's Pond

Mr. and Mrs. Taylor lived in a house in the country and on their property was a pond. The Taylors really enjoyed the pond. It had just enough native plants growing in it and it was full of native fish like bluegills. The Taylors had great fun teaching their grandchildren how to fish. When the weather was hot, they went swimming in the pond to cool off. In the early mornings, they sat and watched a great blue heron who tried to catch the fish in the pond, and every year, a family of ducks built a nest nearby and taught their ducklings how to swim in the pond.

Mr. and Mrs. Taylor also had an aquarium in their house full of colorful tropical fish. They tried to take good care of the aquarium and the fish living there. They knew that the fish needed oxygen, and they read that one way to make sure that there was plenty of oxygen was to put plants in the tank. So they went to the pet store and bought a bunch of plants called Brazilian waterweed. The plants did really well in the aquarium, and soon there were so many plants in the tank that the fish had almost no room to swim. The Taylors decided that the bluegills living in their pond could use the extra plants (after all, bluegills need oxygen, too), so they took the extra waterweed and threw it in the pond. They knew Brazilian waterweed wasn't a native plant, but they didn't think it would matter.

Well, the waterweed grew as well in their pond as it had done in their aquarium. In a few years, the pond was full of it. There was so much that it formed thick mats on the top of the water. When the Taylors tried to go swimming, they got all tangled up in the plants. When they tried to go fishing, their line got all tangled up in the plants too. And there were so many plants covering the water that the ducks had no place to teach their ducklings how to swim, so they left. The Taylors had a major problem!

Mr. Taylor started to do some research on the computer to figure out how to solve the problem in the pond. During his research, he read about a fish called an Asian Grass Carp that only ate plants. Suddenly, he had a wonderful idea. "Aha!" he told Mrs. Taylor. "There's the answer to our problem. Asian Grass Carp only eat plants so they won't eat the bluegills. And since there are a lot of plants in the pond, I'll get a lot of Grass Carp to eat the plants. The more carp the better!" So, he ordered A LOT of carp from a hatchery and put them in the pond. He knew that Asian Grass Carp weren't a native fish, but he didn't think it would matter.

There was so much waterweed in the pond that the Grass Carp thought they were in heaven! Brazilian waterweed was one of their favorite foods, so they ate and ate and ate. And they grew and grew and grew. But finally, they ran out of waterweed to eat, so they began to eat the native plants in the pond. At last, there were no plants of any kind left in the pond. The bluegills had no place to hide, so the great blue heron caught all of them. The Grass Carp were too big for the heron to eat, so it left and now the Taylors had no ducks or herons to watch. In the end, there was nothing for the carp to eat, so they began to die and the pond smelled terrible!

Now the Taylors had an even bigger problem! Their pond was dead – no plants and no fish lived there and besides, it stank! They finally understood that they had made several big mistakes.

Invasion of the Snakeheads Gr: 9-12

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

- Explain what invasive species are and how they are introduced and spread
- Understand the impacts of Northern Snakeheads and how they can spread

Standards:

NGSS	**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.
Core Idea	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** - 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.
Practices	• Asking questions • Planning and carrying out investigations • Analyzing and interpreting data • Constructing explanations • Engaging in argument from evidence • Obtaining, evaluating and communicating information
Cross-Cutting Theme	• Cause and effect • Stability and change
Reading, Writing & Social Studies	**CCSS.ELA.Lit.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. **CCSS.ELA/Lit.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. **CCSS.ELA/Lit.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. **CCSS.ELA/Lit.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.
Environmental Literacy	**1.A.5 –** Use data and references to interpret findings to form conclusions. **5.A.2 –** Analyze the effects of human activities that deliberately or inadvertently alter the equilibrium of natural processes. **7.B.1 –** Examine the influence of individual and group actions on the environment and explain how groups and individuals can work to promote and balance interests.

Invasion of the Snakeheads Gr: 9-12

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

- Explain what invasive species are and how they are introduced and spread
- Understand the impacts of Northern Snakeheads and how they can spread

Materials:

- Board
- Internet Access
- Northern Snakehead poster (in kit)
- Student Pages (on CD)

Teacher Background: Invasive species are non-native species that cause problems. These problems can include outcompeting native species, spreading disease, harming infrastructures, and/or altering ecological processes. It is estimated that the United States spends over $100 million dollars each year to control aquatic invasive species alone!

One aquatic invasive species found within the MidAtlantic is the Northern Snakehead (*Channa argus*), aka "Frankenfish". The Northern Snakehead was imported into the United States as a popular food fish and somehow found its way into local waters. It is believed Snakeheads were likely intentionally released into some waterways and have spread on their own ever since. In 2002, the U.S. banned the import of 28 species of snakehead!

Northern Snakeheads can grow almost 3 feet in length and have a hefty appetite to match their size. These predatory fish may compete with native species for food and habitat. Juveniles eat zooplankton, insect larvae, small crustaceans, and the fry (juveniles) of other fish. Adult snakeheads feed almost exclusively on other fish species. To make matters worse, Snakeheads can lay up to 15,000 eggs at a time and can have up to 5 batches of young each year! Their high reproductive capacities, ability to live in many different aquatic habitats, and their rapid growth make them a formidable invasive species.

In this activity, students will learn about the impacts of Northern Snakeheads and will explore the introduction and spread of this species in the Mid-Atlantic.

Procedure:

Engage

1. Ask students what types of fish they eat. List species on the board.
2. Ask students if they know the native region for the different fish listed. If this information is not known, then allow students time to conduct a quick internet search to find out locations of popular food fish.
3. Tally how many fish are native to your area. Ask students if they are surprised with the number of fish that may be from other areas of the world.
4. Show students the poster of a Northern Snakehead with other fish on it.
5. Ask students if they have ever heard of the Northern Snakehead or "Frankenfish". What have they heard?
6. Go over the definition of invasive species with students and explain that Northern Snakeheads are invasive in the United States. Tell students they are going to investigate the introduction and spread of Northern Snakeheads.

Explore

1. Hand out the Student Page: Invasion of the Snakeheads. Go over the directions and then allow students to complete the sheet using computers with internet access.
2. Following the activity, go over students' answers.
    a. After viewing the animation, what is the first year Northern Snakeheads were found in the United States? In what location were they found? *Snakeheads were first found in California in 1997.*
    b. What do you notice about the spread of the Northern Snakehead?
    c. Review the data table. What patterns do you notice in the data? *Snakeheads were predominantly released for food. Most Snakeheads are found in freshwater.*
    d. Where is the Northern Snakehead native? *China, Russia, North and South Korea*
    e. Why is the introduction of the Northern Snakehead a problem? *Snakeheads grow large and eat native fish, disrupting food webs.*
    f. What can be done to prevent the spread of Northern Snakeheads into new waters? *Encourage anglers to kill any snakeheads they catch. 2002 import ban.*
    g. A Northern Snakehead was recently found near Havre de Grace in Maryland. Use the map to predict where it may spread.
3. Ask students if any would like to share their prediction maps. Have students explain their reasoning for their decisions.

Explain

Have students write a brief summary of what they learned about Northern Snakeheads. Remind students to use sources as evidence for the information they present.

Evaluate

Review Student Pages for completion, accuracy, and for predictive reasoning.

Extend

1. Use the USGS map to research information on Northern Snakehead sightings in your state. What watersheds contain Northern Snakeheads, and what is your state doing to prevent its spread?
2. Northern Snakehead is growing in popularity as a food fish. As a class, discuss the pros and cons of making an invasive species marketable.
3. Refer back to the food fish students listed in the 'Engage' section. Have students research any of the non-native food fish on their original list to see if they have been introduced to the U.S. If so, then what are the impacts?

Student Page: Invasion of the Snakeheads

Northern Snakeheads are an aquatic, invasive species with a large appetite. This predator has rapidly expanded its range in the eastern United States in recent years. Complete the sheet to learn more about this invasive species.

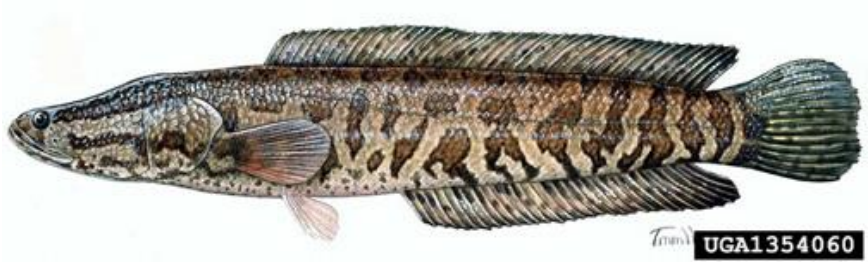


Photo by: Susan Trammell, Bugwood.org

Directions:

1. Go to the United States Geological Survey (USGS) page on Nonindigenous Aquatic Species on Fishes (http://nas.er.usgs.gov/queries/SpeciesList.aspx?Group=Fishes)
2. Find "Northern Snakehead" (*Channa argus*) and select the animated map. Watch the animation.
3. After viewing the animation, what is the first year Northern Snakeheads were found in the United States? In what location were they found?

4. Go back to the 'Northern Snakehead' page and select the point map. Zoom into the Maryland/Pennsylvania region. Randomly click on 10 points and record data in the table below. Answer the corresponding questions.

Record #	Size	Pathway	Water	Other info

a. What do you notice about the spread of the Northern Snakehead?

b. Review the data table. What patterns do you notice in the data?

5. Where is the Northern Snakehead native?

6. Why is the introduction of the Northern Snakehead a problem?

7. What can be done to prevent the spread of Northern Snakeheads into new waters?

8. Northern Snakeheads were found in (2015) near Havre de Grace in Maryland. Locate Havre de Grace (in the northeastern section of Maryland) to find the point by Havre de Grace and the one by Perry Point. Print a copy of the map and predict where Snakeheads will spread in the next 10 years. Label each point you create with approximate date for observations. List reasons for predictions below.

Is it a Snakehead? Gr: 6-8

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

- Explain why there is concern about the introduction of Northern Snakeheads
- Recognize differences between Northern Snakeheads and other similar-looking species
- Understand the laws governing the handling and removal of Northern Snakeheads

Standards:

NGSS	**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 biological diversity and ecosystem services.
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	• Constructing explanations and designing solutions • Obtaining, evaluating, and communicating solutions
Cross-Cutting Theme	• Cause and Effect • Stability and Change
Reading, Writing & Social Studies	**CCSS.ELA/Lit.W.6-8.2** - Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.
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. **7.B.1 –** Examine the influence of individual and group actions on the environment and explain how groups and individuals can work to promote and balance interests.

Is it a Snakehead? Gr: 6-8

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

- Explain why there is concern about the introduction of Northern Snakeheads
- Recognize differences between Northern Snakeheads and other similar-looking species
- Understand the laws governing the handling and removal of Northern Snakeheads

Materials:

- Bandanas
- Board
- Fish print (in kit)
- Internet access
- Larger area for students to spread out
- Pictures of Northern Snakehead (on CD)
- Student pages (on CD)

Teacher Background:

Invasive species are non-native species that cause problems. These problems can include outcompeting native species, spreading disease, harming infrastructures, and/or altering ecological processes. It is estimated that the United States spends over $100 million dollars each year to control aquatic invasive species alone!

One aquatic invasive species found within the Mid-Atlantic is the Northern Snakehead (*Channa argus*), aka "Frankenfish". The Northern Snakehead was imported into the United States as a popular food fish and somehow found its way into local waters. It is believed Snakeheads were likely intentionally released into some waterways and have spread on their own ever since. In 2002, the U.S. banned the import of 28 species of Snakehead!

Northern Snakeheads can grow to almost 3 feet in length and have a hefty appetite to match their size. These predatory fish may compete with native species for food and habitat. Juveniles eat zooplankton, insect larvae, small crustaceans, and the fry (juveniles) of other fish. Adult Snakeheads feed almost exclusively on other fish species.

To make matters worse, Snakeheads can lay up to 15,000 eggs at a time and can have up to 5 batches of young each year! Their high reproductive capacities, ability to live in many different aquatic habitats, and their rapid growth make them a formidable invasive species.

In May 2004, an adult Northern Snakehead was caught in a tributary of the Potomac River, just below Washington, D.C. In 2005, biologists found over 300 Snakeheads in a 15 mile stretch of the Potomac, including numerous young that had been born that year.

As a result, scientists have concluded that Northern Snakeheads have become established in the Potomac River and its tributaries. Fishing for Snakeheads has become a popular sport in the Potomac because they grow quite large and put up a good fight. In order to slow the spread of Snakeheads, anyone who catches one is required to kill it.

In this activity, students will learn about the problems with Northern Snakeheads, how they are introduced and spread, and will learn how to identify Northern Snakeheads in order to educate others.

Procedure:

Engage

1. Explain to students that they are going to be learning more about invasive species. Ask students what the word "invasive" means. Do you they already know of a few invasive species in their area? If so, what are they?
2. Show students the video "Cosmo's World: Invasive Species" (https://www.youtube.com/watch?v=UyvPxU6LUu0) to help further explain what invasive species are.
3. After the video, discuss the difference between native and invasive species. Explain that students will be learning about a particular invasive fish species – the Northern Snakehead.
4. If the Northern Snakehead is originally from Asia, how did it get to your area? Have students brainstorm ideas. Discuss ways in which the Northern Snakehead was introduced. Once the Northern Snakehead arrived, did it stay in just one body of water? How did it spread from place to place, and how quickly?
5. Go to the United States Geological Survey's (USGS) Nonindigenous Aquatic Species Animated Map for the Northern Snakehead (http://nas.er.usgs.gov/queries/SpeciesAnimatedMap.aspx?speciesID=2265). Enlarge the map to focus on the Mid-Atlantic States. Explain that the red dots are Snakehead sightings. Starting with 1997, click on the double arrow to show each year's spread. Have them notice the year that Snakeheads were found in the mid-Atlantic (*2002*). What year were they found in their state?
6. Discuss how quickly the Snakehead spread throughout their state. Is this problematic? Why?

Explore

Explain to students that they are going to complete an activity that will help illustrate why invasive species are so problematic. Have students participate in a modified version of "Oh Deer" from Project WILD that incorporates invasive species.

a. Have students stand shoulder-to-shoulder in 2 lines across from each other in a large area (gym or field). Remind students of the habitat needs of aquatic organisms – food, space, and shelter. One line of students will represent the "habitat needs", while the other line of students will represent native fish species. Have students in each line turn around so their backs face the other line. Have students make a gesture representing which habitat need they are, or which habitat need they want (pat belly for food, spread arms wide for space, put hands over head for shelter). On the count of 3, have students turn around to face each other. The students who are native fish must run across the field and link arms with the habitat need that matches the gesture they were making. Habitat needs that get linked with fish turn into additional fish the next round; fish that don't find a habitat need become a habitat need. After a few rounds, introduce one student as an invasive Northern Snakehead. The Northern Snakehead is able to obtain 2 habitat needs at a time vs. the native fish species that can only obtain 1 need at a time. Northern Snakeheads are designated by a bandana tied around the upper arm.

2. After a few more rounds, discuss what has happened (*Most of the "native fish" should have been replaced by Northern Snakeheads*). Discuss reasons that this is a problem. Return to the classroom and have students list on the board the ways in which invasive animals can cause harm.

3. Show students the picture of the Northern Snakehead (on CD). Using the fish print (in kit), have students compare this image to other similar-looking fish species, including the Bowfin, Channel Catfish, Chain Pickerel, etc. Working together in small groups, have the students come up with a few key characteristics that distinguish the Northern Snakehead from these other similar-looking fish.

4. As one large group, discuss why it is important to distinguish Northern Snakeheads from other fish species. Will efforts to stop the spread of the Northern Snakehead be effective if the fish is confused with other species?

Explain

1. As a group, brainstorm ways that the spread of Northern Snakeheads can be prevented, including educating others about the harm that Northern Snakeheads can cause, and ways to identify the fish.

2. Working in small groups, have students create brochures, posters, pamphlets, short videos, a social media campaign, or other communication materials that provide information to fishermen and other members of the public. Students may use the Student Page but should also conduct research on their own. Be sure that students include:

a. Pictures of a Snakehead and other "look-alike" fish, including the Bowfin, Chain Pickerel, Channel Catfish, Round Goby, American Eel, and Sea Lamprey

b. A description of how to tell the "look-alike" fish from a Snakehead

c. Instructions on what to do if a Snakehead is caught in their state

d. Information on the harm caused by Snakeheads and why it's important to prevent their spread

Evaluate

Student materials should successfully communicate why the Northern Snakehead is problematic, how to identify it, and what can be done to stop its spread.

Extend

1. The Northern Snakehead is growing in popularity as a food fish. As a class, discuss the pros and cons of making an invasive species marketable.
2. A number of laws exist regarding the handling, capture, and removal of Northern Snakeheads. How many federal laws exist that deal with this issue? Are there any laws at the state or local levels?
3. Research rare, threatened, or endangered fish species that are threatened by the presence of the Northern Snakehead. What is special about these fish species? Why are they in need of protection? Are any found in your state?
4. Working in groups, have students determine whether or not the bodies of water in their neighborhoods could support populations of Northern Snakeheads. What factors contribute to this?

Student Page: All About Northern Snakeheads

What are Northern Snakeheads?
Northern Snakeheads (*Channa argus*) are long fish that can grow to over 3 feet and weigh up to 15 pounds. They are predators with sharp teeth. Adult Snakeheads prefer to eat fish, but will also eat frogs, crayfish, small reptiles, birds and mammals. A female Snakehead may lay eggs up to 5 times a year and produce up to 15,000 eggs each time. Unlike most fish, adult Snakeheads guard their young. At 2 years of age they are a foot long and ready to reproduce.

Where do Snakeheads come from and how did they get here?
Northern Snakeheads are native to Asia, where they are a popular food item. They are often imported and sold live to eat, and are used in traditional Asian medicine. They may also be imported for the aquarium trade, because the young fish are easy to keep in tanks. Northern Snakeheads grow quickly; many may have been released into the wild because their owners were unable to keep large adult fish in small tanks.

Why are people worried about Snakeheads?
The spread of Northern Snakehead could upset the ecological balance of aquatic systems and could wipe out populations of native fish. This is possible because Snakeheads are predators of other fish and have no natural predators; they can survive in waters with a wide range of temperatures, salinity, and oxygen levels; they reproduce quickly; and they can spread parasites and disease to native fish populations.

Are there Snakeheads in the Mid-Atlantic States?
In May 2004, an adult Snakehead was caught near the Potomac River. In 2005, biologists found over 300 Snakeheads in a 15 mile stretch of the Potomac, including many young fish that had been born that year. As a result, scientists know that Northern Snakeheads are successfully feeding and reproducing in the Potomac River and have spread to other rivers in Maryland and Virginia. They have also been found in the Delaware River and in New York City.

What are the laws concerning Snakeheads and will they work?
In 2002, a federal law made it illegal to bring a live Snakehead or eggs into the United States; and to move a live fish or eggs across state lines. In several states like Maryland and Virginia it is illegal to keep a live Northern Snakehead**.** It is legal to fish for Snakeheads, but if you catch one, you must kill it right away instead of releasing it. This law is to help control the spread of this invasive fish. Once the fish have become established, laws won't prevent them from spreading further. Many individuals like to fish for Snakeheads. There is worry that live Snakeheads might be deliberately moved from one place to another to provide more chances for fishing, even though it is against the law.

What can you do?
One of the ways to prevent the spread of Snakeheads is to educate people, especially fishermen, about the harm caused by Snakeheads. Unfortunately there are native fish that resemble Snakeheads, and sometimes people cannot tell them apart. These include species such as the Bowfin, Chain Pickerel, Channel Catfish, Round Goby, American Eel, and Sea Lamprey. Educational efforts can improve the chances of protecting native fish species and reducing the impact of Snakeheads.

Not Wanted: Invasive Ninja Turtles Gr: 6-12

Activity Adapted from: Race for Space: ANS vs. Natives
http://www.fws.gov/columbiariver/ANS/Activities/Activity_7.pdf

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

- Explain the impacts of an introduced species on native species
- Explain why non-native pets should not be released into the wild

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. **HS-LS2-6 –** Evaluate the claims, reasoning and evidence 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.
Core Idea	**LS2.A: Interdependent Relationships in Ecosystems** - http://www.nap.edu/openbook.php?record_id=13165&page=150In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** - Extreme fluctuations in conditions or the size of any population can challenge the functioning of ecosystems in terms of resources and habitat availability.
Practices	• Developing and using models • Using mathematics • Constructing explanations • Obtaining, evaluating, and communicating information
Cross-Cutting Theme	• Cause and effect • Stability and change
Reading, Writing & Social Studies	**CCSS.ELA/Lit.RST.6-8.1 –** Cite specific textual evidence to support analysis of science and technical text. **CCSS.ELA/Lit.WHST.6-8.1 –** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **CCSS.ELA/Lit.RST.9-12.1 –** 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.WHST.9-12.**1 - Write arguments to support claims in an analysis of topics or texts, using valid reasoning and relevant and sufficient evidence.
Environmental Literacy	**4.A.1 –** Explain how organisms are linked by the transfer and transformation of matter and energy at the ecosystem level. **5.A.2 –** Analyze the effects of human activities that deliberately or inadvertently alter the equilibrium of natural processes.

Not Wanted: Invasive Ninja Turtles Gr: 6-12

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

- Explain the impacts of an introduced species on native species
- Explain why non-native pets should not be released into the wild

Materials:

- Board
- Die; 1 for each group
- Graph paper; 1 for each group
- Markers (Black, red, and yellow); 1 for each group
- Student Page (on CD)

Teacher Background: Red-eared Sliders (*Trachemys scripta elegans*) are a type of aquatic turtle named for the broad red stripe behind the eye. Juveniles have a bright green and yellow carapace (top shell) while the adults are darker olive and brown. Adult females can range up to 13 inches in shell length, while the males are slightly smaller. They inhabit ponds, lakes, and slow-moving rivers with soft substrate and dense aquatic vegetation. Both adults and juveniles are opportunistic omnivores. Juveniles tend to be more carnivorous, feeding on insects, worms, tadpoles, and small fish. As they get older, they switch to a more herbivorous diet, but adults will still feed on invertebrates, small fish, and small mammals. When mature, females may nest up to 5 times a season, each nest containing 2-30 eggs.

Red-eared Sliders are native to the Mississippi valley, north to Illinois and south to the Gulf of Mexico, and the Cumberland and Tennessee River valleys. However, beginning in the mid-1900s, they became widely available as pets. Most of the tiny turtles sold in pet stores or dime stores did not survive, but the ones that did, eventually outgrew their tanks and their owner's interest. When that happened, they were often released into a local pond or lake. As a result, Red-eared Sliders are now found in waterways all over the United States, wherever the winters are not too cold.

In 1975, due to multiple cases of salmonellosis traced to pet turtles, a law was passed banning the sale of turtles with a shell length of less than 4 inches. Unfortunately, Red-eared Sliders with a shell length greater than 4 inches still are widely available at many pet stores, and smaller ones are still sold illegally, especially at flea markets and over the Internet. Regrettably, the current Teenage Mutant Ninja Turtle craze has just made the situation worse.

The presence of Red-eared Sliders can have a significant impact on native species of turtles, such as painted turtles and red-bellied cooters. They are highly adaptable; they can hibernate in areas where the winters are not extremely cold, and they can survive in brackish water. They are more aggressive than native turtles and compete with them for food, and since they are opportunistic feeders, they will eat almost anything available. Because of their aggressive behavior, they also can successfully compete for basking spots, which are crucial for all aquatic turtles. In addition, the large females produce far more eggs a season than the native turtles do, which allows the slider population to grow more quickly. If they are released pets, Red-eared Sliders may also carry pathogens that can spread to native turtles.

In spite of their possible impact on native species of turtles, not all states consider them invasive. **Invasive species** are non-native species that cause problems in their introduced ranges. Pennsylvania considers them an Aquatic Invasive Species (AIS) and Virginia considers them "naturalized wildlife". No state (including Pennsylvania) bans their possession.

In this activity, students will learn about the impacts of Red-eared Sliders, how they are introduced, and will simulate the spread of Red-eared Sliders in a pond ecosystem.

Procedure:

Engage

1. Ask students how many have or have had a pet turtle? What kind was it? Where did they get it? What happened to it?
    a. For homework, have students ask their parents the same questions as above.
2. On the next day, summarize answers on the board. Go over the answers, including what species were the most popular and what happened to them.
3. One of the species students list will likely be the Red-eared Slider. Have students read the document – "Red-eared Slider". Have them write a paragraph describing the ways that sliders meet the definition of an invasive species. What characteristics do they share?

Explore

1. Tell students they are now going demonstrate the impact of Red-eared Sliders on populations of native turtles.
2. Divide students into groups of 3 and provide each group with a die and Student Page. Briefly describe the directions, and then allow groups time to complete the worksheet.

Explain

1. Discuss the results of the activity. Which species spread across the pond more quickly? Why?
2. Have students graph the results from their data sheet for each species and describe the result in writing. Have the different groups compare their results.
3. Have students write a paragraph answering the question: What factors (environmental or biological) could limit the increase of an invasive population without harming native species?

Evaluate

Evaluate students based on accuracy of their graph, the validity of their reasoning and use of evidence in their written paragraph, and their participation in class discussion.

Extend

1. Have students discuss ways that the simulation could be made more realistic – one possibility is to start with 3 or 4 of the native species and 1 Red-eared Slider
    a. Have students try several variations of the activity.
    b. Have them predict how the changes will affect the outcome.
    c. Which variation seems more realistic? Why?

Student Page: Red-eared Slider

An **invasive species** is a non-native plant or animal whose introduction causes or is likely to cause economic or environmental harm or harm to human health. While all species in an ecosystem must compete to survive, invasive species (including aquatic nuisance species) tend to share common characteristics that enable them to outcompete native species for food and preferred habitats. For example:

- Many invasive species can live in a wide variety of habitat conditions and can consume a broad range of food types.
- Invasive species tend to grow rapidly, reproduce quickly, and/or have a high number of offspring.
- Invasive species may aggressively compete or are more efficient at acquiring important resources than native species.

Red-eared Sliders are a species of pond turtle. They are native to the Mississippi valley, north to Illinois and south to the Gulf of Mexico, and the Cumberland and Tennessee River valleys. However, beginning in the mid-1900s they became widely available as pets. Most of the tiny turtles sold in pet stores or dime stores did not survive, but the ones that did eventually outgrew their tanks and their owner's interest. When that happened, they were often released into a local pond or lake. As a result, Red-eared Sliders are now found in waterways all over the United States, wherever the winters are not too cold. Regrettably, the current Teenage Mutant Ninja Turtle craze has just made the situation worse.

The impact of Red-eared Sliders in the mid-Atlantic has not been well documented. However, their presence may have a significant impact on native species of turtles, such as painted turtles and red-bellied cooters. They are highly adaptable and prefer the same habitats as native turtles. They are larger and more aggressive than native turtles and can successfully compete with them for food. Since they are opportunistic feeders, they will eat almost anything available, including bread thrown to ducks. Because of their aggressive behavior, they also can successfully compete for basking spots, which are crucial for all aquatic turtles. Furthermore, the large females produce far more eggs a season than the native turtles do, which allows their population to grow more quickly. In addition, if they are released pets, they may also carry pathogens that can spread to the native turtles.

In spite of their possible impact on native species of turtles, not all states consider them invasive. On the one hand, Pennsylvania considers them an Aquatic Invasive Species (AIS), but on the other hand, Virginia considers them "naturalized wildlife". No state (including Pennsylvania) bans their possession.

Activity Directions

1. Work in groups of 3; each group will have a grid, die, markers, and a worksheet to record data. Have each group member take a marker.
    - Black marker= Red-eared Slider (invasive)
    - Red marker= Red-bellied Cooter (native)
    - Yellow marker= Painted Turtle (native)
2. The grid represents your pond. Each person should place a mark anywhere on the grid they choose; that mark represents a parent turtle.
3. At the beginning of each year, 1 person rolls the die. This number represents the environmental conditions in the pond for that year.
    - Numbers 1-3 represent poor environmental conditions – lots of predators, cold weather, flooding, etc. Numbers 4-6 represent good environmental conditions – warm weather, plenty of food, few predators, etc.
4. Use the worksheet to calculate the number of "offspring" you have that year. Once you have a number, place a mark on the grid adjacent to the parent for each offspring. Round each answer to the nearest whole number.
    - For example, if the environmental condition is 4:
        - The slider would multiply 1 x 4 x 1.3 = 5.2 (round to 5); mark 5 grid spaces around the parent
        - The cooter would multiply 1 x 4 x 1 = 4
        - The painted turtle would multiply 1 x 4 x 0.5 = 2
5. Take turns rolling the die to determine the environmental conditions for each year.
    - For each year do the calculations and mark "offspring" on the grid adjacent to each "parent".
    - If the grid starts to get crowded, then the slider may take advantage of its more aggressive behavior, and can mark over a native turtle's mark.
6. Use the data sheet to keep track of your data.
7. Once the grid is full, the activity is over even if you don't reach Year 10.

Student Worksheet

Year 1		Red-eared Slider	Red-bellied Cooter	Painted Turtle
1	# of reproducing individuals for Year 1	1	1	1
2	Reproductive potential	1.3	1.0	0.5
3	Environmental suitability (number from die)			
4	# of individuals added to grid (line 1 x line 2 x line 3)			
Year 2				
5	# of reproducing individuals for Year 2 (line 4 + line 1)			
6	Reproductive potential	1.3	1.0	0.5
7	Environmental suitability (number from die)			
8	# of individuals added to grid (line 9 x line 10 x line 11)			
Year 3				
9	# of reproducing individuals for Year 3 (line 8 + line 5)			
10	Reproductive potential	1.3	1.0	0.5
11	Environmental suitability (number from die)			
12	# of individuals added to grid (line 9 x line 10 x line 11)			
Year 4				
13	# of reproducing individuals for Year 4 (line 12 + line 9)			
14	Reproductive potential	1.3	1.0	0.5
15	Environmental suitability (number from die)			
16	# of individuals added to grid (line 13 x line 14 x line 15)			
Year 5				
17	# of reproducing individuals for Year 5 (line 16 + line 13)			
18	Reproductive potential	1.3	1.0	0.5
19	Environmental suitability (number from die)			
20	# of individuals added to grid (line 17 x line 18 x line 19)			

Year 6		Red-eared Slider	Red-bellied Cooter	Painted Turtle
21	# of reproducing individuals for Year 6 (line 20 + line 17)			
22	Reproductive potential	1.3	1.0	0.5
23	Environmental suitability (number from die)			
24	# of individuals added to grid (line 21 x line 22 x line 23)			
Year 7				
25	# of reproducing individuals for Year 7 (line 24 + line 21)			
26	Reproductive potential	1.3	1.0	0.5
27	Environmental suitability (number from die)			
28	# of individuals added to grid (line 25 x line 26 x line 27)			
Year 8				
29	# of reproducing individuals for Year 8 (line 28 + line 25)			
30	Reproductive potential	1.3	1.0	0.5
31	Environmental suitability (number from die)			
32	# of individuals added to grid (line 29 x line 30 x line 31)			
Year 9				
33	# of reproducing individuals for Year 9 (line 32 + line 29)			
34	Reproductive potential	1.3	1.0	0.5
35	Environmental suitability (number from die)			
36	# of individuals added to grid (line 33 x line 34 x line 35)			
Year 10				
37	# of reproducing individuals for Year 10 (line 36 + line 33)			
38	Reproductive potential	1.3	1.0	0.5
39	Environmental suitability (number from die)			
40	# of individuals added to grid (line 37 x line 38 x line 39)			

The Grass Carp Dilemma Gr: 6-12

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

- Explain that sometimes non-native species such as Grass Carp were deliberately introduced to try to control an existing problem
- Explain that there is often disagreement about introducing a potentially invasive species

Standards:

NGSS	**MS-LS2-4:** Construct an argument, supported by empirical evidence that changes to physical or biological of an ecosystem affect populations. **MS-LS2-5:** Evaluate competing design solutions for maintaining biological diversity and ecosystem services. **HS-LS2-6:** Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. **HS-LS2-7:** Design, evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
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. **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** - 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.
Practices	• Asking questions and defining problems • Analyzing and interpreting data • Constructing explanations • Engaging in argument from evidence • Obtaining, evaluating, and communicating information
Cross-Cutting Theme	• Cause and effect • Systems and system models • Stability and change
Reading, Writing & Social Studies	**CCSS.ELA/Lit.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. **CCSS.ELA/Lit.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.

	CCSS.ELA/Lit.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. **CCSS.ELA/Lit.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.
Environmental Literacy	**1.A.1 -** Identify and describe an environmental issue. **1.A.3 –** Given a specific issue, communicate the issue, the stakeholders involved and the stakeholders beliefs and values. **1.A.5 –** Use data and references to interpret findings to form conclusions. **5.A.2 –** Analyze the effects of human activities that deliberately or inadvertently alter the equilibrium of natural processes. **7.B.1 –** Examine the influence of individual and group actions on the environment and explain how groups and individuals can work to promote and balance interests.

The Grass Carp Dilemma Gr: 6-12

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

- Explain that sometimes non-native species such as Grass Carp were deliberately introduced to try to control an existing problem
- Explain that there is often disagreement about introducing a potentially invasive species

Materials:

- Board
- Internet access
- Student Pages (on CD)

Teacher Background: Non-native species are organisms introduced outside of their natural range that are capable of surviving and reproducing in their new habitat. When non-native species cause problems in their introduced environments, they are known as **invasive species**. Many invasive species are quick to adapt to new food sources and can outcompete native species for food. In some cases, they can alter the habitat to the point that native species can no longer use it. Invasive species may also be able to reproduce more rapidly than native species. Also, in their new range, there are often no natural predators to keep the invasive populations in check. As a result, invasive species often have a negative effect on native plant and animal species.

One such non-native species is the Asian Grass Carp (*Ctenopharyngodon idella*), also called white amur (ah-MOORE). They can reach a length of over 40 inches and can weigh 60 pounds (up to 399 pounds in their native range!). The very young fry eat phytoplankton and zooplankton. Once they grow slightly older, they become strict herbivores and can eat up to 10 times their body weight in plants each day.

Grass Carp are native to rivers in eastern China and Siberia. In 1963, the U.S. Fish and Wildlife Service, in cooperation with Auburn University, brought them into the U.S. to test their usefulness in controlling aquatic vegetation in aquaculture facilities in Alabama and Arkansas. Grass Carp are now found in 45 states where they either spread naturally or were introduced (legally or illegally) as biological controls for aquatic plants in freshwater lakes and ponds. One such plant is the invasive Hydrilla which can quickly overtake pond habitats and block sunlight to native plant species.

Unfortunately, Grass Carp can be too efficient in their eating habits and can consume large quantities of aquatic vegetation, which includes native plants. Aquatic vegetation is important as food and shelter for many species, so its loss can have ecosystem level impacts.

In this activity, students will learn about the impacts of Asian Grass Carp and will role play as different community groups to debate whether or not Grass Carp should be introduced to remove the invasive plant, Hydrilla.

Procedure:

Engage

1. Ask students if they have ever seen a pond with a lot of vegetation in it.
2. Did the pond look healthy, why or why not?
3. What happens if some plants grow out of control in ponds? (*Block sunlight, restrict animal movement, etc.*)
4. Have students research American Eelgrass (a native plant) and Hydrilla (an invasive plant). Have students answer the following questions about each species:
    a. Is the plant native to your state? If not, then where?
    b. What is the plant's role in an ecosystem?
    c. Can the plant have a negative impact on the environment? Why or why not?
5. Following their research, discuss students' answers to the questions above. What do they now know about each species? Students should understand that American Eelgrass is a native and vital plant to many aquatic habitats and wildlife. However, Hydrilla is an invasive species that can outcompete American Eelgrass and other important wetland plants, causing issues with the food web.

Explore

1. Explain to students that they are now going to research and role play in a discussion about what to do with excessive plants in a community lake. Read the following scenario to the class:
    a. You are residents of a community that has a large lake that was created by damming a local stream. The residents like to use the lake for swimming, fishing and boating (canoes, kayaks, and paddleboats). Within the last few years, however, the lake has become overgrown with aquatic plants, mainly the invasive Hydrilla. The plants are so big that they have formed large mats on the surface of the water, making it difficult for people to use the lake. The residents of the community are demanding that something be done about the plants.
    b. One suggested solution is to introduce Asian Grass Carp, a large, non-native species of fish. The fish that would be stocked in the lake are sterile (unable to reproduce). You know that Grass Carp were deliberately introduced into the U.S. by the U.S. Fish and Wildlife Service to control aquatic plants.
2. Tell students they are now going to role play different stakeholders and decide what to do with the community lake covered with Hydrilla.

3. Divide the class into 3 groups.
    a. Those in favor of Grass Carp introduction
    b. Those opposed to Grass Carp introduction
    c. A Homeowner's Association Board that will review proposals for feasibility
4. The 2 groups who favor or oppose introduction will have to create a presentation (no longer than 10 minutes) to convince the Homeowners' Association Board of their position. It can be in the form of a poster, PowerPoint presentation, or speech. The members of the Homeowners' Association Board will have to become familiar with Grass Carp as a biological control and will have to put together a list of questions for each side of the debate.

Explain

1. Allow the 2 groups to give their presentations to the Board. Following each presentation, allow the Board and other students 5 minutes to ask questions.
2. After the 2 presentations, the Board will have 10 minutes to come to a decision. They will then have to explain to the other 2 groups why they made the decision they did, providing evidence in support of their decision.
3. Explain to the class that no matter what decision was made, most states consider Grass Carp to be a potentially invasive species and their use is regulated. Delaware, New Jersey, New York, Pennsylvania, Virginia, and West Virginia permit Grass Carp to be stocked provided the fish are sterile (cannot reproduce). Maryland prohibits the introduction of Grass Carp, even if they are sterile.

Evaluate

Evaluate understanding based on class participation and accuracy, including providing proper sources for their evidence.

Extend

1. Aside from Grass Carp, other non-native species have been introduced for biological control. Have students research the pros and cons of non-natives for biological control and present examples of successful and failed attempts.
2. Have students research regulations on Grass Carp in their state. Is it legal to introduce them to ponds and lakes? What rules regulate releases?

Unlikely Cargo Gr: 3-5

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

- Explain how Zebra Mussels were introduced and spread in the United States

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.
Core Idea	**LS4.C: Adaptation -** For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.
Practices	• Use Evidence (e.g., observations, patterns) to Construct an Explanation • Construct an Argument • Support an Argument
Cross-Cutting Theme	• Cause and Effect
Reading, Writing & Social Studies	**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. **CCSS.ELA-LITERACY.RI.3.2 -** Determine the main idea of a text; recount the key details and explain how they support the main idea. **CCSS.ELA-LITERACY.RI.3.3 -** Describe the relationship between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text, using language that pertains to time, sequence, and cause/effect. **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).
Environmental Literacy	**1.A.1:** Identify an environmental issue.

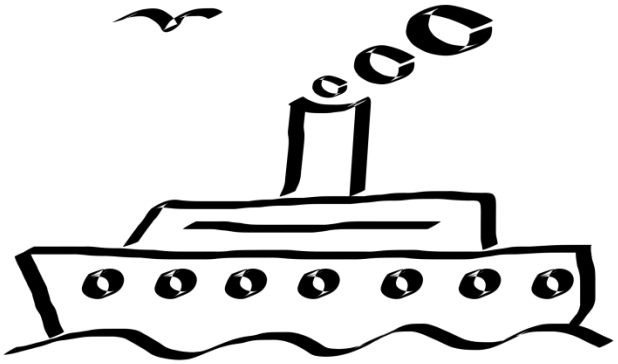
Unlikely Cargo Gr: 3-5

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

- Explain how Zebra Mussels were introduced and spread in the United States

Materials:

- 25 tokens of 6 different colors (about 150 tokens total; in kit)
- 6 buckets or similar containers
- 6 cones or field markers (in kit)
- 6 signs – 1 each for Lake St. Clair, Lake Erie, Lake Ontario, Lake Huron, Lake Michigan, and Lake Superior (in kit)
- How Stuff Works Cargo Video http://science.howstuffworks.com/28789-how-do-they-do-it-container-ship-video.htm
- Large picture of a cargo ship
- Large picture of a Zebra Mussel (on CD)
- Large, open area like a field or gymnasium
- Tape
- Timer
- Zebra Mussel specimen (in kit)



Teacher Background: An **invasive species** is an exotic species that invades natural systems and out competes natives or transmits disease. An **exotic** species is one that was introduced from another part of the world. Not all exotic species are invasive, but all invasive species are exotics. Zebra Mussels are one of several invasive mollusk species in North America.

Zebra Mussels are small aquatic mollusks classified as **bivalves** due to their 2-hinged shells. The species is native to streams and rivers in southern Russia, but has also invaded much of Europe. The mussels were officially discovered in North America in 1988 when scientists sighted the mussels in Lake St. Clair, a body of water between Lake Huron and Lake Erie on the border of Canada and the United States. It is generally believed that these Zebra Mussels were first introduced to the Great Lakes region by transoceanic ships entering from the St. Lawrence Seaway. The Zebra Mussels may have been released through ballast water exchanges or attached to protected hull areas. From this entry point Zebra Mussels have spread throughout numerous waterways in

the United States with 30 states affected as of 2013. The Great Lakes are now a significant donor region for Zebra Mussels.

Zebra Mussels are adept at establishing themselves in new locations. They tolerate a wide-range of water temperatures and flourish in most freshwater environments. In addition, Zebra Mussels have a limited number of predators in North America. They can even survive in poor water quality conditions and out of water for several days.

Zebra Mussels grow and reproduce quickly with individuals becoming sexually mature after 1 year. The average egg production for 1 female Zebra Mussel is a million eggs per year. Eggs are released into the water where they are fertilized by males. After 3 to 5 days, the eggs hatch into microscopic Zebra Mussels called **veligers**. Veligers then drift/disperse in the water for up to a month. The juvenile stage begins when mussels settle to the bottom, crawl around, and then find a suitable surface to attach to. Zebra Mussels can fasten themselves to most hard surfaces including boats, anchors, buoys, pipes, docks, rocks, other mollusks, and more. These characteristics combine to allow Zebra Mussels to hitchhike to new locations during each stage of their life cycle.

Zebra Mussels have a profound impact on the ecosystems they invade. Their presence causes native mussel and clam populations to plummet. They can also clog pipes, deteriorate dock pilings, sink buoys, and encrust boat hulls. They disrupt aquatic food webs and can alter the flow of nutrients in an environment. Toxins accumulate in the mussels' tissues, which are then transferred to fish and birds when they are eaten. Zebra Mussels are so destructive that their introduction single handedly prompted a new division of scientific study called invasion ecology.

In this activity, students will simulate the dispersal of Zebra Mussels through ship's "cargo".

Procedure:

Engage

1. Ask students to describe a boat. Discuss the following:
    - What boats are used for. Emphasize that boats carry people and things to different places.
    - Discuss where boats are found.
    - Ask students to describe what a boat looks like.
2. Show students the picture of a cargo ship and discuss what this type of boat may do. Make sure to note that some large boats can move across very big lakes and the ocean.
3. You may want to show students the cargo video on How Stuff Works: http://science.howstuffworks.com/28789-how-do-they-do-it-container-ship-video.htm

Explore

1. In a large area like a playing field or gym, place the 6 cones about 10 feet from each other to form a rough hexagon.
2. Place of the Lake signs (in kit) next to each cone in addition to a bucket with one color of token. Be sure to pay attention which color tokens are "Lake St. Clair".
3. Divide students into groups, directing an equal number to stand next to each cone.
4. Explain to students the rules of the activity:
    1) Each student will pretend they are a boat captain.
    2) Each boat captain has to take cargo (token) to a new lake by running to another cone and dropping it into the bucket there.
    3) The boat captains then have to run back to their cone, get another piece of cargo, and take it to another lake.
    4) Students will have 3-5 minutes to deliver as many pieces of cargo (tokens) as they can to other lakes.

Explain

1. Explain to students that some cargo is brought to a new place on purpose while other cargo is brought by accident.
2. Discuss what a Zebra Mussel is and how it can attach to a ship and travel with it. Show students pictures of Zebra Mussels and specimens (in kit).
3. Tell students that Zebra Mussels were first found in Lake St. Clair but can now be found in all the Great Lakes. Point out the color of the Lake St. Clair tokens and have students look in their buckets. Do they have any cargo from this Lake?
4. Have students turn to a partner and explain how that might have happened. Call on a pair (or a few pairs) of students to explain their ideas.
5. Tell students that Zebra Mussels are not naturally found in Lake St. Clair.
6. Discuss the definitions of **invasive** and **native** species. Ask students to explain why Zebra Mussels may be considered an invasive species.

Evaluate

1. Ask students to think about how Zebra Mussels might have gotten into Lake St. Clair. (Zebra Mussels attached to a ship, which accidently brought them to Lake St. Clair.)
2. Have students describe how the tokens in their bucket are different from the start of the activity. (There should be a mixture of colors, when they started with only one color.)
3. Ask students what else may be spread accidentally from cargo ships.

Extend

1. Students can further research the life cycle of a Zebra Mussel and how they can spread to new places as young mussels and eggs. Have students research ways to prevent the introduction and spread of Zebra Mussels into new systems.
2. Students can watch the Dynamic Map of Zebra Mussel Distribution to see how Zebra Mussels have spread from state to state. (http://www.nationalatlas.gov/dynamic/an_zm.html)

Zebra Mussels- Coming to the Water Near You? Gr: 6-12

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

- Explain how Zebra Mussels are introduced and spread
- Predict the risk (low or high) of Zebra Mussels invading a local body of water

Standards:

NGSS	**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 [Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.]
Core Idea	**LS2.C: Ecosystem Dynamics, Functioning, and Resilience** - 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.
Practices	• Planning and carrying out investigations • Analyzing and interpreting data • Constructing explanations and designing solutions
Cross-Cutting Theme	• Cause and effect • Stability and change
Reading, Writing & Social Studies	**CCSS.ELA/Lit.RST.6-8.7** - Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). **CCSS.ELA/Lit.WHST.6-8.1** – Write arguments focused on discipline-specific content. **CCSS.ELA/Lit.WHST.6-8.7 -** Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. **CCSS.ELA/Lit.RST.11-12.7** – Evaluate and integrate multiple sources of information presented in diverse formats and media. **CCSS.ELA/Lit.WHST.9-12.7** – Conduct short as well as sustained research projects to answer a question or solve a problem.
Environmental Literacy	**1.A.1** – Identify an environmental issue. **1.A.4** – design and conduct the research. **1.A.5** – Use data and references to interpret findings to form conclusions. **4.B.1** – Analyze the growth or decline of populations and identify a variety of responsible factors.

Zebra Mussels- Coming to the Water Near You? Gr: 6-12

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

- Explain how Zebra Mussels are introduced and spread
- Predict the risk (low or high) of Zebra Mussels invading a local body of water

Materials:

- Board
- Internet Access
- Pictures of Zebra Mussels (on CD)
- Student Page (on CD)
- Thermometer
- Water body (pond, lake, stream, etc.)
- Water quality test kit (pH, salinity, dissolved oxygen, etc)
- Water velocity test supplies (optional)

Teacher Background: Invasive species are non-native species that cause problems. These problems can include outcompeting native species, spreading disease, harming infrastructures, and/or altering ecological processes. It is estimated that the United States spends over $100 million dollars each year to control aquatic invasive species alone!

One aquatic invasive species found within the Mid-Atlantic is the Zebra Mussel (*Dreissena polymorpha*). Zebra Mussels are small, aquatic mussels native to streams and rivers in Russia. They were officially discovered in the United States in 1988 in Lake St. Clair, Michigan. It is believed that Zebra Mussels were introduced by transoceanic ships that had mussels either attached to the hulls or living in ballast water. From this entry point, Zebra Mussels have spread throughout numerous waterways in the United States.

Zebra Mussels are adept at establishing themselves in new locations. They tolerate a wide-range of water temperatures and flourish in many freshwater aquatic systems. Zebra Mussels have few predators in their introduced range, can survive in poor water quality, and can survive in the absence of water for several days. One female Zebra Mussel can produce up to a million eggs, which develop and mature in less than a year. The juvenile stage (**veligers)** is mobile and can float to new locations before eventually settling down to attach to hard surfaces like boats, buoys, pipes, and even other mollusks. These characteristics allow Zebra Mussels to be successful invaders.

Zebra Mussels have a profound impact on the ecosystems they invade. Their presence causes native mussel and clam populations to plummet. They can also clog pipes, deteriorate dock pilings, sink buoys, and encrust boat hulls. They disrupt aquatic food webs and can alter the flow of nutrients in an environment. Toxins accumulate in the mussels' tissues, which are then transferred to fish and birds when they are consumed. Zebra Mussels are so destructive that their introduction single handedly prompted a new division of scientific study called invasion ecology.

In this activity, students will learn about the introduction and spread of Zebra Mussels through a research and mapping exercise.

Procedure:

Note: Before beginning the activity, you will need to visit a local body of water that students can study. It can be a river, stream, lake, reservoir, or pond. Be sure that it is easily accessible, and safe (no fast currents or dangerous debris!). State or county parks often have water features that would work well. Students will visit site in Explore section of activity.

Engage

1. Ask students what they know about invasive species. Go over the definition of invasive species. Ask students if they know of any invasive species. If they do, then ask how these species can get into new ecosystems. List student ideas on the board. Separate introduction ideas into those that were intentional and those that were unintentional.
2. If Zebra Mussel wasn't listed in the brainstorm, then ask students if they have heard about Zebra Mussels. What do they know? Show pictures and specimens to students. Ask students if they think Zebra Mussels were intentionally or unintentionally released.
3. As a class, view the animation of the Zebra Mussel spread on the United States Geological Survey (USGS) page on Nonindigenous Aquatic Species (http://nas.er.usgs.gov/queries/SpeciesAnimatedMap.aspx?speciesID=5). Zoom into the Great Lakes region. Start with the map for 1986. Where are the original points? (*Lake Erie*).
4. Slowly click the arrows to show years 1987-1990. Have students describe the trends. (*Zebra Mussels are spreading through the Great Lakes.*)
5. Click on 1991. What do they notice? (*Zebra Mussels have spread outside of the Lakes.*)
6. What important event happened this year in terms of the spread of the mussels into the Mid-Atlantic states?
7. Zoom the map out. Continue animation through 2015. What do they notice?
8. Click on the link for the 'Point Map' and then zoom into your state. Click on a representative point and then click the 'Specimen ID'. Have students pay attention to where the specimen was found and the introduction pathway. Click

on at least 4 other points and then have students summarize how Zebra Mussels are spread. Ask if the introductions were intentional or unintentional.

9. Given what they have learned about the spread of Zebra Mussels, ask students if they think the mussels could spread to a local body of water. Do they think the risk is low or high?
10. Assign students a research assignment to find out additional pathways Zebra Mussels can be introduced and preferred habitat parameters for Zebra Mussels (temperature, salinity, etc). Tell students that this research will be used for their field investigation of a local water body.

Explore

1. As a class, have students list ways that Zebra Mussels can be introduced into waterways. These methods may include:
    a. Juvenile mussels drifting to new location; Flooding of invaded lakes; Ballast water in large ships; Recreational boaters transporting mussels on boat hulls, motors, and trailers and/or in live wells and bilge water; Hulls of canoes and kayaks; Anglers transporting juvenile mussels in bait buckets or on equipment used in infested waters; Dive gear; Aquatic plants with juvenile mussels attached transported by wading birds or on boat motors or trailers
2. After listing introduction methods, discuss habitat needs required by Zebra Mussels. For high school students, challenge them to take this information to create data sheets.
3. Explain to students that they are now going to visit a local body of water to decide if the risk of introduction and spread of Zebra Mussels is low or high based on their research.
4. Before heading outside:
    a. Show students aerial images of site using Google Earth or another mapping program. Encourage students to look for possible entry points including tributaries or adjacent bodies of water.
    b. Review the procedures for doing the water quality tests (if applicable) and any safety protocol they should follow prior to visiting the stream. Depending on your students' level of knowledge, you may also want to review the importance of the different parameters (like pH) for aquatic wildlife and Zebra Mussels.
    c. Provide copies of student-designed data sheet or use the Student Page attached at the end of this lesson. If using the data sheet, then have students fill in their researched water quality parameters. Encourage students to include additional information from their research.
    d. Remind students their ultimate goal is to determine possible risk factors for Zebra Mussel introduction.
5. At the site:

a. Divide students into 4 or 5 groups. Depending on equipment and time, have each group do all the water quality tests so that there are several sets of data for comparison, or have each group focus on one specific test that they can conduct a couple of times in order to average numbers.
b. Give students time to conduct the tests, assess the possibility of introduction, and fill out their data sheet.

Explain

1. In the classroom, create a chart to compile all the data. Average numbers. If there are significant discrepancies, what might have happened?
2. Have each student write a paragraph explaining whether they think the risk of spread is low or high. They must use data and reasoning to justify their position.
3. Have a class discussion – what were the conclusions? Did everyone agree? Did someone point out evidence that the others had not considered? If more resources were available, what additional tests would students like to perform?
4. What are the possible impacts if the mussels were to become established?
5. Zebra Mussels have quickly spread across the United States' waterways. What characteristics of Zebra Mussels have contributed to their rapid spread?
6. What predictions can you reach about the future dispersal of Zebra Mussels in North America?

Evaluate

Evaluate students based on their class participation, both in class and at the site, the accuracy of their data collection, and on the validity of their reasoning and use of evidence in their written paragraph.

Extend

1. Even if they feel that the risk of having Zebra Mussels spread into the body of water they studied is low, have the students design a way to inform people about the impacts of Zebra Mussels and how to prevent their spread. It can be in the form of a poster, brochure, public service announcement, newspaper article, etc. Remind students that even if the risk seems low where they live, Zebra Mussels have spread all the way from the Great Lakes to the West Coast and Gulf Coast.

Student Page: Field Investigation Sheet

Name:_____ Date:_____

Type of Aquatic System (Circle one): Lake Pond Stream River Other:_____
Nearby Water Bodies or sources of Zebra Mussels:

General Description:

Table 1: Water Quality Parameters

	Preferred	Test 1	Test 2
Dissolved Oxygen (mg/L)			
pH			
Salinity (PPT)			
Temperature (^{0}C)			
Velocity (m/s)			

Hard Substrates or Possible Attachment Sites:

Boats or other Watercrafts used in area (Circle one)? Yes No

Wildlife Observed:

Other Possible Risk Factors:

Photo by: Amy Benson, USGS