Invasive Crayfish Collaborative
Great Lakes

Lesson 6

Competing Crayfish Game

Subjects Science, Math, Language Arts, P.E.

Grade Levels Ideal for grades 6–12, adaptable for 2–5

Time 45–60 minutes or more

Lesson Overview

In this lesson, students model impacts of invasive species by playing an engaging game designed to help them think critically about native and invasive species and their roles in freshwater ecosystems. Through kinesthetic learning, students experience how aggressive exotic species can over consume a wide range of resources to expand their territory and compete in a non-native habitat. In a race for survival, each team represents a different species found near you. Team members take turns in the "lake" (game area) to gather food resources in hopes that their species will survive, while struggling against competition from other species and environmental stressors. Multiple rounds are played and graphed to illustrate fluctuations in species strength due to stress factors. The game can be played with groups as small as eight students, or as many as 60.

Different "species" compete for resources
Photo: National Park Service

Goals

- Increase students' understanding of native and invasive crayfish and their roles in freshwater ecosystems
- Get students to think critically about how invasive crayfish and other invasive species can be a threat to a variety of native species as well as biodiversity
- Increase student skills with analyzing and visualizing data they have collected

Objectives

- Students will participate in an educational simulation and demonstrate their understanding of the roles of invasive crayfish species in freshwater ecosystems.
- Students will analyze data collected as a class and create visualizations with it.
- Students will express orally and/or in writing what they have learned about native and invasive crayfish and their impacts on freshwater ecosystems.

Next Generation Science Standards

Performance Expectations

- 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.

Building toward

- HS-LS2-1: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
- HS-LS2-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- HS-LS2-6: Evaluate 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.

Crosscutting Concepts

- Patterns
- Cause and Effect
- Stability and Change
- Systems and System Models

Science & Engineering Practices

- Analyzing and Interpreting Data
- Constructing Explanations and Designing Solutions
- Developing and Using Models
- Obtaining, Evaluating, and Communicating Information

Core and Component Ideas in the Life Sciences

LS2: Ecosystems: Interactions, Energy, and Dynamics

- LS2.A: Interdependent Relationships in Ecosystems
- LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Core and Component Ideas in Earth and Space Sciences

ESS2: Earth's Systems

- ESS3.C: Human Impacts on Earth Systems

Common Core State Standards

Math Standards

Measurement & Data. Represent and interpret data

Statistics & Probability. Summarize and describe distributions

Speaking and Listening Standards for Grade 6

(similar standards for grades 4–5; 7–12)

Standard 1. Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

Standard 4. Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

Center for Great Lakes Literacy Principles

Principle 5. The Great Lakes support a broad diversity of life and ecosystems.

Teacher Background

Invasive Species

The US Department of Agriculture recognizes different types of non-native species classifications. While the classification of each species varies between states, all can be categorized into two groups:

- **Naturalized–**A non-native species that is controlled by certain factors in the environment (predators, climate, reproductive patterns, etc.)
- **Invasive–**An invasive species is defined as any non-native organism that causes harm to the environment, economy, or human health. It can take over the habitat of native species, forcing the native species to decline in population or to disappear from their natural environment. Invasive species tend to be highly competitive, highly adaptive, and successful at reproducing (Washington Invasive Species Education: wise.wa.gov).
  - Invasive species can negatively impact an environment in many ways. The most common is increased competition for a particular food source. This may only impact a few species or it can impact the entire food web. Invasive species also compete for water resources (especially important in desert and some freshwater habitats) or for space within the habitat (available sunlight for plants, space for burrows, etc.). All invasive species have adaptations that help them survive the environment more effectively than native species.
  - In addition to environmental impacts, invasive species also cause economic damage by clogging waterways, damaging infrastructure, and threatening fisheries that many people depend on as a source of livelihood. In the Great Lakes, these damages cost over $100 million dollars each year to fix ("Detecting and Monitoring Aquatic Invasive Species.")

Many invasive species can be found in the Great Lakes region and beyond.

- A number of invasive crayfish species outcompete natives for food and space, such as:
  - Red swamp crayfish (*Procambarus clarkii)*
  - Rusty crayfish *(Faxonius rusticus)*
  - Allegheny crayfish (*Faxonius obscurus)*

An invasive rusty crayfish, *Faxonius rusticus**; Photo: Lake County AIS CC0***

A few crayfish species are invading freshwater ecosystems around the world at an alarming rate. This negatively impacts countless species, including many native crayfish species, which have become one of the most threatened groups of organisms in the world. In fact, an estimated "48 percent of North American crayfish species are at risk of extinction" (Larson & Olden 2010: jstor.org/stable/40864210) Invasive crayfish are believed to be the leading cause of this decline, and humans have played a significant role in their spread, through release of classroom science organisms, live fishing bait, etc.

- Sea lamprey (*Petromyzon marinus*)–native to the Atlantic Ocean basin; responsible for declines in some fish populations
- Round goby (*Neogobius melanostomus*)–native to Eurasia; released into the lakes by ocean ships discharging their ballast waters
- Zebra mussel (*Dreissena polymorpha*)–native to Eastern Europe; negatively impacts some native species of invertebrates and fish
- Common reed (*Phragmites australis autralis*)–native to Europe; similar to a native reed species, but this non-native species crowds out other native plants

Native (Indigenous) Crayfish

Northern clearwater crayfish *(Faxonius propinquus)* are one of the most common native crayfish species in the Great Lakes region.

Additional information and visuals about invasive and native crayfish are found in this educator's guide and in the "Expand Knowledge + Skills" section listed at the end of the lesson.

Other concepts that can be incorporated into the game:

- **Adaptation**

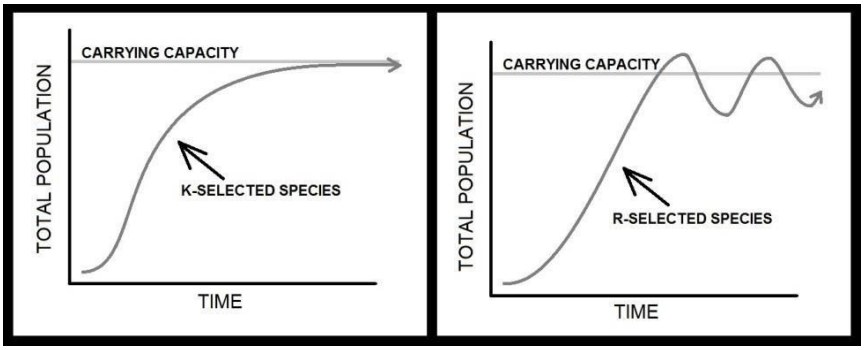
  This is an evolutionary advantage of a particular species. Adaptations allow individuals to thrive in their environment and alter their physiology or behaviors to survive certain changes to that environment. There are numerous examples of adaptations in all organisms including fungi, protists, bacteria, and archaebacteria.

- **Carrying capacity**

  The carrying capacity of an environment is the maximum number of organisms a habitat can support without collapsing. Typically, carrying capacity is expressed as a logarithmic function. There are two major carrying capacity patterns, each of which begins with a sharp population increase due to a high level of available resources (food, shelter, water) and limited disease. These two major patterns continue as follows:

  - **K-selected species**

    An initial population increase slows as resources become limited. As the rate of population growth approaches zero, the population reaches a stable number with a death-to-birth ratio of 1:1.



- **R-selected species**

  An initial population increase does not slow as resources become limited. The population eventually exhausts its resources. The death rate increases dramatically and the population total drops sharply. As resources renew, the population increases again. This pattern continues in a boom/bust cycle.

- **Endemic species**

  An endemic species or taxonomic group is unique to a particular area. Its geographic region is restricted because of factors such as isolation or response to soil or climatic conditions. Some are only found in one small area, such as the dwarf lake iris *(Iris lacustris)*, which grows along the northern shores of Lakes Huron and Michigan. These species are often protected because they have the highest risk of extinction due to habitat loss, competition from invasive species, etc.

- **Extirpated/Locally Extinct**

  The population of a species may become extinct in an area, but other populations survive elsewhere. The species is considered locally extinct or "extirpated." One of the most infamous examples of extirpation is the beaver. During the fur trade, beaver pelts were highly prized. Trappers nearly hunted the beavers to extinction in both Europe and North America, but small pockets of beavers remained. Today, beaver populations have recovered and have re-colonized most of their former extent.

- **Indigenous species**

  An indigenous species occurs naturally in an area; it is a synonym for native species. Many schools have a high population of Native Americans/American Indians so you may choose to use "indigenous" in place of "native" species for culturally sensitive reasons or to highlight a personally relevant link between indigenous peoples and indigenous species.

- **Kleptoparasitism**

  When animals steal food from other animals it is called kleptoparasitism: it is not a common trait in species suggested for this game, but is for species such as gulls, eagles, foxes, and coyotes.

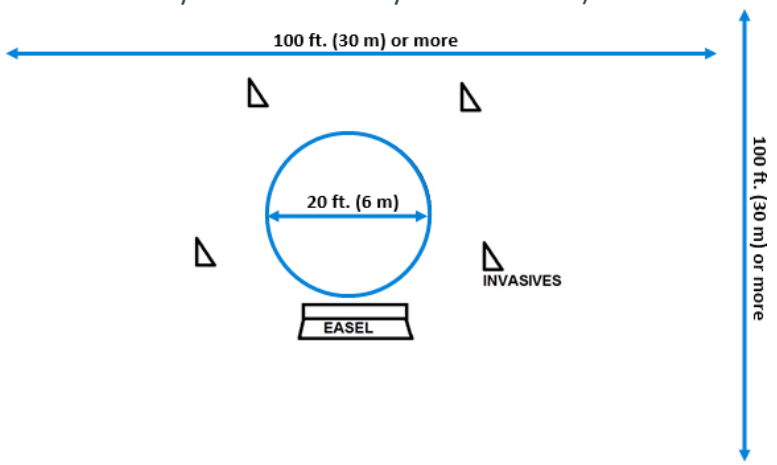
Materials

- One-gallon bag of three different dried beans; we suggest pinto bean, red kidney bean, and lima beans
- 60-foot (or longer) section of rope

- Four signs that stand up on poles or easels (signs you can lie on the ground would also work) showing different species: a native crayfish, two other native species, such as northern leopard frog and cutthroat trout, and one invasive crayfish species
- Blue, brown, red, and purple washable markers
- Masking tape
- Four clear containers (plastic or strong glass jars, for collecting beans)
- Easel
- Print graph paper sheets found online at print-graph-paper.com/paper-size/11x17
    - Print out graph on 11” x 17” paper
    - Can use one sheet or two sheets taped together
- Timer (cell phones work well, as do egg timers)
- *Optional:* Colored pencils, markers and/or crayons for students to share

Preparation

1. Prepare a large play area with at least 400 square feet (37 sq. m) of packed dirt (ideally free of weeds): school playground, baseball diamond, etc.; very thin grass will also work. The ground needs to camouflage dried beans, but not completely hide them. Set out the rope on the ground and form into a 20-foot (6 m) diameter circle (or larger) across the play area.
2. Allow for plenty of space outside the main play area circle, too, for a total diameter of 100 feet or more (40 feet beyond each side of the circle). This provides enough space around the circle so that, later in the game, groups lined up can get pushed away from the circle in 5-foot increments. This simulates increasing stress as it becomes more challenging to find food.
3. Set up the easel and tape a graph to the front (or draw one).
4. Take the one-gallon bag of bean mixture and evenly distribute beans inside the rope circle.
5. Set out “sign-a-cades”—signs held up vertically—as shown below as triangles, one for each of the four species in the game. (See the signs at the end of the lesson.) Signs should be about 5 feet (1.5 m) from the rope circle. (Simple signs with weights such as rocks so they don’t blow away will also work).



6. *Optional:* Learn more about native and invasive crayfish and/or review the information presented in the sources listed in the More Resources/References section at end of the lesson to prepare to answer student questions.

Teaching Suggestions in the 5E Model

Engage

1. Gather students outside of the game area. Tell them they will be playing the Competing Crayfish Game in teams representing different species. They can be the species below, listed with the type of bean(s) they can eat, or other species that you choose:
    - Lake sturgeon (native–red kidney beans)
    - Northern leopard frog (native–pinto beans)
    - Devil crayfish (native–all 3 types of beans: lima, pinto, and red)

      Note: Studies found that rusty crayfish actually consume lake sturgeon eggs in spawning areas, so this could be a good story to tie to the activity at this point, if time allows, or during the Explain portion of the lesson, below: habitat.fisheries.org/nowhere-to-hide-an-invasive-crayfish-species-poses-a-threat-to-lake-sturgeon-in-critical-spawning-habitats.
    - An invasive crayfish species that is a problem in your area: red swamp crayfish, rusty crayfish, etc. (all three types of beans: lima, pinto, and red)
2. Discuss which species are **native** to your area and which are **invasive**. Ask the students what those terms mean. Explain that the goal of the game is to survive: not only as an individual, but also as a species/team.

Explore

3. Divide students into four groups (or ask them to quickly count off "1-2-3-4" to divide them). Assign each group to a different species.
4. Ask each group to stand in a straight line behind the sign for their species.
5. Show the student teams which of the three beans their team will "eat." **Tell them they can only pick up that bean type. Other beans will not be counted**.
6. Play the first round of the game with the three native species after briefly explaining the rules below (the invasive species join in round 2):
    - When you say "SPRING—GO!", the first student from each native species enters the circle to forage for food and picks up ONLY five beans (of the type they eat). Note: Limiting students to five beans each turn allows more of them to participate per round and keeps the energy high.
    - The first student runs back to their team and drops the five beans in the team cup.
    - The second student in line then enters the circle to forage and so on. The species should make as many trips as they can until you call "WINTER—STOP!" At that point, students must stand up immediately and move out of the circle. Any beans they have in their hand can be taken back to their cup.

- Students will count how many beans their species collected and tell you so the data can be recorded (and later graphed).

7. **SAFETY: Tell students that they are not to push or shove each other**, since this will draw attention from "fishermen." Anyone seen doing so will be "caught" and removed from the game.
8. **Round 2**
    - Tell students that the invasive species will now join the game. The red swamp crayfish (or whatever species you choose) are aggressive, voracious eaters that can each pick up eight beans per player (instead of five). Like the native crayfish species, they are also not picky eaters, so they can eat all three types of beans.
    - Record the number of beans collected by each species in a chart that the students can see, similar to the one below. Later the students can record their crayfish data in science notebooks, in a shared spreadsheet, etc.

Species	Round 1	2	3	4	5	6	7
Species 1 (such as lake sturgeon)							
Species 2 (such as northern leopard frog)							
Native crayfish (such as devil or northern clearwater)							
Invasive crayfish (rusty, red swamp, etc.)							

9. **Additional rounds**
    - After the third round, compare the numbers on the chart. Ask students, "What **patterns** do you notice so far?"
    - If any species fails to collect beans during a round, their species becomes **extirpated** (locally extinct). You may choose to add their numbers to the invasive species as their bodies are recycled into the environment to become new pike fry.
    - Consider adding new rules, one at a time, to simulate different natural phenomena. Discuss with students how they relate to real-world issues faced by animals in the wild.
    - After the last round, work with students to pick up all the beans. Discuss how they are introduced species that we don't want to become established.

Game variations include:

- **"Habitat Loss"**
    - Move the signs back 3–5 feet (1–2 meters) for each species that does not meet or exceed the bean count from the previous round. *(Don't tell the students this is your reason; give the reason below.)*
        - Simulates reduced ability to access foraging grounds and stress on species
        - May also be due to factors such as drought, seasonal lake draining, log jams, etc.
- **Climate Change**
    - Researchers have found that warmer water and air temperatures are allowing red swamp crayfish to produce two broods of eggs per female per season, instead of one for native crayfish.
    - After the round starts, allow another player from the team to join the game, and potentially a third and fourth toward the end of the round, to simulate the exponential growth rate that this advantage might give to the invasive crayfish.
- **"Stress Death"**
    - Remove an individual from each species that does not meet or exceed the bean count from the previous round *(you may or may not choose to point this reason out to students.)*
        - Simulates loss of individuals from a population due to starvation
        - Choose well-behaved individuals or a student who can perform a dramatic death scene
- **"Kleptoparasitism"**
    - The invasive species can take the beans of another species. They must tag the species (GENTLY) and the tagged student must then hand over their beans; after that, they continue collecting their beans.
    - This may be done freely or only once per round, depending on the students.
    - This simulates the phenomena of **kleptoparasitism**: when animals steal food from other animals. It is not a common trait in the species used for this game, but is seen in species such as gulls, eagles, foxes, and coyotes.
    - Remind students that if they act roughly or throw beans, they will be "caught" and removed.
- **Predation on Natives and/or Cannibalism**
    - Be very careful/selective when using this variation.
    - Invasive species can eat one of the natives. They must tag the species (GENTLY) and the tagged student must join the invasive team.
    - No more than one player per round per person can be removed. Consider limiting total predation to 1–2 students per round.

- Remind students that anyone acting roughly or throwing beans will be "caught" and removed.

- **Population Boom**
  - Multiple members of the invasive species may enter the circle at the same time.
  - Explain that this simulates a boom in the population of the invasive species.

- **Invasive Species Cook-Off**
  - Help restore balance to the game by assigning a student to be a fisherman who "traps" invasive crayfish.
  - If an invasive crayfish player is tagged, they must leave the game. Another player from the invasive team can then join the game, but there is no limit to the number of invasive crayfish that can be tagged per round.
  - *Additional rule option for the same round or the next one:* If a player from the native crayfish team is tagged, they must freeze in place. Another player from their team can enter the game and tag the frozen player to release them (to simulate releasing live native crayfish).

10. *For students that have experience with visual data analysis:* Ask students to work with their team (or just a partner) to visually present the data you collected as a class. Or guide them by asking them to think about how the data can be analyzed and how it can be presented visually. Discuss how it can be used to calculate averages, present histograms (bar charts), etc., and have students do the calculations and create the visualizations you discuss.

Explain

11. *For students that have little to no experience with visual data analysis:* Work with students to create bar charts (histograms) to analyze the data. Discuss how this helps visualize any **patterns** that occur.

12. Review the concept of **adaptation**: developing a trait that helps a plant or animal survive in its environment. What behavioral and/or physical adaptations might crayfish—especially invasive crayfish—have that help them?

13. Review the ecological term **competition**: when different species need the same resource, but there are limited amounts of it (MS-LS2-1). Discuss with students how competition from invasive crayfish impacted the native species—and how they compete in the wild.

14. Review the data analysis with the class and close with a discussion about native and invasive crayfish and how they can impact freshwater ecosystems.

Enrich/Extend

- Play the game on another day with more of the in-game variations listed above. Ask students to record and analyze the data with less support from you. Additional variations you might try include:

"Limited Carrying Capacity"

- Throw out fewer beans during setup OR don't throw back beans that were used in previous rounds
- Increases competition and highlights limited resources caused by climate change, natural disasters, and/or human impact
- This variation is strongly suggested for middle grade students; it helps meet NGSS DCI MS-LS2-4 ("Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.") Students should construct the argument orally and/or in writing.

"Real World Conditions"

- Allow ALL students to enter the foraging area during each round. This may be used in combination with any other variables listed above.
- To slow them down, introduce the rule that fish, frogs, and crayfish don't run. To be fish or frogs, they need to keep their feet together and wiggle-hop/swim. Length of time per round can be extended to 30 seconds.
- For larger groups or older students, a longer rope (such as 100-feet) could be used to expand the circle.
- You may need larger buckets for teams to collect their beans.

- Ask students to create a written analysis of the game and what it taught them about invasive crayfish species.
- Students can complete the "Invasive Species Project" explained on the handout in this educator's guide.
- Have students read cartoons about invasive crayfish and/or create their own cartoons. Excellent examples and ideas are listed in the "Stone Soup: Invasive Species and Cartooning" lesson plan found on the Take AIM website: takeaim.org/wp-content/uploads/2016/11/StoneSoupTeachersLP.pdf
- Encourage students to "Design the Ultimate Invader" as explained in this lesson plan from Oregon Sea Grant's "Menace of the West" website: seagrant.oregonstate.edu/sites/seagrant.oregonstate.edu/files/design-ultimate-invader-lessonplan.pdf
- Show one or more short video clip(s) about crayfish, such as:
  - "Invasive crayfish threaten species in Oregon's Crater Lake." Oregon Public Broadcasting (OPB): pbs.org/video/invasive-crayfish-threaten-species-in-oregon-s-crater-lake-1458950673
  - "Crayfish Invasion." The first part of this Oregon Field Guide episode from OPB: watch.opb.org/video/oregon-field-guide-season-22-episode-10
- Invite students to create public service announcement videos about invasive crayfish and ways to keep them from spreading.

Evaluate

- Review student tables of data, as well as data visualizations and/or written analyses.
- Record levels of oral participation and student understanding.
- Ask students to reflect on the lesson in writing and/or orally, including about what they learned and what you, as the teacher, might do to improve the lesson next time.

Expand Knowledge + Skills

- "Invasive Crayfish 101." Invasive Crayfish Collaborative: invasivecrayfish.org/invasive-crayfish-101
- "Great Lakes Crayfish Regulation." Invasive Crayfish Collaborative: invasivecrayfish.org/publications/
- Michigan Invasive Species: Crayfish: michigan.gov/invasives/id-report/crustaceans
- Callaway, E. "Geneticists Unravel Secrets of Super-Invasive Crayfish." Scientific American. scientificamerican.com/article/geneticists-unravel-secrets-of-super-invasive-crayfish/
- "Detecting and Monitoring Aquatic Invasive Species." EPA: epa.gov/water-research/detecting-and-monitoring-aquatic-invasive-species
- "How You Can Help." Stop Aquatic Hitchhikers!: stopaquatichitchhikers.org/prevention/
- USDA Invasive Species resources: invasivespeciesinfo.gov/us

Lessons/Activities

- "Land of Many Opportunists." Activity adapted for this lesson by permission. National Park Service: nps.gov/laro/learn/education/opportunists.htm
- "Stone Soup: Invasive Species and Cartooning." Jan Eliot: takeaim.org/wp-content/uploads/2016/11/StoneSoupTeachersLP.pdf

Education Standards

- More information about the Next Generation Science Standards, to which this lesson was aligned: nextgenscience.org
- More information about the Common Core State Standards and links to the complete documents: thecorestandards.org

Lake Sturgeon

Acipenser fulvescens

Photo: NYS Department of Environmental Conservation CC BY-NC-ND 2.0

Native

Kidney Beans

Northern Leopard Frog

Lithobates pipiens

Photo: Mykola Swarnyk CC BY-SA 3.0

Native

Pinto Beans

Devil Crayfish

Lacunicambarus diogenes

Photo: Chris Lukhaup

Native

All Beans

Red Swamp Crayfish

Procambarus clarkii

Photo: Luc Hoogenstein CC BY-SA 4.0

Invasive

All Beans