# Investigating Crayfish + Freshwater Ecosystems

## *Great Lakes Region*

## Teacher's Guide

## *Hands-On Science Lessons Adaptable for Grades 2–12*

Aligned to NGSS + CCSS + CGLL

Invasive Crayfish Collaborative
Great Lakes

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*Photo: Chris Lukhaup*

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Adaptable for Grades 2–12

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Published by Invasive Crayfish Collaborative
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Great Lakes

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Cover: A group collects crayfish with a seine net.
*Image: Illinois-Indiana Sea Grant*



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# About This Guide

+ Invasive Crayfish Collaborative

This teacher's guide contains lesson plans designed to help educators engage students in thinking critically about crayfish and their freshwater ecosystems. Lessons are aligned to the Next Generation Science Standards, Common Core State Standards, and Center for Great Lakes Literacy Principles. They contain numerous adaptations/extensions to meet the divergent needs of students in grades 2–12.

**A common goldeneye gulps down a northern (virile) crayfish.**
*Photo: Tom Koerner/USFWS CC 0*

The curriculum will help prepare you and your students to participate in the Invasive Crayfish Collaborative's crayfish study,* an effort to collect data about the native and invasive crayfish found in the Great Lakes region. The data students collect is shared through iNaturalist and ArcGIS Online, enabling them to compare what they discover with data from other student groups, as well as professional scientists. Just as importantly, it provides critical information for researchers and wildlife managers seeking to better understand and manage crayfish populations.

**A scientific collection permit is required for the crayfish study, and approval may take up to 4 months. Plan early to avoid delays.*

## Problems of Invasive Crayfish

Invasive crayfish pose a substantial threat to aquatic habitats in the Great Lakes region because of their ability to reduce habitat quality and dramatically alter aquatic food webs. Efforts to prevent the introduction and spread of invasive crayfish consist largely of reducing the size of existing populations and encouraging people to refrain from releasing crayfish into new bodies of water.

## Invasive Crayfish Collaborative

The Invasive Crayfish Collaborative (ICC) brings industry, science, and land management stakeholders together to improve management of invasive crayfish in the Great Lakes region. The ICC focuses on improving upon our collective management and outreach capabilities. Illinois-Indiana Sea Grant and the Illinois Natural History Survey oversee and facilitate ICC, with funding from the Great Lakes Restoration Initiative.

Invasive Crayfish Collaborative
Great Lakes

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ILLINOIS

Sea Grant ILLINOIS–INDIANA

ILLINOIS Illinois Natural History Survey PRAIRIE RESEARCH INSTITUTE

TRM The River Mile

Learn more about crayfish throughout this Teacher's Guide, in the resources listed at the end of each lesson plan, and at invasivecrayfish.org.

# Contents

Lesson 1

# Crayfish + Freshwater Ecosystems

**Subjects** Science, Language Arts, Art

**Grade Levels** Ideal for grades 2–8, adaptable for 9–12

**Time** 75 minutes or more

## Lesson Overview

This lesson is designed to be highly adaptable, but options include a brief "crayfish trivia" activity to assess students' current understanding of crayfish and their freshwater ecosystems, followed by a quick brainstorming session in pairs about what students already know, then a short multimedia presentation. Next, students can act out a simple food chain of different organisms that feed on each other in freshwater ecosystems. They may conduct a short research project about a freshwater organism and create a more complex model of freshwater food webs with the whole class, which demonstrates the resilience that comes with biodiversity.

**A northern (virile) crayfish *(Faxonius virilis)* in its freshwater ecosystem**
*Photo: Missouri Dept. of Conservation*

The lesson closes with a short discussion of the many interdependent relationships in the ecosystem that allow species, including crayfish, to survive. Their important roles in freshwater ecosystems are highlighted.

See the "Enrich/Extend" section at the end of the lesson for more ways to engage all learners, including field experiences.

## Goals

- Students will understand that crayfish and a multitude of organisms in freshwater ecosystems are woven together in an interconnected web of life known as a food web. They will understand that this interdependence among species, supported by nonliving things such as water, air, rocks, and soil, enables animals and plants to survive and live in balance with each other for the ecosystem's long-term health.
- Students will think critically about the particular roles of crayfish in freshwater ecosystems, and how they can help keep the ecosystem healthy.

## Objectives

- Students will create a visual representation of the concepts of a food chain and food web and how organisms are linked to one another by the transfer of matter and energy in an ecosystem.
- Students will research an organism from the freshwater ecosystem and write about its interactions with other organisms in it.
- Students will show visually and explain verbally how energy from the sun and photosynthesis forms the foundation of freshwater ecosystems.
- As a class, students will simulate a freshwater web of life, including the interactions in the ecosystem and the factors which create healthy ecosystems, including biodiversity.

## Next Generation Science Standards

### Performance Expectations

- MS-LS2-3: Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.
- 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.

#### Building toward

- MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- MS-LS1-6: Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.
- HS-LS2-3: Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
- HS-LS2-4: Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
- HS-LS2-5: Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
- 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.
- HS-LS1-5: Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

### Crosscutting Concepts

- Energy and Matter
- Systems and System Models
- Stability and Change

### Science & Engineering Practices

- Developing and Using Models
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

### Core and Component Ideas in the Life Sciences

#### LS1: From Molecules to Organisms: Structures and processes

- LS1.B: Growth and Development of Organisms

#### 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

- ESS2.C: The Roles of Water in Earth's Surface Processes

## Common Core State Standards

### Speaking and Listening Standards for Grade 6

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

**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.

**Standard 6.** Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

### College and Career Readiness Anchor Standards for Writing

**Standard 6.** Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

**Standard 7.** Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

## Center for Great Lakes Literacy Principles

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

## Teacher Background

### Crayfish

Crayfish are **crustaceans** that are closely related to lobsters, their saltwater cousins, and they play an important role in freshwater ecosystems, such as rivers and lakes. They are an important food source for many species of fish, birds, amphibians, reptiles, and mammals, even those that spend much of their time on land, such as raccoons.

Crayfish are opportunistic **omnivores** that eat both dead and living plants and animals, including insects, snails, and fish on river and lake bottoms. Their role in reducing decaying matter and filtering the water is especially important for improving water quality. In addition, their habit of burrowing provides benefits for water quality, although burrowing near the water's edge can sometimes contribute to erosion (Helfrich, Parkhurst, and Nevis 2001). Predators as well as scavengers, crayfish—especially **invasive**, non-native species, can sometimes negatively impact ecosystems in other ways. We will explore the positive and negative roles more fully in later lessons.

There are 620 species of crayfish (also called crawfish, crawdads, or mudbugs) worldwide, and 39 of these species are native to the Midwest United States (Taylor et al., 2015). Crayfish are a diverse group of decapod (10-legged) crustaceans related to shrimp, crabs, and lobsters. Crayfish breathe primarily through gills but can breathe air when necessary, as long as their gills are wet or humidity is very high. They live semi-aquatic lifestyles in lakes, streams, ponds, flooded fields, or ditches. Some species spend most of their lives in underground burrows, while others burrow only if necessary, such as during droughts. Midwestern crayfish species live on average three years but have been known to live up to six years.

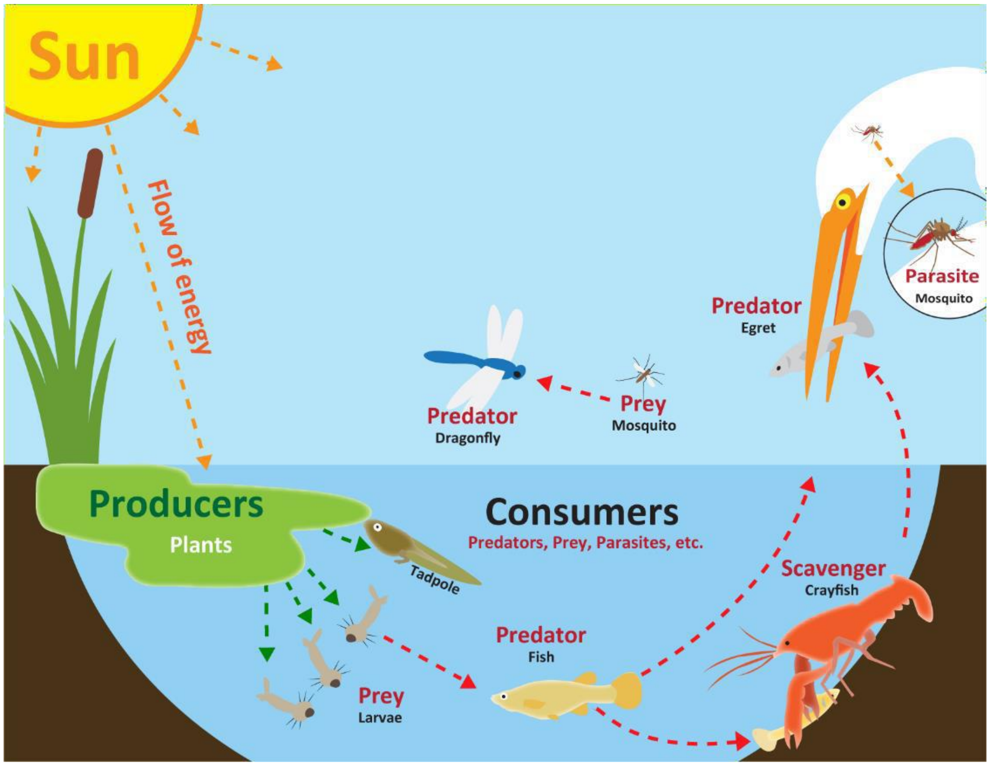
The vast majority of the world's crayfish species are found in North America, especially the southeastern United States. They can be found on every continent except Antarctica. Many species are at risk of extinction due to a variety of factors, such as habitat loss, pollution, and the spread of invasive crayfish species and disease (Larson et al. 2020).

*Photo: Jeff Benca; used by permission*

### Ecological Concepts

An **ecosystem** is any group of living and nonliving things that interact with one another. Some are relatively small like streams and ponds where crayfish often thrive, and others are large **biomes** like wetlands or forests.

**Biodiversity** is a measure of the number of different species in a specific area, and it is also used as a general description of species richness, ecosystem complexity, and genetic variation. In general, the more biodiversity, the more stable the environment and the less it is impacted by changes. The organisms that interact with each other in their ecosystems are called a **community** (or **ecological community** for high school students).




**Visual model of a freshwater ecosystem showing flows of energy**
*Graphic by Eric Engh and Rick Reynolds; used by permission*

Some members of a community, such as crayfish, are particularly important to the community's vitality. For example, crayfish recycle nutrients through the consumption of decomposing organisms. This helps clean the water. They are also an important food source for many predators such as fish, birds, reptiles, and amphibians. Because of all these important roles, crayfish can be considered a **keystone species** for their ecosystem; just like the keystone at the top of an architectural arch that helps hold the whole structure together, a keystone species is vital to the stability of an ecosystem. If it is in trouble, the whole ecosystem can be negatively impacted.

Creating ecosystem **food webs** helps students understand the basic ecological principle that everything in nature is connected. By analyzing the relationships between the various living and nonliving things, students will increase their understanding of community ecology and the underlying relationships that bind living things together.

## Materials

- "Crayfish Trivia" handout (one for each student, found at the end of the lesson)
- "Crayfish and Freshwater Ecosystems" PowerPoint presentation available on the Invasive Crayfish Collaborative website: invasivecrayfish.org/products
- Computer access and Microsoft PowerPoint software
- Display screen
- Markers, crayons, or colored pencils for students to share
- Ball of yarn
- Class whiteboard, chalkboard, or interactive whiteboard

- *Optional:*
    - Copies of the "Organism Presentation Rubric" found at the end of the lesson
    - "Curious Crayfish + Freshwater Ecosystems" activity, which follows the lesson
    - Large pieces of paper or poster board (one per student or one per group), if available, for the activity listed at the end of the Enrich/Extend section

## Preparation

1. Ensure all materials above are ready for student use.
2. In addition to helping students understand crayfish and freshwater ecosystems, this lesson is designed to help you teach and reinforce a variety of concepts and skills, and it is adaptable for a wide range of grades and connections across the curriculum. For example, several different kinds of models are suggested, including diagrams and kinesthetic models to help students understand the content presented, while simultaneously helping them to understand how to use models themselves to find deeper meaning in the science and better convey information to others.

   Your focus could be on crayfish and their roles in freshwater ecosystems, or you might choose to focus on the importance of biodiversity, or a concept such as adaptation. Keep in mind that Lesson 3 of the curriculum focuses on fascinating crayfish adaptations, including their structures and functions, as well as their behaviors that help them to survive.
3. *Optional:*
    - Review more information about crayfish and freshwater ecosystems to prepare to answer student questions. Good sources include those listed at the end of the lesson in the Expand Knowledge + Skills section.
    - Identify an expert partner to work with your class. Contact [invasivecrayfish.org/contact-us](invasivecrayfish.org/contact-us) for possible recommendations.

## Teaching Suggestions in the 5E Model

### *Engage*

1. Introduce the expert visitor if one is present and tell students they will be starting an exciting new unit about crayfish and their habitats (where they live).
2. *Optional:* Explain to students they will first find out what they already know. Pass out the "Crayfish Trivia" handout to each student and allow 10–15 minutes for them to complete it. Tell the students they are not expected to know the answers, so they should just do the best they can. This activity serves many purposes, including evaluating current student knowledge, helping students focus on topics to be discussed, and evaluating change in understanding over time. Collect the handouts. This activity could also be done later as a review game or assessment.
3. Ask students to turn to a neighbor and brainstorm everything they can think of about crayfish, where they live, what they eat and what eats them, etc. They should record all their ideas on a piece of paper, without worrying about if they are right or wrong. Circulate around the room, answering questions, if necessary. After about five minutes, ask for a few to share their best ideas. Then explain to students that this lesson will be

all about the fascinating places where crayfish most often live, called freshwater ecosystems.

4. Open the "Crayfish and their Ecosystems" PowerPoint presentation and you and/or the visitor can lead a brief interactive discussion about crayfish and their ecosystems, drawing on the student ideas shared earlier and the information in the slide notes to talk about the important roles crayfish play, and how they get what they need from their environment, including food, water, shelter, space, and oxygen. If available, you can show the students live crayfish and/or any other organisms from freshwater ecosystems that interact with them, such as a variety of plants, fish, turtles, or frogs/tadpoles.

### *Explore*

5. Ask the class to arrange their desks in groups of four, if necessary, and pass out blank paper (one sheet per student) and coloring supplies. Ask the students to each share the name of one of their favorite species from freshwater ecosystems with each other and demonstrate how they can write its name in large letters in the top third of a blank piece of paper using a pencil. Then they can make the names dark enough to read from across the room with a marker or other coloring supplies. This can be an animal or plant that they have learned about in the presentation or seen in nature. Each student should choose a different organism, and one or more students in each group should choose a plant, because plants are so important for almost every ecosystem.
   *Note:* To help students understand what to do, you can show them the "Rainbow Trout" example that follows the lesson, create your own example, and/or show student samples. For more advanced students, it may be valuable to have them write the common *and* scientific names of the organism they choose. This will teach them the importance of understanding scientific names, as they provide a universal code for identifying species.

6. Ask the students to create a basic illustration of their organism below the organism's name on the paper. They can use available reference sources such as books and the Internet for reference and/or live specimens if you are lucky enough to have some. Tell students they will only have about five minutes (or however much time you want to allow) to create their illustrations, but that they will be able to add more details and color later if they wish.
   Depending on where you live you might suggest:
   - Animals and plants presented in the PowerPoint presentation, including those shown in the food web diagrams
   - Options of freshwater plants such as those presented in the PowerPoint presentation

7. Next, have students conduct research about the organisms using the available reference sources to prepare a short (perhaps one minute) oral presentation or short nonfiction piece (perhaps 2–3 paragraphs) about:
   - Where the animal or plant lives (its habitat).
   - What it eats and/or what eats it.
   - Other ways in which it interacts with living and nonliving things in the ecosystem (i.e. getting energy from the sun, nutrients from decaying plants and animals, etc.)

- *Note:* These details could be written below the illustration and/or on the back of the sheet. They could also be used as a sample English Language Arts assignment or performance assessment. Pass out the “Organism Presentation Rubric” at the end of the lesson so students know how they will be assessed.

## *Explain*

8. While the students finish their illustrations and/or short research projects, ask the groups to choose 2–3 species and choose volunteers to represent the group to act out a simple **food chain** for the rest of the class. Write the term on the board and ask one of the student groups to send a representative to the front of the room (or the center of the circle if you’d like to ask the groups to arrange themselves in one) to play the role of an animal at the top of the food chain, a large predatory one that eats other animals. Ask the student to try to make themselves look and/or act like the animal they are playing.

9. Ask another group to send a representative to play a different animal that eats other animals, but that might be eaten by the first animal. Ask the second student to act out their animal, while the first gets ready to try to eat it. Ask the class if they know a word used for animals that eat other animals and a word for the animals that get eaten. Write or type the words **predator** and **prey** on the board. Then ask the groups to identify another animal that might get preyed upon and what predator might eat it; have a student representative come to the front of the room (or center of the circle) and ask one of its predators to move near its prey, as well. Ask if students know the name for a meat eater—**carnivore**—and a plant eater—**herbivore**—and write those words on the board below “predator” and “prey.” Then ask if they know the name for an animal that eats many types of food. Discuss the term **omnivore** and write that on the board, too.

10. Ask the class what important parts of the freshwater ecosystem food chain are missing. Where do the prey species get their energy from? Instead of calling on a student raising her/his hand, tell the class that at the count of three, all of them should shout out the organisms (living things) they think are most important for the ecosystem. Count 1-2-3, and hopefully many of them will shout PLANTS!—or something else important, like algae (a type of plant) or insects.

11. Ask for volunteers from the groups to play the role of freshwater plants—the **producers**—and invite those students to join the food chain simulation while you write the word producers on the board, as well. Ask the class to again shout out—at the count of three—where the plants get their energy from, and hopefully many of them will shout THE SUN! or PHOTOSYNTHESIS! Write the words **Sun** (perhaps within a quick doodle depicting it as a large circle with rays coming out of it) and **photosynthesis** (perhaps within a quick doodle of a leaf) on the board. Ask the students playing plants to act like they are soaking up the sun’s energy so they can convert it into food—sugar, starch, and other nutrients—that supports the whole ecosystem.

12. Ask students if they know the prefix of the word photosynthesis, and what the prefix means. Write **photo-** when someone says it and ensure students understand that it means “light.” Then ask what the main part of the word—synthesis—means. Some students may already know that it means “combining.” Then ask: How and what do plants combine to make energy? Review with students that plants use **chlorophyll** (write the word on the board)—what makes them green—to combine sunlight with

water and carbon dioxide ($CO_2$) gas found in the air to complete the amazing process. Ask the students to say at the count of three what gas the plants give off, which animals need to live, and many should shout OXYGEN! Finally, ask the students to share at the count of three what gas animals exhale—CARBON DIOXIDE!—and ask the students playing the role of plants to inhale the $CO_2$ and exhale "oxygen" dramatically for the students representing animals to inhale deeply; this will complete the photosynthesis analogy and reinforce the idea that all of the living things in an ecosystem—as well as non-living things such as sunlight, air, and water—are interconnected.

13. Explain that all other organisms that don't produce their own food are called **consumers**, and write that word below carnivore and herbivore in the middle.
14. Ask students what prey species in freshwater ecosystems might eat, and they may suggest smaller organisms such as tadpoles or insect larvae. Hopefully, one will also say dead things, the way **scavengers** like crayfish eat, or you can suggest dead organisms and ask students which living organisms eat them. Explain that this function of eating dead matter is very important for keeping the water clean and with enough dissolved oxygen for animals to breathe. Also explain that freshwater ecosystems can be very complex, with many hundreds of animal and plant species, all interconnected through a complex **food web** and supported by nonliving things such as sunlight, water, and air. Write food web under food chain and explain that it is the interaction of many food chains and cycles.
15. Ask for a round of applause for the ecosystem actors, and they can take their seats. Explain to students that they will now create a more complex model of the food web—or web of life--that will better represent the rich **biodiversity** of a healthy freshwater ecosystem. Write the word on the board, and if time allows, talk about the prefix bio- (life) and the root diversity (variety).
16. Simulate the freshwater ecosystem web of life with yarn:
    - Lead the students outside so you have a large area in which to form a circle with the whole class, directing students to take their organism illustrations with them. Anywhere outside will work, but it is best if you can go to the most natural area available, ideally one with native plants, or even better, an area that is close to a freshwater ecosystem, such as a stream or pond.
    - Ask the class to form a large circle and tell students that you will now be recreating the freshwater ecosystem web of life.
    - Take your place in the circle and tell students that you represent the ultimate source of just about all the energy in the ecosystem—the sun.
    - Hold the end of the ball of yarn firmly in your hand while you toss the ball to one of the students representing a plant species, saying the species name out loud. Ask students to hold up their organism signs if they think the organism you tossed the yarn to interacts with them. This will help the students know who to toss the ball, and keep the whole class engaged. Ask the student to say the name of an organism it interacts with and toss the ball of yarn to the student representing it. (Each student should hold onto their piece of yarn while tossing the ball to another classmate.)

**Students create a model of a web of life as a class. If you can, go outside for the activity, ideally near a freshwater ecosystem or other natural area.**

17. Ask the second student to do the same thing, passing the ball to another organism it interacts with while holding the end of the yarn; continue until all the students are connected in the web of life, completing the model of the freshwater ecosystem.

18. Ask the students to step back and/or gently pull on the yarn until the web is taut. Then ask the students to remain still. Explain that in a moment, the student who started the web will tug on it, and only those students who feel a tug will tug back.

    Ask the student playing the plant to begin the process, and continue until all the students can feel a vibration moving through the web. Then ask students to choose an organism that might be less critically important for the ecosystem and ask that student to drop the yarn.

19. Continue this "organism removal" process several more times, then ask students a few questions to promote critical thinking and generate discussion:

    - How did removing organisms from the freshwater ecosystem impact the web? *Possible answer:* Organisms that depend on the food web are impacted and the web changes shape.
    - When were the changes to the web most dramatic? *Possible answers:*
        - When there were fewer species; losing one of them had a greater impact on the ecosystem.
        - When certain species that had multiple interactions were lost.
    - When was the web the most stable and why? *Possible answers:*
        - The web was most stable when there was the largest number of species.
        - In general, the more **biodiversity**, the more stable the environment and the less it is impacted by changes in the environment.
    - How might humans impact the web if they were added to it? *Possible answers:*
        - They might cause more species to leave the web.
        - This would be especially true if humans don't try to minimize their impact and to protect the biodiversity of the ecosystem.

20. Direct students to roll up the yarn, walk back to the classroom, and help clean it up. Write **community** on the board and close by having students discuss how all the different organisms living in the interconnected communities of freshwater ecosystems—and every other ecosystem, such as forests or grasslands—are linked together, enabling them to survive. Ask students if they hear the word community used in other ways, too. Briefly discuss how both humans and other living things exist together and support each other in communities, as well, such as the ones found in your neighborhood, city, and/or town.

21. Extend the lesson with activities such as those listed below and/or pass out the "Curious Crayfish + Freshwater Ecosystems" handout that follows the lesson and ask students to complete it for homework or in class as time allows as another way to reinforce the concepts you just talked about. An answer key follows the activity, which can also be used as a short reading prior to asking students to complete the activity version with missing vocabulary words.

## *Enrich/Extend*

- Pass out cards with the names of freshwater species and other important components of freshwater ecosystems. Students can use these to get them started on their short research projects to prepare to create the "web of life," or the cards themselves could be used for the activity if you are limited for time. Sets of cards can be found online, including:
  - "Pond Connections–The Food Web" listed in the Procedure section of the "Pond Connections" lesson plan from New Mexico Game & Fish: wildlife.state.nm.us/discover-new-mexico-home/aquatic-wildlife/pond-connections
  - "Aquatic and Marine Ecosystem Connections" lesson plan from the Univ. of Florida Ext. Service (pp. 50–52): studylib.net/doc/8282863/lesson-1-aquatic-and-marine-ecosystem-connections
- Have students work with a partner to create a visual diagram of freshwater ecosystems. Pairs will need a large sheet of paper or poster board to share; consider having a few stacks of used sheets around the room from which students can choose (to use the backs of them). Completed diagrams—or the best of them—can be displayed on the classroom walls or on a hallway bulletin board or other display.
  - Consider directing students to use different colored arrows for the different types of interactions on their diagrams, and write this on the board with color-coded markers or chalk, if available, or type it to display on the screen or interactive whiteboard:

    **Orange** to connect the **sun** with producers (plants)

    **Green** to connect **herbivores** to plants

    **Red** to connect **predators** to their prey

    **Brown** to connect **decomposers** to the plants and animals they break down after they die.
  - *Optional:* Show students the Sagebrush Ecosystems poster/graphic available from the U.S. Fish and Wildlife Service on the Greater Sage-Grouse Education page as an example of one type of visual diagram they could create: fws.gov/media/sagebrush-education-posters
  - *Optional:* Students can include humans in their diagrams, if desired.

- It is recommended that you take students on a field trip to a stream or other area of freshwater to explore the ecosystem firsthand. Have students engage in an activity such as observing the macroinvertebrates found in the water and/or creating a nature journal and/or field guide of the organisms they observe.
- Students can work together to create a large mural of a diagram depicting freshwater ecosystems with their illustrations and/or nonfiction writing about them. Diagrams can be created on classroom walls and/or other walls in the school or larger community. Yarn and/or arrows can be used to show ecosystem interactions, and students can help to illustrate additional important aspects of the ecosystem, such as the sun, algae, bacteria, and detritus.
- Discuss the important role of watersheds and create a model of one using crumpled paper, as explained in this lesson from the Ferguson Foundation: fergusonfoundation.org/resources. Search "crumpled paper" to access the PDF.
- Show a short video clip about crayfish and/or freshwater ecosystems, such as:
  - "Queen Nerdling Presents Freshwater Ecosystems:" youtube.com/watch?v=hdeGM65Enko
  - "I Speak for the Fish: Facing the Wrath of a Crayfish:" greatlakesnow.org/2023/07/i-speak-for-the-fish-facing-wrath-crayfish
- Students can write fictional stories or poems about one or more organisms from freshwater ecosystems.
- Have each student choose a freshwater ecosystem organism to research in depth. They can research elements, such as what the organism needs to survive and how human activities have impacted it over time. Provide a rubric so students know how they will be evaluated on the project, and findings could be shared with the rest of the class through written reports and/or oral presentations.
- For younger grades, read a story or nonfiction book with your class about crayfish. Examples include:
  - "The Life Cycle of a Crayfish" by Bobbie Kalman, Crabtree Pub Co: amazon.com/Crayfish-Cycle- Paperback-Bobbie-Kalman/dp/0778707032
  - "Crayfish" by Meg Gaertner, North Star Editions: barnesandnoble.com/w/crayfish-meg- gaertner/1129536594
  - "Crayfish" by Phillis W. Grimm, Lerner Pub Group: amazon.com/Crayfish-Early-Bird-Nature- Books/dp/0822530309

### *Evaluate*

- 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.
- Use completed student diagrams to evaluate student understanding of the concept of freshwater ecosystems.
- Review the short research projects about an organism from freshwater ecosystems and its interactions with other organisms.
- Use student participation in class discussion and activities, including the simulation of a freshwater web of life, to determine student understanding.

## Expand Knowledge + Skills

- "The Crayfishes." Missouri Stream Team: mostreamteam.org/assets/factsheet22.pdf
- "The Freshwater Biome." UC Berkeley: www.ucmp.berkeley.edu/exhibits/biomes/freshwater.php
- "Freshwater ecosystems filter pollutants before they reach oceans." ScienceDaily: www.sciencedaily.com/releases/2018/04/180430212349.htm
- Helfrich, L.A., Parkhurst, J., and Neves, R. 2001. The control of burrowing crayfish in ponds. Dept. of Fisheries and Wildlife Services, Virginia Tech: vtechworks.lib.vt.edu/items/9f97d586-a543-4613-b707-44f137b4930b
- Taylor, C. A., Schuster, G. A., & Wylie, D. B. (2015). Field Guide to Crayfishes of the Midwest. Manual 15. Illinois Natural History Survey, Champaign, Illinois. 145 pages: shop.inrs.illinois.edu/inhs-man.html

**Freshwater Food Web Diagrams**

- "Aquatic Food Web." Univ. of Michigan: michiganseagrant.org/wp-content/uploads/2018/08/09-400-Aquatic-Food-Web-GLEP.pdf
- "Freshwater Channel Food Web." Cary Institute of Ecosystem Services: caryinstitute.org/eco-inquiry/teaching-materials/hudson-river-ecology/freshwater-channel-food-web

**Plants and Animals of the Great Lakes Area Connected to Freshwater Ecosystems**

- Great Lakes Wildlife: glerl.noaa.gov/data/waterlife/additionalResources.html
- Great Lakes Water Life (PowerPoint): Highlights different plants and animals that one can find in the Great Lakes: glerl.noaa.gov/data/waterlife/docs/WaterlifeAnnotated.ppt
- "Priority Colonies for Great Lakes Waterbirds." Audubon: gl.audubon.org/sites/default/files/colonial_waterbird_summary_may_1_update.pdf
- Reptiles and Amphibians of Michigan: michigan.gov/dnr/education/michigan-species/reptiles

**Lessons/Activities**

- "Freshwater Lesson Plans." Fresh Water Live: freshwaterlive.org/resources/lesson-plans
- "Aquatic Food Web" flashcards in Quizlet: quizlet.com/40755546/aquatic-food-web-flash-cards
- "Food Webs" lesson plan. CPALMS, Florida State University: www.cpalms.org/Public/PreviewResourceLesson/Preview/75952

**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

# Crayfish Trivia

1. What kind of animals are crayfish? (Circle one)
   a. Amphibians
   b. Crustaceans
   c. Fish
   d. Insects
   e. Mollusca (mollusks)

2. Put an "X" or checkmark in front of all the places where crayfish live.
   _____Dry sand
   _____Lakes and ponds
   _____Mud puddles
   _____Oceans
   _____Rivers and streams

3. Mark all of the animals below that eat crayfish.
   _____Birds, such as herons and ducks
   _____Fish, like trout
   _____Amphibians, such as frogs
   _____Reptiles, such as turtles and snakes
   _____Mammals, like raccoons, river otters, and humans

4. Crayfish breathe through their:
   _____Gills
   _____Lungs
   _____Mouth
   _____Nose
   _____Skin

5. Do crayfish live in our state? Circle one: Yes No

6. In what ways can crayfish be good for the environment?
   _____They are scavengers that eat dead animals and plants.
   _____They are food for many different animals.
   _____They can eat lots of food that other animals like to eat.
   _____They can eat lots of salmon and trout eggs.
   _____They help to keep streams and other bodies of water clean.

7. Which of these are better for ecosystems?
   a. Invasive plants and animals
   b. Native species

8. Please write all the reasons why you think native or invasive crayfish are better for their ecosystems below and on the back of this paper.

_______________________________________________

_______________________________________________

_______________________________________________

# Crayfish Trivia Answer Key

1. What kind of animals are crayfish? (Circle one)
   - a. Amphibians
   - b. **Crustaceans** (circled)
   - c. Fish
   - d. Insects
   - e. Mollusca (mollusks)

2. Put an "X" or checkmark in front of all the places where crayfish live.
   - _____Dry sand
   - __X_ Lakes and ponds
   - __X_ Mud puddles
   - _____Oceans
   - __X_ Rivers and streams

3. Mark all the animals below that eat crayfish.
   - __X_ Birds, such as herons and ducks
   - __X_ Fish, like trout
   - __X_ Amphibians, such as frogs
   - __X_ Reptiles, such as turtles and snakes
   - __X_ Mammals, like raccoons, river otters, and humans

4. Crayfish breathe through their:
   - __X_ Gills
   - _____Lungs
   - _____Mouth
   - _____Nose
   - _____Skin

5. Do crayfish live in our state? **Yes! Crayfish are found in all 50 states, with more than 400 species found in North America. Over 600 total species have been identified around the world.**

6. In what ways can crayfish be good for the environment?
   - __X_ They are scavengers that eat dead animals and plants.
   - __X_ They are food for many different animals.
   - _____They can eat lots of food that other animals like to eat.
   - _____They can eat lots of salmon and trout eggs.
   - __X_ They help to keep streams and other bodies of water clean.

7. Which of these are better for ecosystems?
   - a. Invasive plants and animals
   - b. **Native species** (circled)

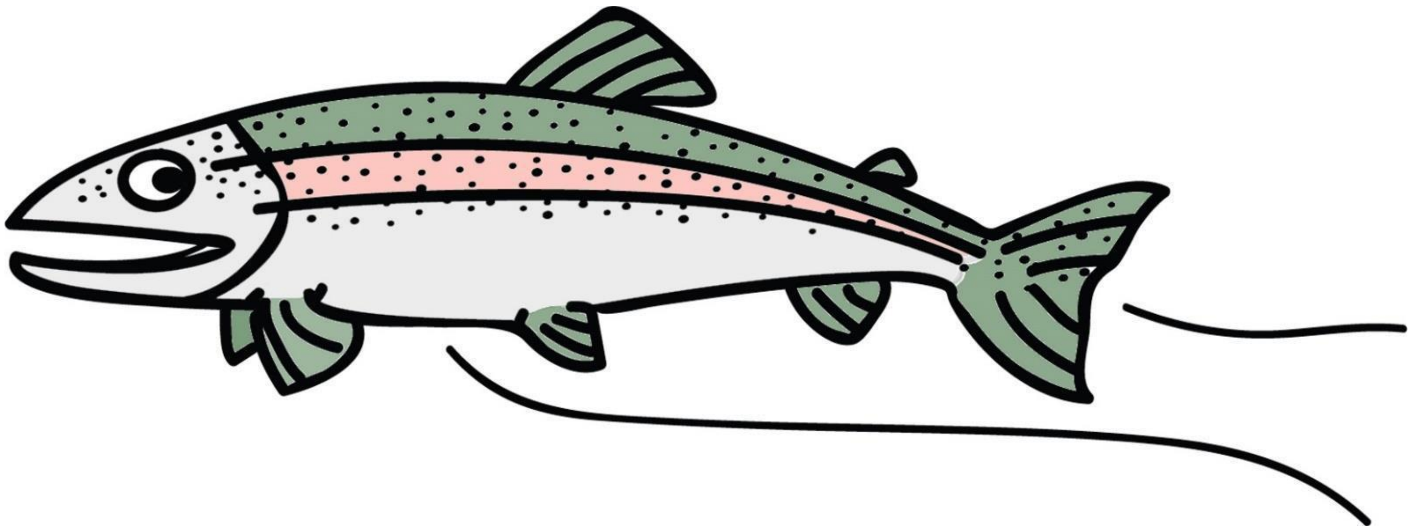
8. Please write all the reasons why you think native or invasive crayfish are better for their ecosystems below and on the back of this paper.

   **Native crayfish live in balance with other species in their ecosystem. They are important food for many other native species of animals, and they are omnivores/scavengers that consume dead animals and plants, helping to keep their freshwater ecosystems clean and recycling nutrients.**

   **Invasive crayfish can outcompete native species for food, shelter, and space. They can sometimes reproduce more quickly, too, and can be consumed less by native predators. Their burrowing activity can also be a problem, increasing erosion and decreasing water quality, for instance.**

# Rainbow Trout

*(Steelhead trout that stay in freshwater)*
Scientific name: *Oncorhynchus mykiss*



**Habitat:** Clean, cool freshwater in streams, rivers, and lakes

**Diet:** Eats invertebrates like insects (larvae and adults), crayfish and other crustaceans, and zooplankton; small fish and fish eggs; algae

**What eats them?**

- Fish, like bass and larger trout
- Birds, like herons, kingfishers, eagles, and osprey
- Mammals, like raccoons, otters, and humans
- Crayfish (as scavengers of dead fish and when trout are eggs)
- Decomposers, like bacteria

**Other interesting facts:**

- Steelhead and rainbow trout are the same species, but steelhead travel to the ocean to continue growing into adults. Then they travel back to where they hatched as eggs. There they spawn (lay eggs) and die. The nutrients from their bodies feed the ecosystem for the next generation.
- Rainbow trout are the only salmonids that stay in freshwater their entire lives.
- Native to the west of the Rockies, rainbow trout were introduced in almost every other state and on every continent except Antarctica.

**Sources:**


- "Rainbow Trout *(Oncorhynchus mykiss)*." U.S. Fish and Wildlife Service. fws.gov/species/rainbow-trout-oncorhynchus-mykiss
- "Rainbow Trout and Steelhead." National Wildlife Federation: nwf.org/Educational-Resources/Wildlife-Guide/Fish/Rainbow-Trout-Steelhead

Name: _____________________________ Period: ________ Date: _______________________

# Organism Presentation Rubric

**Name of Organism:** _____________________________________________

| Presentation Component | Maximum Points Possible | Self-Score (fill out before presentation) | Teacher Score |
|---|---|---|---|
| **Content** | | | |
| Organism's key traits explained, including:<br>• Habitat(s) and ways it survives in freshwater ecosystems<br>• What it eats and/or what eats it | 10 | | |
| Interactions with other living and nonliving things clearly explained | 10 | | |
| **Delivery/Audience Engagement** | | | |
| Speech delivered clearly at appropriate volume and speed (not too fast, slow, loud, or soft) | 5 | | |
| Speed, volume, and voice inflection are varied to engage audience and emphasize key points | 5 | | |
| Speaker connects with audience through eye contact and does not spend too much time looking at notes or screen | 5 | | |
| Speaker demonstrates enthusiasm for topic throughout presentation; audience is persuaded by speaker about important role(s) in ecosystem | 5 | | |
| **Visual(s)** | | | |
| Illustration helps to explain organism's adaptations and/or role(s) in ecosystem | 10 | | |
| **Writing Conventions** | | | |
| Grammatical/spelling conventions followed in written summary | 10 | | |
| **TOTAL:** | **60** | | |

Teacher Comments:

# Crayfish + Freshwater Ecosystems

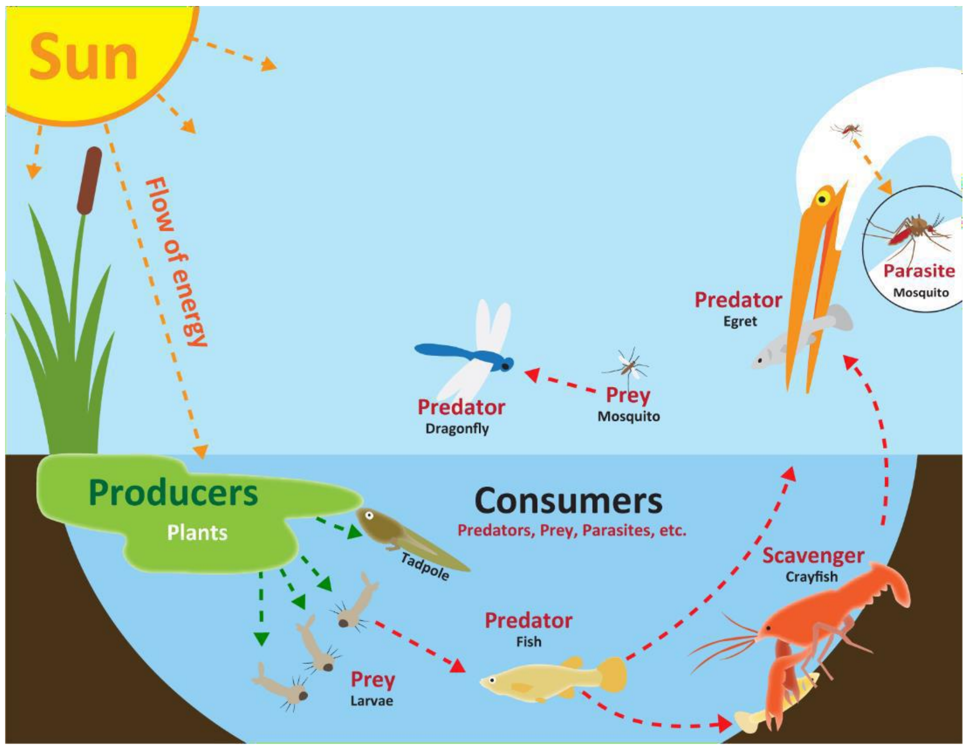
## Crusty Crustaceans

Crayfish are **crustaceans**, named for their hard, crust-like **exoskeleton**. Their upper shell is known as a **carapace**. They are closely related to lobsters, their saltwater cousins. Like insects and spiders, crustaceans are **arthropods**, named for their jointed legs. Crayfish have ten legs: four pairs of **walking legs** and two **chelipeds** with **chelae** (claws). They have two pairs of **antennae** for sensing food and danger in their murky **habitat**; the smaller pair are known as **antennules**.

*Image by Jeff Benca*

## Key in the Web of Life

Crayfish are an important part of **freshwater ecosystems**, such as rivers and lakes. They are food for many species of fish, birds, amphibians, reptiles, and mammals. Even some land-dwelling animals, such as raccoons, love to eat them, so they play important roles in **terrestrial** ecosystems, as well. Many people enjoy cooking them for dinner, too—especially in southern states like Louisiana.




**Model of a Freshwater Ecosystem**
*Graphic by Eric Engh and Rick Reynolds*

## What Do Crayfish Eat?

Crayfish are **omnivores** that eat both dead and living plants and animals. Their role in reducing **detritus** (decaying **organic matter**) and filtering the water is important for improving **water quality**. (One way to remember what "detritus" means—and what a crayfish might say about it—is that it sounds like, "Dude, try this!") Crayfish eat almost anything.

**A crayfish feast!**

Crayfish, along with **microorganisms**, such as **bacteria** and **plankton** (tiny plants and animals), breakdown and **recycle** nutrients in the ecosystem's complex **food web**. Dead fish and leaves can be a feast for a crayfish, which becomes a feast for a **rainbow trout**, which can feed a human family. All living things are linked in countless ways to the web of life, which also includes essential nonliving things, like water, oxygen, carbon dioxide, and space.

## Heroes or Villains?

**Predators** as well as **scavengers**, crayfish can negatively impact ecosystems, too. **Invasive**, non-native species have the most impact. For example, they can outcompete **native** species for food, and eat too many fish and amphibian eggs. Their habit of **burrowing** in mud can provide benefits for water quality, but burrowing near the water's edge can sometimes increase **erosion** (Helfrich, Parkhurst, and Nevis 2001). This can add more **sediment** to the water, reducing its **clarity** and overall quality for wildlife and humans.

**Can you spot this camouflaged crayfish in its burrow?** *Photo: Brocken Inaglory, Wikimedia Common*

## Where are Crayfish Found?

About 400 of the world's 600+ crayfish species are found in North America, especially the southeastern United States. The rest are found on every continent except Antarctica. Many species are at risk of **extinction**, due mainly to habitat loss, pollution, and the spread of invasive crayfish species and disease (Larson et al. 2020).

**Animals like crayfish need food, water, air, shelter, and space to survive. This clear spring is excellent crayfish habitat, with plenty of rocks for shelter.**
*Photo: Eric Larson*

## Ecology: The Study of Interconnections in Nature

An **ecosystem** is any group of living and nonliving things that interact with one another. Some are relatively small, like streams and ponds where crayfish often thrive. Others are large **biomes**, like wetlands or forests.

**Biodiversity** is a measure of the number of different species of **organisms** (living things) in a specific area. The term is also used as a general description of species richness, ecosystem complexity, and genetic variation. In general, the more biodiversity, the more stable the environment and the less it is impacted by environmental changes. The organisms that interact with each other in their ecosystems are called an **ecological community**.

Name(s): ______________________________________ Period: _____ Date: __________________

# Delving Deeper into Crayfish + Freshwater Ecosystems

1. How would you describe crayfish to someone who had never heard of or seen them before? Continue on the back if you need more space.

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

2. How might freshwater ecosystems be impacted if there were no crayfish? Include at least three positive and two negative impacts in your answer. Continue on the back if you need more space.

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

3. What does **extinction** mean? Why are many crayfish species at risk of it?

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

4. How can the loss of **biodiversity** be a problem for ecosystems? Provide an example to help explain your answer. Continue on the back if you need more space.

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

5. Crayfish are **polytrophic** (opportunistic feeders) that will eat almost any organic matter. A crayfish might eat 50% plant detritus, 40% living plant matter, 8% dead animal matter, and 2% living animal matter. Create a graph to show this crayfish's diet visually.

6. If the crayfish described above in question 5 consumed 100 grams (0.22 pounds) of food in a week, what would the mass of the food types consumed be in grams and pounds?

   plant detritus: ____________grams ____________pounds

   living plant matter: ____________grams ____________pounds

   dead animal matter: ____________grams ____________pounds

   living animal matter: ____________grams ____________pounds

7. If the crayfish described in question 5 consumed 167 grams (0.37 pounds) of food in two weeks, what would the mass of the food types consumed be in grams and pounds?

   plant detritus: ____________grams ____________pounds

   living plant matter: ____________grams ____________pounds

   dead animal matter: ____________grams ____________pounds

   living animal matter: ____________grams ____________pounds

Name: ______________________________ Period: ____ Date: _____________________

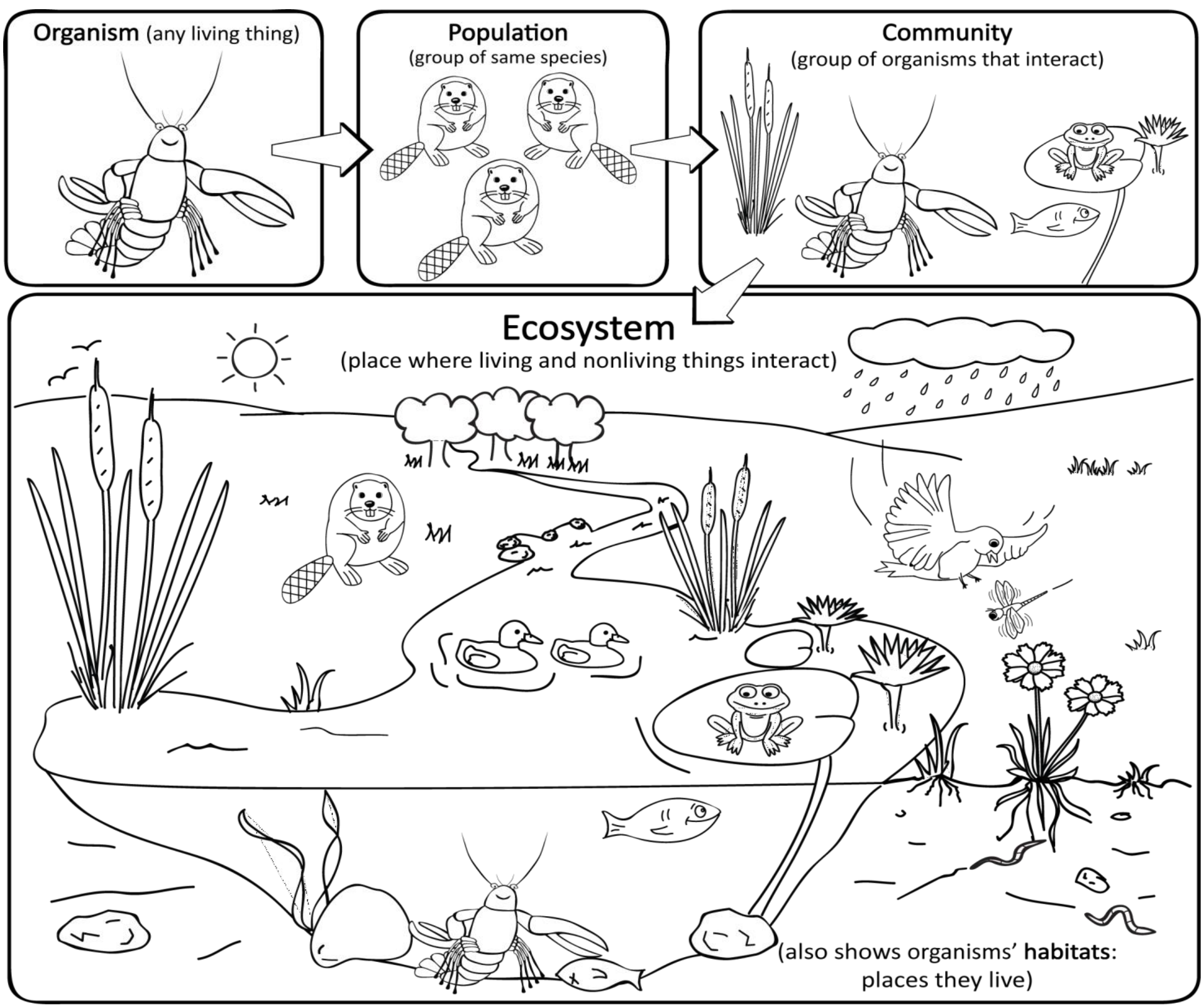
# Curious Crayfish + Freshwater Ecosystems

Complete the description of crayfish and where they live with these terms: amphibians, biodiversity, birds, ecosystems, fish, freshwater, invasive, humans, lakes, native, omnivores, predators, reptiles, scavengers, species

Crayfish play an important role in **freshwater** ____________________, such as ___________and ______________. Most often found on river and lake bottoms, crayfish are ____________________that eat both animals and plants. As ____________________of dead organisms, they help to clean the water. Crayfish are also an important food for many organisms including:

- ______________, such as trout.
- ______________, such as herons and ducks.
- ______________, such as turtles and snakes.
- ______________, such as raccoons and river otters.
- ____________________, such as frogs.
- ____________, especially in places like Louisiana.

Sometimes crayfish that come from other places can harm ecosystems, too. These ________________ species can be ______________of many _______________species. They can also compete with natives for the food, water, shelter, and space that every animal needs to survive. This can reduce native populations and _________________.

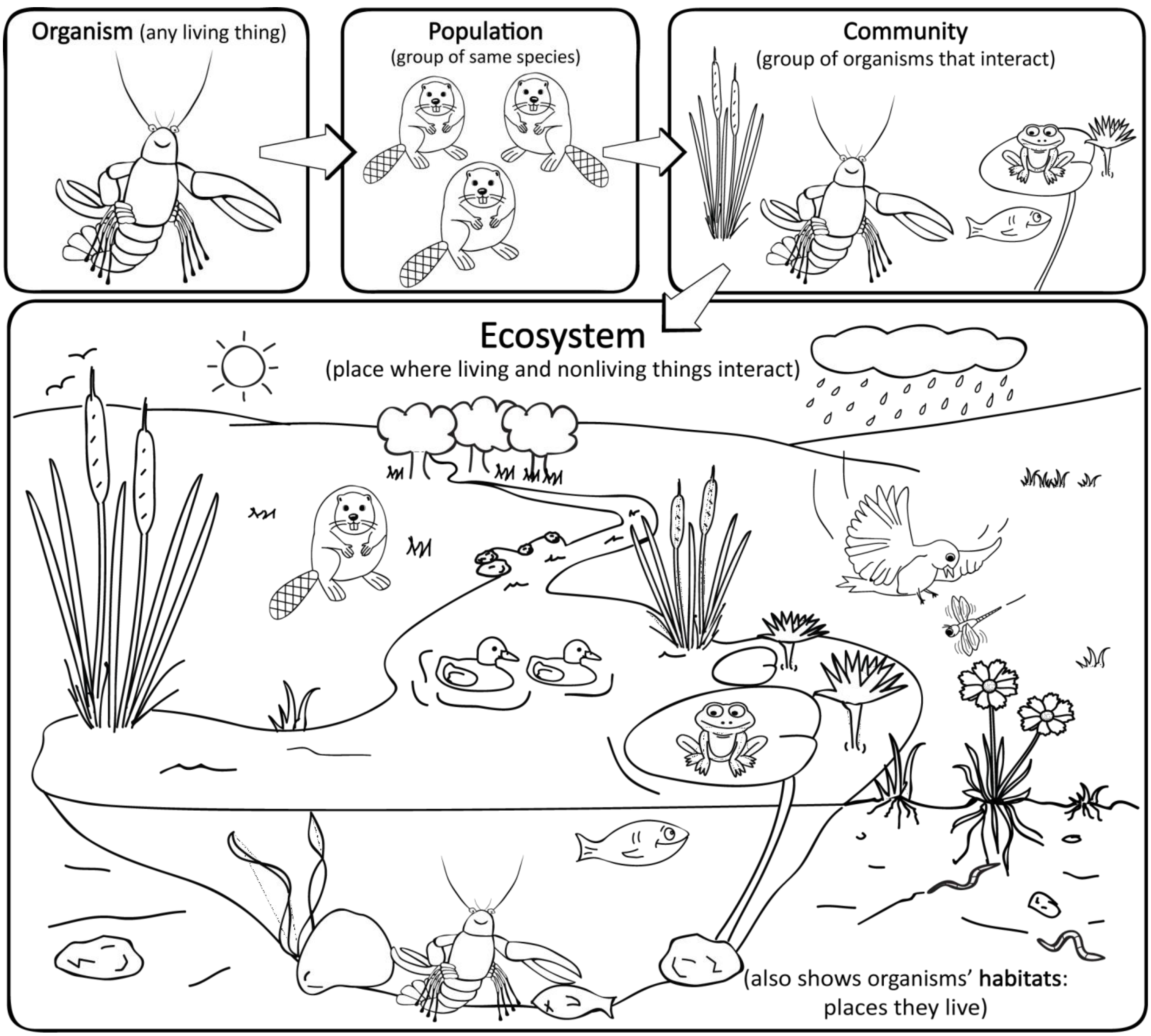


# Curious Crayfish + Freshwater Ecosystems

Crayfish play an important role in **freshwater ecosystems**, such as **lakes** and **rivers**. Most often found on river and lake bottoms, crayfish are **omnivores** that eat both animals and plants. As **scavengers** of dead organisms, they help to clean the water. Crayfish are also an important food for many organisms including:

- **Fish**, such as trout
- **Birds**, such as herons and ducks
- **Reptiles**, such as turtles and snakes
- **Mammals**, such as raccoons and river otters
- **Amphibians**, such as frogs
- **Humans**, especially in places like Louisiana

Sometimes crayfish that come from other places can harm ecosystems, too. These **invasive** species can be **predators** of many **native** species. They can also compete with natives for the food, water, shelter, and space that every animal needs to survive. This can reduce native populations and **biodiversity**.



Lesson 2

# Invasive Crayfish + Community Changes

**Subjects** Science, Language Arts, Art

**Grade Levels** Ideal for grades 6–12, adaptable for 3–5

**Time** 45 minutes or more

**Kind of cute, but big trouble: an invasive species**
*Photo: Flowermaze via Pixa*

## Lesson Overview

Students first read about mysterious population changes in a freshwater ecosystem, then create line graphs to show the changes over time. They think about what might be causing the changes and brainstorm with a partner about how the changes might be causing problems in the freshwater ecosystem. Lesson options are listed in the "Enrich/Extend" section.

## Goals

- Students explore issues around native and invasive species by analyzing hypothetical data about changing populations over time.
- Students become aware of how certain species can have negative impacts on ecosystems, including through reductions in biodiversity.
- Students increase their understanding of native and invasive crayfish and the roles that they and other macroinvertebrates play in freshwater ecosystems.
- Students think critically about how invasive crayfish can be a threat to different native species and biodiversity.

## Objectives

- Students will read about a hypothetical situation and use the information to graph data and help them analyze it.
- Students will research species from the Great Lakes region to determine their roles in freshwater ecosystems.
- 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.
- 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.

#### Building toward

- MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

### Crosscutting Concepts

- Cause and Effect: Mechanism and Explanation
- Stability and Change
- Systems and System Models

### Science & Engineering Practices

- Developing and Using Models
- Asking Questions and Defining Problems
- Constructing Explanations and Designing Solutions
- 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

## Common Core State Standards

### 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.

**Standard 6.** Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

### College and Career Readiness Anchor Standards for Writing

**Standard 6.** Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

**Standard 7.** Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

## Center for Great Lakes Literacy Principles

**Principle 5.** The Great Lakes support a broad diversity of life and ecosystems.
**Principle 6.** The Great Lakes and humans in their watersheds are inextricably interconnected.

## Teacher Background

An **invasive species** is defined as any non-native organism that causes harm to the environment, economy, or human health (EPA: epa.gov/greatlakes/invasive-species-great- lakes-0). 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).

A few species of crayfish are spreading rapidly in freshwater ecosystems worldwide, disrupting local habitats and negatively affecting countless species. Native crayfish species are now among the most threatened groups of organisms. 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 the release of classroom science organisms, live fishing bait, pets, etc.

Additional information and visuals are found in the introduction to this curriculum and in the "Expand Knowledge + Skills" section at the end of the lesson.

## Materials

- Copies of the following for each student (found after lesson):
  - "The Mystery of the Changing Crayfish Populations"
  - *Optional:* "Invasive Species Project"
- Graph paper or graphing software
  - Graph paper can be generated in different formats and printed free at incompetech.com/graphpaper.
  - Alternatively, Microsoft Excel and Google Sheets are two programs that can be used to create graphs. "How to Make a Line Graph in Excel" is one of many videos and web pages online that explains the process: youtu.be/3o11OlLgYDo
- Markers, crayons, or colored pencils for students to share
- *Optional:* Posterboard

## Preparation

1. Ensure all materials above are ready for student use.
2. *Optional:* Learn more about topics in the lesson in the More Resources/References section at end of the lesson to prepare to answer student questions.
3. *Optional:* Arrange for a guest speaker with expertise on freshwater habitat restoration projects to visit your class. Contact us here for possible recommendations: invasivecrayfish.org/contact-us

## Teaching Suggestions in the 5E Model

### *Engage*

**Bluegill sunfish are native to the Great Lakes basin and get their name from a darkened blue spot on their gills.**
*Photo: U.S. Fish and Wildlife Service*

1. Engage students and encourage them to apply prior knowledge by asking what they would do if they discovered that native crayfish and other macroinvertebrates (small animals without backbones) seem to be less common in a nearby stream, while some new crayfish species are appearing there.
2. Ask students to think about what research project(s)/tests they might conduct to get more information, who they might talk to about it, and what other problems might be related to the issue. Tell them they will have a few minutes to brainstorm their ideas with a neighbor, recording them on paper or with an electronic device in words and pictures.
3. Circulate through the groups, answering (and asking) questions to help students arrive at their own conclusions. After a few minutes, tell students they will have one more minute to brainstorm and to be prepared to share their best ideas with the class.
4. Allow the groups to share their ideas and tell them that they will be working with a partner to graph some data to learn about the issue.

### *Explore*

5. Ask students to form groups of 2–3 while you pass out the "The Mystery of the Changing Crayfish Populations" activity sheet. Ask them to first read through the scenario. Explain that after they finish reading, they should work together to graph the data and answer the questions in the "Your Challenge" section.
6. Tell students they should conduct additional research, as necessary, to determine what roles each of the species listed in the table play in the Great Lakes ecosystem. They may use the Internet and other available reference sources; they should cite the sources they use for additional information.

### *Explain*

7. Circulate through the room answering (and asking) questions, helping the groups get started. Encourage students to use reliable sources to research the organisms listed in the table on the student activity sheet. Suggest sites listed in the Expand Knowledge + Skills and Resources sections, if needed.
8. Allow students time to complete their investigation outside of class, if necessary.
9. Once students have completed their research, ask a group to share their graph of organism abundance during a full class discussion. Ask other groups if their graphs are similar and discuss different ways of displaying data.
10. Ask students to share their observations about what is happening to organisms in Large Lake. Consider asking different groups to share what they discovered about each organism listed in the table.
11. Write the terms "native species" and "invasive species" on the board. Ask students if they know what these terms mean and how the terms were used in sources they found through their research. Ask students if they have heard about any other invasive species found in the U.S.

12. If students haven't already mentioned that Rusty and Red Swamp Crayfish are invasive species found in Large Lake (and the Great Lakes), share that information. Ask students what impacts these two crayfish species might be having on the other species in Large Lake, based on the data.
13. Ask students to think about the different ways an invasive species could negatively impact a native species. Help them understand that invasives can outcompete natives for space and food, introduce new diseases, and disrupt an entire ecosystem.

## *Enrich/Extend*

- Students can complete the "Invasive Species Project," explained on the handout following the lesson plan.
- Ask students to read "Native & Invasive Crayfish of the Great Lakes Region" found in Lesson 4. They can use it as a reference to help them compare two crayfish species. This can be done using a graphic organizer such as a Venn diagram and/or a written analysis.
- 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
- Show some or all of the TED-Ed Animation "The Threat of Invasive Species–Jennifer Klos" at ed.ted.com/lessons/the-threat-of-invasive-species-jennifer-klos. Ask the students to work through the "Think" questions with a partner, recording their ideas in science notebooks or via the online system. Discuss their ideas as a class and/or through the discussion board accessed via the "Discuss" link.
- For younger and/or less experienced students, consider reading through "The Mystery…" scenario as a class and answering questions before forming groups to work on the project.
- Investigate the biodiversity of macroinvertebrates in a nearby stream to evaluate water quality based on the prevalence of different species. You can also help to improve water quality by doing a service project such as planting native plants or removing trash. Good activities to support this field work are found in:
  - "Stream Side Science" lesson plans from Utah State Univ. Extension Service: extension.usu.edu/waterquality/files/Stream-Side-Science.pdf
  - SOLVE's *Environmental Service-Learning* curriculum: engagingeverystudent.com/project/solve-environmental-service-learning-curriculum
- Invite students to create public service announcement videos about ways to help keep invasive species of animals and plants out of our ecosystems.

## *Evaluate*

- Review student research projects and answers to the questions.
- Use student participation in class discussion and activities to determine 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

### Science/References

- Data in "The Mystery of the Changing Crayfish" activity adapted from: Wilson, K. A., Magnuson, J. J., Lodge, D. M., Hill, A. M., Kratz, T. K., Perry, W. L., & Willis, T. V. (2004). A long-term rusty crayfish *(Orconectes rusticus)* invasion: dispersal patterns and community change in a north temperate lake. Canadian Journal of Fisheries and Aquatic Sciences, 61(11), 2255-2266. jvzlab.limnology.wisc.edu/wp-content/uploads/sites/1902/2022/11/WIlson_2004_long-term_CJFAS.pdf
- Helfrich, L.A. and DiStefano, R.J. "Sustaining America's Aquatic Biodiversity–Crayfish Biodiversity and Conservation." Dept. of Fisheries and Wildlife Sciences, Virginia Tech: pubs.ext.vt.edu/420/420-524/420-524.html
- Invasive Species in the Great Lakes, EPA: epa.gov/greatlakes/invasive-species-great-lakes-0
- "Field Guide to Michigan Crayfish." Department of Fisheries and Wildlife Michigan State University: docslib.org/doc/2887390/field-guide-to-michigan-crayfish
- "Invasive Crayfish 101." Invasive Crayfish Collaboration: https://invasivecrayfish.org/invasive-crayfish-101/
- "Research Reveals Hope for Managing Invasive Red Swamp Crayfish." U.S. Fish & Wildlife Service: fws.gov/story/2024-02/research-reveals-hope-managing-invasive-red-swamp-crayfish
- "Marbled Crayfish Raises Eyebrows, and Concerns." Great Lakes Now: greatlakesnow.org/2024/04/marbled-crayfish-raises-eyebrows-and-concerns

### Videos

- "The Threat of Invasive Species–Jennifer Klos." TED-Ed: ed.ted.com/lessons/the-threat-of-invasive-species-jennifer-klos
- "What Are Invasive Species?" Explore Nature/National Park Service via YouTube: youtube.com/watch?v=_ZzPM7Dw9Gg

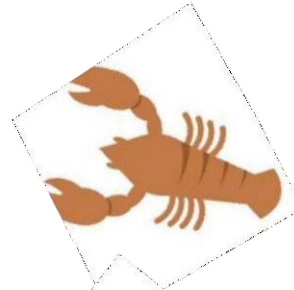
### Lessons/Activities

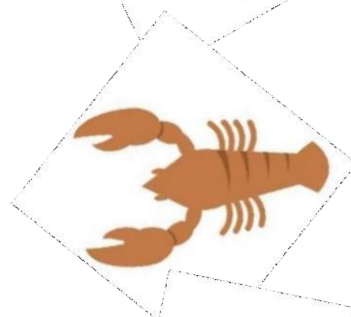
- "Bugs Don't Bug Me" and many more aquatic macroinvertebrate lessons, in the "Stream Side Science" program from Utah State Univ. Extension Service: extension.usu.edu/waterquality/educator-resources/lessonplans
- IDAH$_2$O water education resources, including curriculum and videos, Univ. of Idaho Ext.: uidaho.edu/extension/idah2o/resources
- "Watershed Detectives" lesson from Utah State University Ext.: extension.usu.edu/waterquality/files/watershed-detectives.pdf

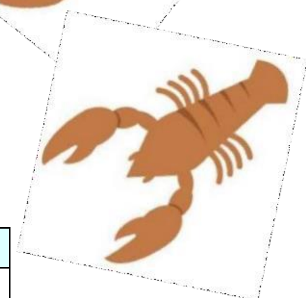
### Education Standards

- More information about the Next Generation Science Standards, including a link to the *Framework for K-12 Science Education* to which this lesson was aligned: www.nextgenscience.org/framework-k%E2%80%9312-science-education
- More information about the Common Core State Standards and links to the complete documents: www.corestandards.org

# The Mystery of the Changing Crayfish Populations







***Scenario:*** Scientists monitoring wildlife at Large Lake were alarmed when they observed different species of crayfish in the area. A historically popular fishing lake, the scientists and wildlife managers were concerned that the introduced species might be negatively impacting fish populations and biodiversity.

To discover how many of these new species were present, they trapped crayfish at different locations around the lake over several years. They also sampled for snails, fish, and amphibians to determine if there were changes in the numbers of organisms. At one monitoring location, they recorded the following numbers of organisms captured in one day.

| Species | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Virile crayfish | 10 | 9 | 6 | 3 | 1 |
| Rusty crayfish | 0 | 1 | 4 | 7 | 10 |
| Red swamp crayfish | 0 | 2 | 3 | 6 | 9 |
| Snails per square meter | 8,500 | 7,000 | 4,000 | 1,500 | 500 |
| Bluegill sunfish | 20 | 17 | 12 | 10 | 7 |
| Eastern newts | 16 | 14 | 10 | 6 | 2 |

## Your Challenge:

1. Create a graph that shows the numbers of species collected over time.
2. Explain the data changes over time in writing. What might be causing them?

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

3. Brainstorm with a partner about how the changes might be causing problems in the freshwater ecosystem. Record your ideas in words and pictures on the back of this sheet or in science notebooks.
4. Research the roles that each of the organisms listed in the table play in the Great Lakes ecosystem. Going back to question 3, how do you think rusty crayfish and red swamp crayfish are impacting the other species? What evidence do you have? What other studies would you want to conduct to be more certain of your ideas?

Name: ______________________________ Period: ____ Date: ______________________

# *Invasive Species Project*

*Adapted with permission from a similar project by Erin Cole*

**Your Assignment**

Research an invasive species that is impacting an ecosystem near you. Create a "management sales pitch" to share your information and warn others about the dangers of these invasive organisms.

**Overall Guidelines**

You will be trying to convince your classmates that your animal or plant is the most damaging to the ecosystem it has invaded. Our money and other resources should go to managing it NOW! Some things to think about in your sales pitch:

1. What kind of damage is your organism causing? Economic? Environmental? Aesthetic (natural beauty)?
2. If it is not a big problem in our area yet, could it become really damaging? How?
3. What are cost-effective ways to get rid of it?
4. Is there an organization that is already trying to get rid of it? If so, could they use help?

**Information Requirements**

1. Common and scientific name of your plant or animal
2. Detailed description of what it looks like; how to not confuse it with similar organisms
3. Its original ecosystem (where it is native and originally from)
4. Where it can be found now (region, specific place in ecosystem)
5. How scientists think the organism arrived in its new location
6. How it harms humans and ecosystems (Be specific: for example, if it takes over land from other plants, How does it do it? If it causes economic damage, to what industries or structures?)
7. What humans are trying to do to stop the invasion (Again, be as specific as possible: is there a specific organization that is already trying to stop it? What tools/chemicals/methods are they using, and are there pros and cons to the various methods?)
8. All sources of information, including photos, are cited in MLA format

**Formatting Requirements**

1. 4–10 slides created with PowerPoint, Google Slides, Prezi, or another program, including a sources page at the end
2. A title slide with a photo or drawing of the plant or animal (created with graphics software or drawn by hand and scanned or photographed)
3. The presentation should last **no longer** than 3 or 4 minutes and should seem like a "sales pitch," not just an informational speech—be persuasive!

**Evaluation**

Your presentation will be scored as follows:

| Requirement | Score |
|---|---|
| **Information:** All information accurate and requirements met; sources listed | / 20 |
| **Organization:** Presentation is neat and organized | / 5 |
| **Visual Engagement:** Photo or drawing on first slide and other visuals engage the audience and help to communicate information | / 5 |
| **Persuasiveness:** Presentation is persuasive about the need to control the species | / 5 |
| **Conventions:** Correct grammar and spelling used | / 5 |
| **Total** | / 40 |

**Choices Include:**

**Invasive Animals**

1. Zebra mussels or quagga mussels
2. Chinese mitten crab
3. Nutria
4. European starling
5. English house sparrow
6. Sea lamprey
7. American bullfrog
8. Rusty crayfish
9. Feral pig/feral swine
10. Red-eared slider
11. Pond Loach
12. Northern snakehead
13. New Zealand mud snail
14. Round goby
15. Asian clam
16. Silver, bighead, black, or grass carp
17. Red swamp crayfish
18. Spotted lanternfly
19. Emerald ash borer
20. Marbled crayfish

**Invasive Plants**

1. Cheatgrass (downy brome)
2. Honeysuckle
3. Curly-leaf pondweed
4. Bull, Canada, or musk thistle
5. Common or cutleaf teasel
6. Brazilian waterweed
7. Common reed
8. European frogbit
9. Purple loosestrife
10. Spotted or Japanese Knapweeds
11. Hydrilla
12. Brittle waternymph
13. Starry stonewort
14. Garlic mustard
15. Narrow-leaved cattail
16. Eurasian watermilfoil
17. Tree of heaven
18. Butterfly bush
19. Kudzu
20. Reed canary grass

**Resources**

- "Invasive Species" Illinois Dept. of Natural Resources: dnr.illinois.gov/conservation/iwap/invasivespecies.html
- MLA citation guide, Purdue Online Writing Lab (OWL): owl.english.purdue.edu/owl/resource/747/02
- USDA Invasive Species resources: invasivespeciesinfo.gov/us
- USDA Plants database: plants.usda.gov
- USGS Nonindigenous Aquatic Species database: nas.er.usgs.gov

Invasive Crayfish Collaborative
Great Lakes

*Lesson 3*
# Crayfish Adaptations

**Subjects** Science, Language Arts, Art

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

**Time** 50–75 minutes or more


**Red swamp crayfish *(Procambarus clarkii)*: one of the most invasive crayfish species shows off its chelipeds.**
*Photo: National Park Service*

## Lesson Overview

In this lesson, students explore crayfish adaptations that help them to survive in freshwater ecosystems. Like the other lessons in the crayfish curriculum, it is designed to be highly adaptable. Options include having students brainstorm crayfish adaptations that help them to survive in their freshwater ecosystems, a short interactive multimedia presentation about crayfish anatomy and adaptations, and student-designed and engineered models of crayfish or a new type of scavenger/predator that is well-adapted to survive in an aquatic environment.

## Goals

- Students will increase their understanding of crayfish adaptations that help them to survive and reproduce.
- Students will be provided the opportunity to apply the concept of adaptations to the process of engineering design.
- Students will demonstrate critical thinking about the particular roles of crayfish in freshwater ecosystems, and how they can help keep ecosystems healthy.

## Objectives

- Students will demonstrate understanding of crayfish adaptations, including ways they are able to find food, reproduce, and escape predators.
- Students will create models of crayfish or new student-designed and engineered organisms adapted to be successful scavengers/predators in freshwater ecosystems and share them with their peers, gaining feedback that could be incorporated into new design iterations.
- Students will write about how crayfish or their own engineered organisms are adapted to survive, then share their ideas and models in class presentations and/or discussion.
- Students will verbalize the importance of food, water, shelter, and space in the survival of crayfish and other organisms, and how they are adapted to best use them.

## Next Generation Science Standards

### Performance Expectations

#### Building toward

- MS-LS4-4: Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.
- MS-LS4-6: Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.
- MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-LS1-4: Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
- HS-LS4-4: Construct an explanation based on evidence for how natural selection leads to adaptation of populations.
- HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

### Crosscutting Concepts

- Structure and Function
- Stability and Change

### Science & Engineering Practices

- Asking Questions and Defining Problems
- Constructing Explanations and Designing Solutions
- Developing and Using Models
- Obtaining, Evaluating, and Communicating Information

### Core and Component Ideas in the Life Sciences

#### LS1: From Molecules to Organisms: Structures and processes

- LS1.A: Structure and Function
- LS1.B: Growth and Development of Organisms

#### LS2: Ecosystems: Interactions, Energy, and Dynamics

- LS2.C: Ecosystem Dynamics, Functioning, and Resilience

#### LS4: Biological Evolution: Unity and Diversity

- LS4.C: Adaptation

### Core and Component Ideas in Earth and Space Sciences

#### ESS2: Earth's Systems

- ESS2.C: The Roles of Water in Earth's Surface Processes

## Common Core State Standards

### 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 clarity.

**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.

**Standard 6.** Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

### College and Career Readiness Anchor Standards for Writing

**Standard 4.** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

**Standard 10.** Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

## Center for Great Lakes Literacy Principles

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

## Teacher Background

### Crayfish Life Cycle and Behaviors

Crayfish have adaptations that help them survive at each stage of their life cycle. They start out as one of 50–500 or more eggs that their mothers typically carry in their swimmerets, small appendages on the ventral side (underside) of their abdomen.

*Photo: Rick Reynolds*

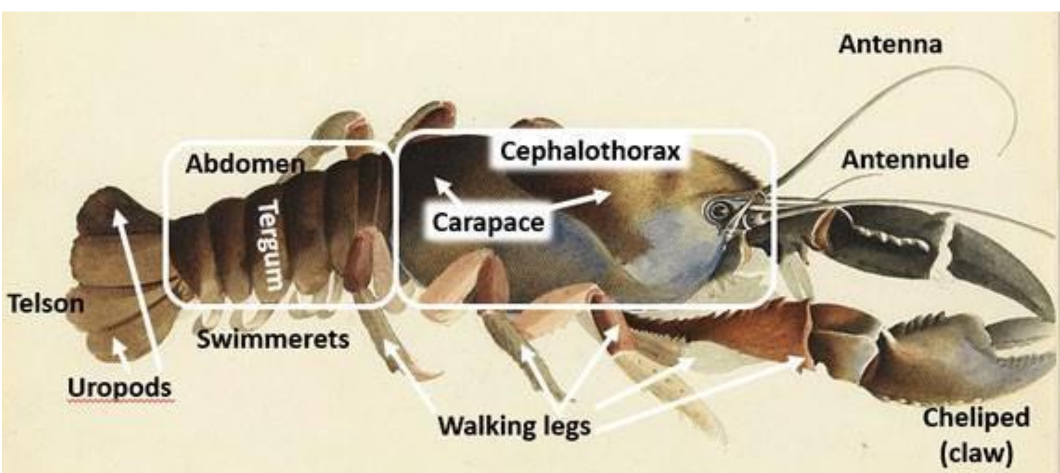
Crayfish go through incomplete metamorphosis during their life cycle. Unlike many other invertebrates, such as butterflies, which go through complete metamorphosis with distinct larval and pupal stages, they hatch from eggs directly into tiny crayfish and go through roughly 11 molts, in which they shed their exoskeleton and then replace it with a new one, growing into adults.

Crayfish are generally nocturnal. Being most active at night helps them to stay hidden from predators and stay sheltered from the hot sun. When they do venture out from shelter beneath rocks or burrows during the day, it is in well-shaded areas.

### Crayfish Anatomy/Structures

The body of a crayfish is divided into three segments: head, thorax, and abdomen. The head and thorax are fused together to form the cephalothorax.

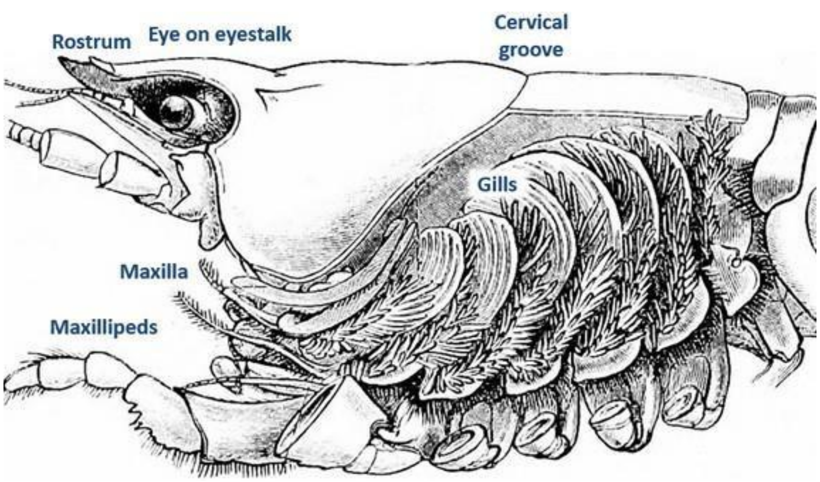
- **Thorax**: the crustacean equivalent to a chest; fused with the crayfish head to form the cephalothorax
- **Cephalothorax**: joined thorax and head of crayfish and other arthropods




*Graphic: Rick Reynolds from public domain illustration*

- **Abdomen**: section behind the thorax covered in six plates

- **Tergum**: name for the thickened plates on each segment of the body of crayfish and other arthropods; helps to protect soft interior
- **Carapace**: hard upper shell of crayfish and other arthropods that extends from the tip of the rostrum to the start of the abdomen; protects the crayfish
- **Rostrum**: beak-like projection; ask students what function might be; protects eyes, antennae, and antennules
- **Antenna** (plural antennae): long organs used for touch, taste, and smell; helps to sense prey and predators in murky water
- **Antennules**: shorter organs also used for touch and taste, as well as balance
- Five pairs of legs to move along river or pond bottom (locomotion)
- **Chelipeds**: Pair of legs nearest to the head, enlarged with claws (chelae) to hold food, provide protection, and use in combat
- **Chela**: claw located at the end of each cheliped (plural chelae)
- **Uropods**: Last pair of abdominal appendages of crayfish and related crustaceans; found on sides of the telson, completing the tail fan used for swimming
- **Telson**: An extension of the last abdominal segment; triangular-shaped structure found in between the uropods, completing the tail fan used for swimming
- Eyes on **eyestalks**: can be rotated for very large field of vision




*Graphic: Rick Reynolds from public domain illustration*

- **Cervical groove**: indentation that separates head and thorax, which are connected in crayfish
- **Gills**: extract oxygen from water; used to breathe
- **Maxilla**: help draw water over gills
- **Maxillipeds**: hold food; can touch and taste
- **Mandible**: crushes food to be swallowed by mouth

- **Green glands**: help to filter waste products and balance salt levels in blood; similar to kidneys in humans
- **Genital pores**: used in reproduction
- **Swimmerets:** small appendages on the ventral side (underside) of their abdomen; in males, they are used in mating; in females, they are used to hold eggs and baby crayfish

Crayfish body structures and other adaptations are presented with larger images and labels in the slides and notes of the Crayfish Adaptations PowerPoint presentation.

Additional sources for teachers and/or students are listed in the "Extend/Enrich" and "Expand Knowledge + Skills" sections at the end of the lesson.

## Materials

- "Crayfish Adaptations" PowerPoint presentation available on the Invasive Crayfish Collaborative website: invasivecrayfish.org/products
- Computer access, data projector, display screen, and Microsoft PowerPoint (or other software capable of displaying a .ppt file)
- *Optional:*
    - "Crayfish Adaptations" reading and questions, "Crayfish External Anatomy" diagram activity, "Crayfish External Anatomy" descriptions, and "Comparing Adaptations" handout at the end of the lesson
    - Modeling clay or Play-Doh and natural materials like dried vegetation, twigs, pine needles, and pinecones for students to share
    - Human-made materials for students to share, such as used paper towel tubes and/or toilet paper tubes, popsicle sticks, elastic bands, paper, cardboard, tape, and non-toxic glue
    - Paper plates on which to construct creatures
    - Colored pencils, markers and/or crayons for students to share
    - Live native crayfish and/or preserved crayfish specimens
    - Microscope(s) and/or hand lens(es)
    - Enlarged photographs of crayfish
    - "Curious Crayfish + Freshwater Ecosystems" activity, which can be found before this lesson in the crayfish curriculum.

## Preparation

1. If possible, identify an expert partner to work with your class about crayfish and their adaptations. Contact us here for possible recommendations: invasivecrayfish.org/contact-us.
2. Write the word "Adaptations" on the board to refer to during the lesson.
3. Ensure all materials above are ready for student use.

4. *Optional:*
    - Review more about crayfish and their anatomy/adaptations to prepare to answer student questions. Good sources include those listed at the end of the lesson in the Expand Knowledge + Skills section.

## Teaching Suggestions in the 5E Model

### *Engage*

1. Introduce the expert visitor, if one is present, and tell students they will be learning more about crayfish today to prepare them for a field trip to find crayfish in a nearby freshwater ecosystem (if you will be visiting one). But first, tell students you'd like them to think about what they already know about crayfish and their freshwater ecosystems.
    - Ask them to turn to a neighbor and quickly brainstorm on a piece of paper all of the **adaptations** they would need to survive in their underwater **environment**.
    - Write "adaptations" on the board and explain they are traits of crayfish and every other **organism** (living thing) that **evolved** over millions of years to help them survive—both physical structures of their bodies, as well as behaviors that help them find food, escape predators, reproduce more crayfish, etc.
    - They should record all their ideas from their brainstorm without worrying about if they are good ideas or not, and they can also draw pictures of the adaptations.
2. Circulate through the room, answering any questions. After a minute or two, tell students they have one more minute to brainstorm and that they should be prepared to share one or more of their best ideas with the class.
3. Ask the pairs to share their best ideas with the class and discuss them.
4. Open the "Crayfish Adaptations" PowerPoint presentation and you and/or the visitor can lead a brief interactive discussion about it, drawing on student ideas and information in the slide notes to talk about important crayfish body structures, behaviors, their life cycle, and the functions adaptations play in helping crayfish survive and reproduce. If available, you can also show the students live crayfish, which is especially engaging.

### *Explore*

5. Next, tell students that they will have the opportunity to create a model of either a crayfish or a new organism that is adapted to be a successful scavenger and predator in freshwater ecosystems.
    - Explain that they will be able to use a variety of materials, their creativity, and what they have learned about adaptations to help with their engineering designs.
    - Show them the available materials, such as clay, Play-Doh, natural vegetation, toilet paper tubes, pipe cleaners, and scrap paper, with which they will be able to create their designs.

6. Ask students to choose a partner (if desired, or they can work individually) and collect materials with which to work. Rotate though the groups of students, answering questions and helping students get started, if necessary. Tell students that they should be prepared to present their work to the class, including about how the organisms' adaptations help them to survive. If they have time, they can create another life stage for their organism (such as a crayfish's egg stage or an insect's aquatic larval stage).

**A student-created organism**
*Photo: Lucinda Watson*

## *Explain*

7. After about 15 minutes, or whenever groups start to complete their designs, explain that you will be looking for volunteers to make a brief presentation to the class about their organisms, and ask them to start cleaning up when they are finished.

8. Ask students to explain their organisms' adaptations in writing using one of the following methods or another way that they devise:
   - They can create labels with small pieces of card stock, attached to their organisms with toothpicks and tape or another method.
   - They can illustrate their engineering designs on paper, labeling the adaptations that help them to survive. Color can be added with pencils, markers, or crayons.
   - They can write a narrative in paragraph form that explains the organism's adaptations.

9. Ask students to share their work, giving other class members a chance to ask questions about the organisms' adaptations at the end of each short presentation.

10. Tell students that they will be able to finish their projects for homework or in class the next day (if necessary and as you deem appropriate). Collect the finished projects to review more carefully and display around the classroom and/or the school. You could also ask students to refine their creations based on constructive feedback you and/or the rest of the class has provided before the creations are displayed publicly.

11. Close with a quick review of concepts learned during the lesson and crayfish adaptations that help them survive in their aquatic habitats.

## *Enrich/Extend*

- Ask students to complete the "Crayfish External Anatomy" diagram activity at the end of the lesson with the support of the "Crayfish External Anatomy" descriptions handout, which is also found at the end of the lesson. The "Crayfish Adaptations" reading can also be used to support the activity and the others below.
- Ask students to compare crayfish with their new organism—or one of their peers' new organisms. For example, a Venn diagram could be used. They should compare

their creature's physical and behavioral adaptations to those of crayfish, including their organism's different structures and functions that help them to survive.

- Ask students to first plan their organisms on paper before they start engineering them with physical materials, labeling the adaptations that will help the organisms to survive.
- If you have access to live or preserved crayfish, students can view them and/or their body structures under magnification with a microscope, hand lens, and/or macro lens to better see their unique adaptations. You can also use a microscope or macro lens connected to a computer and/or data projector to show specimens to the whole class. Obtain and dispose of your live crayfish responsibly– always use native or non-invasive species and NEVER release your classroom plants or animals into the wild.
- Ask students to dissect crayfish specimens with the guidance of one or more resources, such as:
  - "Crayfish Dissection" page from Biology Junction: biologyjunction.com/crayfish_dissection.htm
  - "Detailed Crayfish Dissection: Part I" video: youtu.be/AOZdmUKoViY
  - "Detailed Crayfish Dissection: Part II" video: youtu.be/0QgB9xNqtGU or
- Students can write fictional stories or poems about crayfish and/or the new organisms they created.
- Take students on a field trip to a stream or other area of freshwater to observe crayfish and their ecosystems firsthand.

**A student prepares to dissect a preserved invasive crayfish**
*Photo: Deb Berg*

- Set up classroom centers with other activities related to adaptations, the new organisms, and/or crayfish, such as those listed above. This would provide more opportunity for student choice and differentiated learning experiences.
- Show one or more short video clip(s) about crayfish:
  - Crayfish babies hatching: youtube.com/watch?v=_e1LV9MR9MQ
  - Crayfish molting: youtube.com/watch?v=mF6NgMBcNCM
- For younger grades, read a story or nonfiction book with your class about crayfish. Examples include:
  - "The Life Cycle of a Crayfish" by Bobbie Kalman, Crabtree Pub Co: amazon.com/Crayfish-Cycle- Paperback-Bobbie-Kalman/dp/0778707032
  - "Crayfish" by Meg Gaertner, North Star Editions: barnesandnoble.com/w/crayfish-meg- gaertner/1129536594
  - "Crayfish" by Phillis W. Grimm, Lerner Pub Group: amazon.com/Crayfish-Early-Bird-Nature- Books/dp/0822530309

## *Evaluate*

- Review student descriptions of their model crayfish or new organism's adaptations, including ways they are able to find food, reproduce, and escape predators. Students should also be able to discuss crayfish adaptations orally.
- Students can be asked 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

- Carpenter, M.E. (2017). "Adaptations of the Crawfish." Sciencing: sciencing.com/adaptations-crawfish-10006220.html
- "Crayfish Biology." Biological Surveys and Assessment Program. University of Illinois: publish.illinois.edu/biologicalsurveys/research/crayfish-biology/
- Helfrich, L.A., Parkhurst, J., and Neves, R. 2001. "The Control of Burrowing Crayfish in Ponds." Dept. of Fisheries and Wildlife Services, Virginia Tech. vtechworks.lib.vt.edu/server/api/core/bitstreams/163b1c0e-5ba8-465c-99f4-52072a1f5b7f/content
- "Marbled Crayfish Raises Eyebrows, and Concerns." Great Lakes Now: Detroit PBS: greatlakesnow.org/2024/04/marbled-crayfish-raises-eyebrows-and-concerns

### Lessons/Activities

- "Crayfish Dissection." Biology Junction: biologyjunction.com/crayfish_dissection.htm
- *Crawfish Educational Materials for Grades K-8 & High School Biology*. Louisiana Crawfish Promotion and Research Board: lsuagcenter.com/~/media/system/4/4/6/b/446b98e3a69c8f3bdedd57feb2802c7b/crawfishlessonplank8hslab.pdf
- "COSIA Outreach Activities- Crayfish Investigations." Lawrence Hall of Science: marestage.lawrencehallofscience.org/college-courses/COSIA/outreach-activities
- *Crayfish Student Activity Book.* Elementary Science Program: currikicdn.s3-us-west-2.amazonaws.com/resourcefiles/54d26e5197a40.PDF
- "Introduction to Scientific Sketching" lesson plan. California Academy of Sciences: calacademy.org/educators/lesson-plans/introduction-to-scientific-sketching

### 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

# Crayfish Adaptations

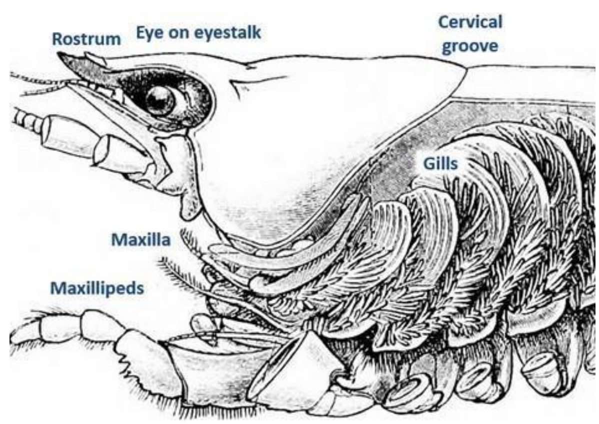
Crayfish have many adaptations that help them to survive: physical structures, like their hard exoskeleton, as well as behaviors (things they do). As you read, think about similarities and differences between crayfish adaptations and those of other species (including humans).

**A red swamp crayfish defends itself with its chelipeds.**
*Photo: National Park Service*

**Finding Food + Staying Safe**

Crayfish are not picky eaters. They will eat almost any dead or living animal or plant that they can get their **chelae** (claws) on. They can use their **chelipeds** (the pair of legs with chelae) for defense against predators and other crayfish, too.

Crayfish also use their chelipeds for digging and to get food to their mouths. Three **maxillipeds** and a pair of **maxillae** are used in feeding, too. Strong **mandibles** crush food before it enters their mouths. Crayfish grind up their food even more with teeth inside their stomachs! This is called the "**gastric mill**."

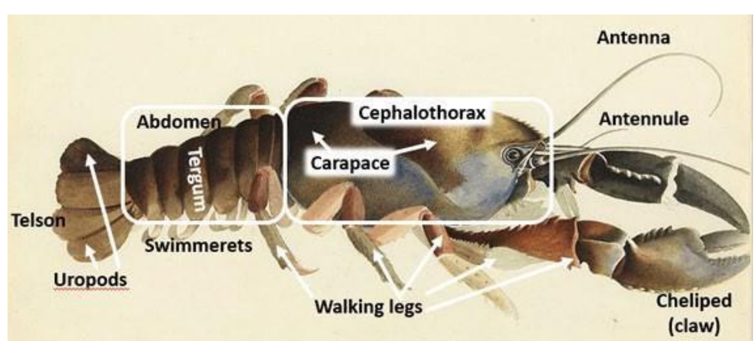



*Graphic: Rick Reynolds from public domain illustration*

Crayfish have **compound eyes** made up of many small eyes. Their eyes are on **stalks**, which gives them a larger field of view to spot food and predators. They are protected by the **rostrum**, also called the **supraorbital spine**, which sticks out in front of and above their eyes.

Crayfish have two pairs of **antennae** used for sensing food and danger in their murky habitat. The smaller pair are known as **antennules**.

If crayfish sense danger, they usually swish their **tail fan** down to escape backwards. The tail fan is made up of the **telson** with two pairs of **uropods** on either side that can spread out to move more water. Powerful muscles in their **abdomen** provide the downward force to make their quick escape. Protective plates cover their abdomen; each plate is known as a **tergum** on the **dorsal** (top) side and a **sternum** on the ventral side.




*Graphic: Rick Reynolds from public domain illustration*

Crayfish are generally **nocturnal**. Being most active at night helps them to hide from predators and stay sheltered from the hot sun. When they do venture out from the shelter of rocks or burrows during the day, it is in well-shaded areas.

**Burrowing** in mud not only provides safety from predators; it can also help crayfish survive cold and/or dry periods. Burying themselves in the mud can help keep their gills moist and prevent them from freezing.

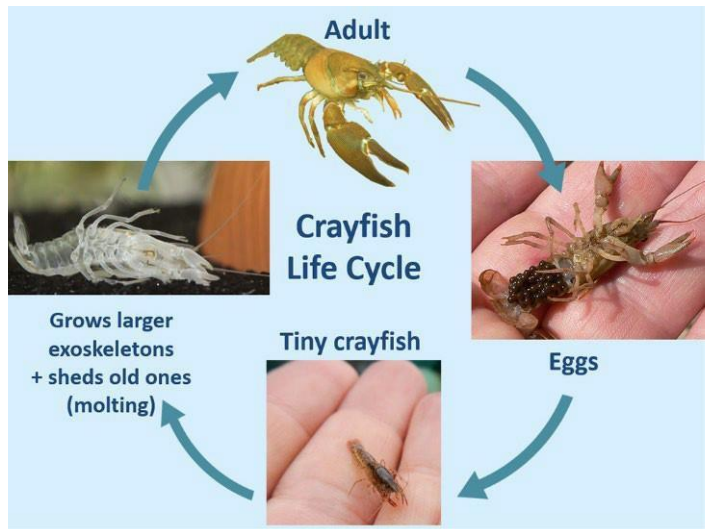
**A female crayfish holding her eggs in her swimmerets**

### Life Cycle

Adult females lay 50 to 500 or more **eggs** at a time. The eggs are usually carried in their **swimmerets**, small **appendages** on the underside (**ventral** side) of their **abdomen**.

Crayfish go through **incomplete metamorphosis** during their **life cycle**. They hatch from eggs directly into tiny crayfish, which their mothers usually shelter until they grow larger.

Before they reach adulthood, they go through roughly 11 **molts**; each time they shed their **exoskeleton**—and they usually eat it! This recycles the calcium so they can quickly grow a hard, new one. Their life cycle differs from that of butterflies and many other **invertebrates** that go through **complete metamorphosis** with different **larval** and **pupal** stages—caterpillar and chrysalis, etc.




*Graphic: Rick Reynolds*

### Male or Female?

Crayfish males have **gonopods** (modified swimmerets that are firmer than the feathery swimmerets). The gonopods are used to deposit sperm in the female when they mate. This fertilizes her eggs so they will develop into baby crayfish.

### Getting Oxygen

Crayfish get dissolved oxygen from freshwater using their **gills** (like fish). They use one of their two pairs of **maxillae** around their mouth to draw water over the gills. Their gills are attached to four pairs of **walking legs**, which also helps draw water over the gills as they walk.

Crayfish can survive out of water for short periods, as long as their gills stay wet. If they start to dry out, they need to return to water or bury themselves in wet mud so they can get the oxygen they need.

**A male crayfish with gonopods circled**
*Photo: Deb Berg*

Name(s): ______________________________ Period: ____ Date: ________________

# What Do You Know about Crayfish Adaptations?

1. Describe five interesting crayfish adaptations. Use complete sentences and include how they help the crayfish survive in their freshwater ecosystems. You might also add illustrations.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

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______________________________________________________________________

______________________________________________________________________

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2. How could you divide a crayfish up into parts to explain what it is to someone who has never seen one? You might also add an illustration below or on the back of this sheet.

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

3. How do swimmerets compare to walking legs?

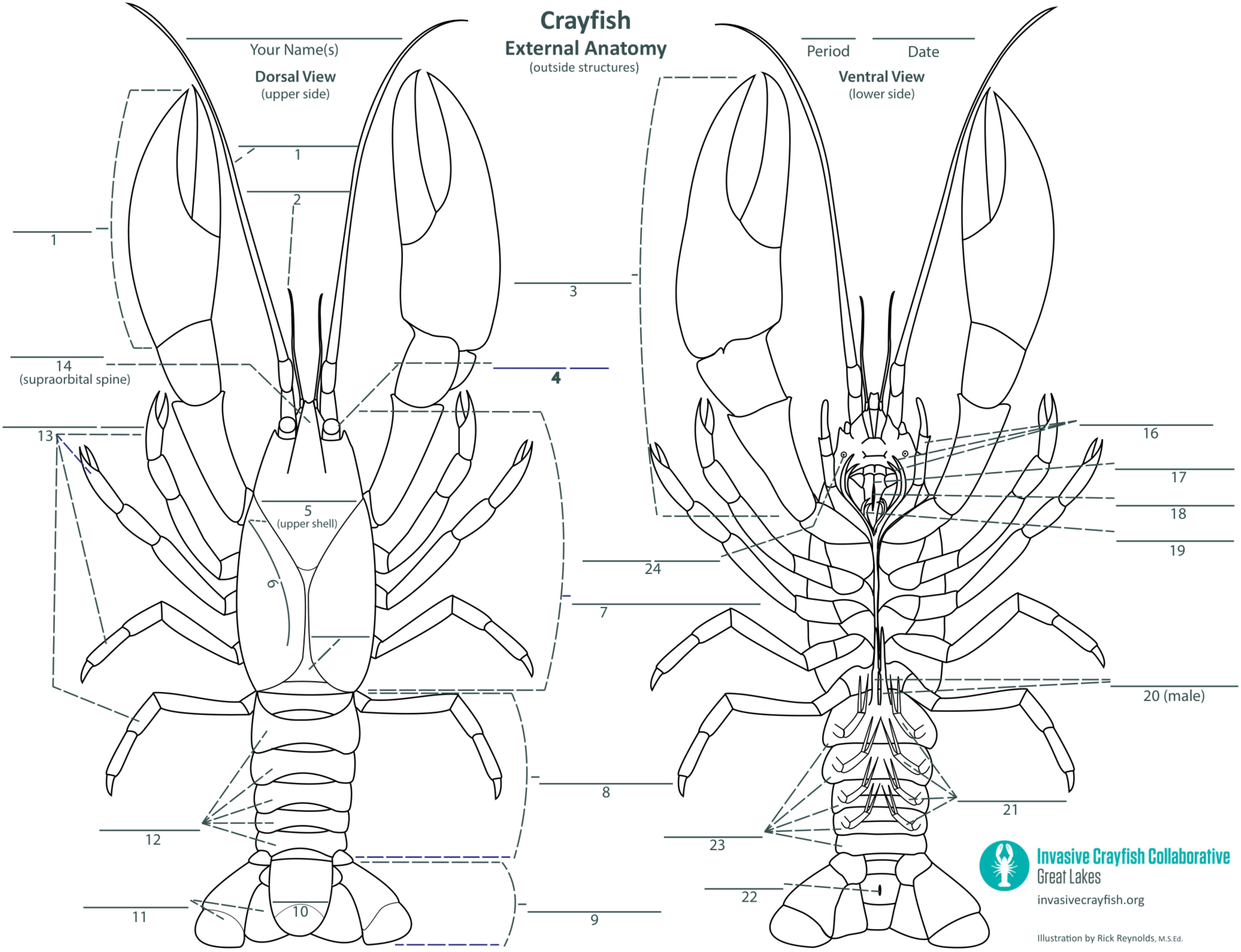
______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

# Crayfish
## External Anatomy
(outside structures)

Your Name(s) ______ Period ______ Date ______




Invasive Crayfish Collaborative
Great Lakes
invasivecrayfish.org

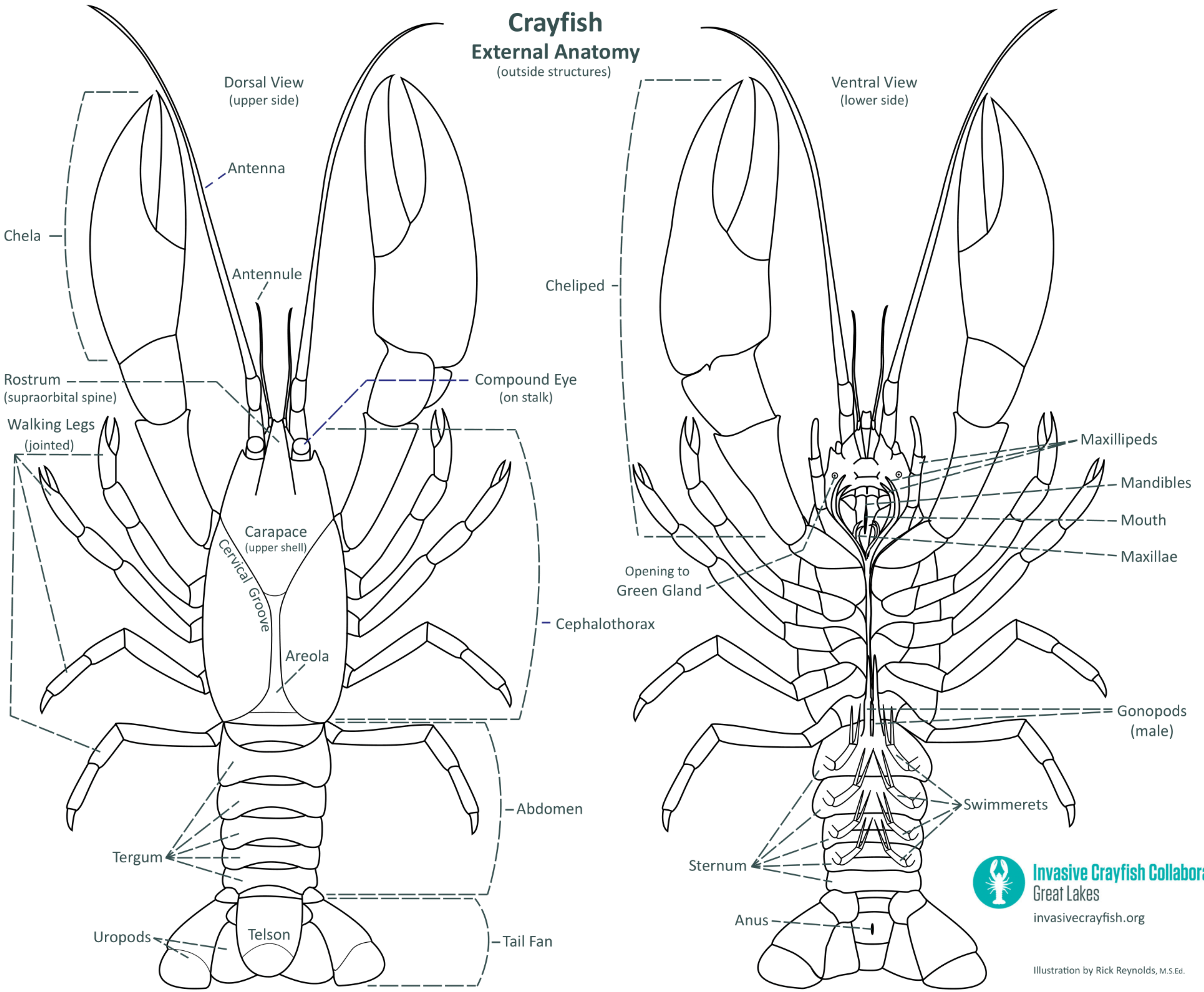
Illustration by Rick Reynolds, M.S.Ed.

# Crayfish External Anatomy

**(outside structures)**

| | |
|---|---|
| **Abdomen** | Tail area with segments; swimmerets, telson, and uropods are attached to it |
| **Antenna** | One of two long sensory organs at front of crayfish (**antennae**: two or more) |
| **Antennule** | One of two short antennae |
| **Anus** | End of digestive tract; located on lower part of telson |
| **Carapace** | Upper protective **exoskeleton** (shell) of cephalothorax |
| **Cervical Groove** | Indentation in carapace between head region and thorax region |
| **Cephalothorax** | Combined head and thorax; contains the heart, gills, stomach, and other organs |
| **Chela** | One of two big claws used for defense and food handling (**chelae**: two or more) |
| **Cheliped** | One of two long legs with chela |
| **Compound Eye** | Two eyes made up of many small eyes; located on **stalks** |
| **Gonopods** | Modified swimmerets of males; used to pass sperm to females |
| **Green Gland** | One of a pair of organs used to remove waste products and balance salt levels in blood; two openings to them are on the lower side of the head |
| **Mandible** | One of two strong **jaws** used to crush food |
| **Maxillae** | First pair of maxillae helps hold, tear, and pass food to mouth; second pair helps draw water over the **gills** (used to get oxygen from the water) |
| **Maxillipeds** | One of three pairs of feeding appendages; attached to jaws |
| **Mouth** | Opening at start of **digestive tract** |
| **Rostrum** | Beak-like structure above eyes; also called the **supraorbital spine** |
| **Swimmerets** | Five pairs of short appendages on bottom of abdomen used for swimming; females also use them to hold their eggs and young crayfish. |
| **Tail Fan** | The telson and four uropods; used for swimming backwards—fast! |
| **Telson** | Center section of tail fan |
| **Tergum** | Upper protective plates of abdomen |
| **Sternum** | Lower protective plates of abdomen |
| **Uropods** | Two pairs of appendages on tail fan that surround the telson |
| **Walking Legs** | Four pairs of jointed legs; the gills are attached to them |

# Crayfish
## External Anatomy
(outside structures)

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invasivecrayfish.org

Illustration by Rick Reynolds, M.S.Ed.

Name(s): ___________________________________ Period: ____ Date: _________________

# *Comparing Adaptations*

Compare the structural and behavioral adaptations
of two species using words and illustrations.

Species 1: ______________________________________ Different Adaptions

Adaptations in Common

Species 2: ______________________________________ Different Adaptations

Invasive Crayfish Collaborative
Great Lakes

*Lesson 4*
# Native + Invasive Crayfish

**Subjects** Science, Math, Language Arts

**Grade Levels** Ideal for grades 6–12, adaptable for 3–5

**Time** 50 minutes or more

## Lesson Overview

In this lesson, students explore native and invasive crayfish species of the Great Lakes and their roles in freshwater ecosystems. Activity options include having students brainstorm what they already know about native and invasive crayfish, matching cards of crayfish ecosystem roles and photos with their descriptions, and writing creatively about what they have learned. See the "Enrich/Extend" section near the end of the lesson with more ways to engage all learners.

**A native white river crayfish** *Photo: Chris Lukhaup*

## Goals

- Increase students' understanding of native and invasive crayfish and their roles in freshwater ecosystems
- Get students to think critically about how invasive crayfish can be a threat to different native species and biodiversity
- Increase students' understanding of how certain species can have negative impacts on ecosystems
- Increase students' understanding of the various ways that invasive crayfish can be introduced to new waterbodies

## Objectives

- Students will learn about species from the Great Lakes region to determine their roles in freshwater ecosystems.
- Students will demonstrate understanding of native and invasive crayfish species, including ways to identify them and their impacts on freshwater ecosystems.
- 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

### Building Toward

- MS-LS1-4: Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
- MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
- MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- 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

- Structure and Function
- Cause and Effect: Mechanism and Explanation
- Stability and Change

## Science & Engineering Practices

- Asking Questions and Defining Problems
- Obtaining, Evaluating, and Communicating Information
- Constructing Explanations and Designing Solutions

## Core and Component Ideas in the Life Sciences

### LS1.A: Structure and Function

### LS1.B: Growth and Development of Organisms

### LS2: Ecosystems: Interactions, Energy, and Dynamics

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

# Common Core State Standards

## 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.

**Standard 6.** Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

**College and Career Readiness Anchor Standards for Writing**

**Standard 6.** Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

**Standard 7.** Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

## Center for Great Lakes Literacy Principles

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

**Principle 6.** The Great Lakes and humans in their watersheds are inextricably interconnected.

## Teacher Background

### Crayfish Diversity

The eastern United States is home to more than 60% of the world's known crayfish species, making it a global hotspot for crayfish biodiversity (Richman et al., 2015). The American states and Canadian provinces surrounding the Great Lakes are home to approximately 40 crayfish species (Taylor et al., 2015), and a number of these species are rare or have narrow natural ranges (Page, 1985; Taylor et al., 2015; Richman et al., 2015). Some states in the southernmost areas of the Great Lakes region such as Illinois, Indiana, and Ohio have numerous crayfish species with narrowly endemic ranges, including the sinkhole crayfish *(Faxonius theaphionensis)* in central Indiana and the depression crayfish *(Cambarus rusticiformis)* in southern Illinois.

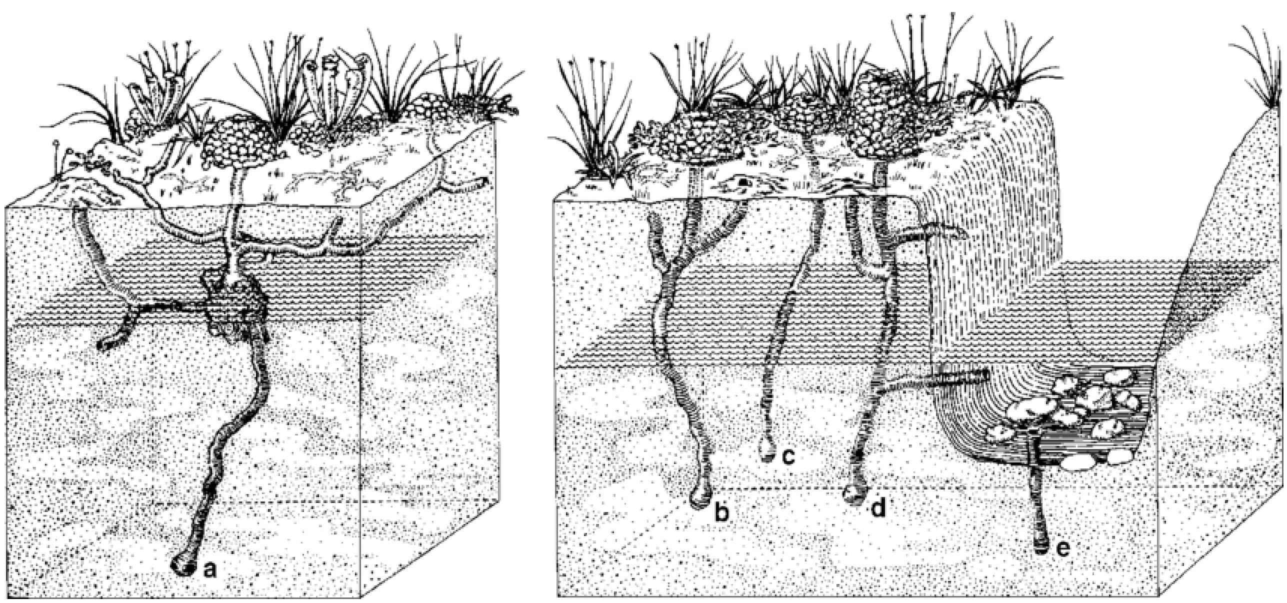
**A terrestrial crayfish burrow** *Photo: C.A. Taylor*

Many crayfish species in the Great Lakes region are known to occur only in streams and rivers (i.e., "lotic" ecosystems with actively moving water), but some species can persist or even thrive in "lentic" habitats (still waters) such as ponds, lakes, or reservoirs. An even smaller number of these crayfishes are almost completely terrestrial and spend most of their lives in underground chambers removed from direct contact with permanent water bodies.

The Great Lakes region includes a number of native species that are important to freshwater ecosystems. Many are described in the species guide at the end of the lesson. Important roles they serve include:

- **As food:** Over 200 animal species, including mammals, birds, reptiles, amphibians, fishes, and insects eat crayfish (DiStefano, 2005). Fish, such as bass, are especially prominent crayfish predators (Probst et al., 1984; Rabeni, 1992). A wide variety of other fish species, from brook trout to creek chubs, also consume crayfish (Gowing & Momot, 1979; Newsome & Gee, 1978). Crayfish are a vital food source for other important animals in freshwater ecosystems, such as the hellbender, an endangered salamander (Wiggs, 1976). Crayfish are also consumed by many terrestrial animals including minks, raccoons, and wading birds (Baker et al., 1945; Martin & Hamilton, 1985; Toweill, 1974).
- **As consumers:** Crayfish are opportunistic omnivores. They eat a wide variety of food items from phytoplankton to fish.
    - **Detritus**: Crayfish can consume large amounts of detritus, primarily in the form of leaf litter and other decaying plant material (Huryn & Wallace, 1987; Schofield et al., 2001). The processing of large amounts detritus by crayfish, such as dead animals and plant matter, can help keep freshwater ecosystems clean and healthy. It can also strongly alter the abundances of insect larvae, such as heptageniid mayflies (Creed & Reed, 2004), which can be an important food source for fishes and other aquatic vertebrates (Hoopes, 1960).
    - Crayfish also eat primary producers such as algae (Goldman, 1973) and aquatic plants (Creed, 1994). Some crayfish can consume so much algal and plant material that they strongly influence the population densities of these organisms (Goldman, 1973). Crayfish also feed on many different types of invertebrate prey, including snails (Kreps et al., 2012), insects and their larvae (Parkyn et al., 2001), and even other crayfish (Nakata & Goshima, 2006). Crayfish also eat vertebrates such as fish (Rahel & Stein, 1988) and amphibians, particularly their eggs or larvae (Axelsson et al., 1997).
- **As ecosystem engineers:** Crayfish live in a variety of aquatic and terrestrial (land-based) habitats. They can impact habitat quality and available resources for other organisms (Reynolds et al., 2013).
    - **Burrowing** is a fascinating crayfish behavior. The ability to dig burrows and other underground chambers is an important behavioral adaptation of many species of crayfish that helps them survive in multiple ways:
        - **Protection from predators**: Burrowing provides protection from the many animals that eat crayfish. It offers them a secure hideaway from fish, birds, insects such as dragonfly larvae, and even other crayfish.
        - **Shelter**: Burrows provide shelter against harsh weather conditions, such as drought and heat.
        - **Temperature and moisture regulation**: Burrows allow crayfish to regulate their body temperature and stay hydrated. Crayfish that spend most of their life in burrows will usually dig vertically to reach the water table, which allows their gills to remain moist and allows them to survive times of drought. In areas where water levels fluctuate, such as ponds or creeks that may dry up occasionally, crayfish burrow into the moist soil to avoid dehydration.

- Crayfish burrows also create spaces that can be used by other organisms (Creed & Reed, 2004).
- Burrowing can also increase erosion rates (Statzner et al., 2000; 2003). In terrestrial habitats, primary burrowing crayfish (species that spend most– or all–of their adult lives underground in fields, ditches, prairies, and wet meadows) construct complex networks of tunnels and chambers deep into the soil. These often-expansive subterranean networks can serve as critical conduits for water or gas exchange, thus oxygenating and draining otherwise poor soils (Richardson, 1983; 2007).
- **Types of Crayfish Burrowers** (as shown with letters a–e in the image below):
    - **Primary Burrower (a)**: Primary burrowing crayfish spend most of their lives in burrows they dig in the ground. These burrows can be very deep, sometimes as deep as three meters (about 10 feet). Inside, the burrows have many openings, tunnels, and chambers where the crayfish can move around and live.
    - **Secondary Burrower (b, c, d)**: Secondary burrowers also spend a lot of time in burrows, but their burrows are usually not as deep or complicated as those of primary burrowers. They often dig their burrows near creeks or ponds. These burrows are simpler but still provide a safe home for the crayfish.
    - **Tertiary Burrower (e)**: Tertiary burrowers are sometimes called non-burrowers and only occasionally retreat into simple and shallow burrows when they need to, like during a drought or when water levels are low. Most of the time, they stay out in open water.




**Different types of crayfish burrows, ranging from primary (a), secondary (b, c, d) and tertiary (e)**
*Illustration from Hobbs (1981)*

### Impacts of Invasive Species

Unfortunately, non-native crayfish species introduced through human activities present a significant threat to many of the native crayfish species in the Great Lakes and surrounding areas. In some cases, these non-native crayfish can be considered invasive (i.e., cause ecological and economic harm), given their abilities to rapidly colonize new habitats and displace native species. Invasive crayfish have already displaced native crayfish from considerable portions of their ranges and have dramatically altered ecosystem structure in some places (Wilson et al., 2004). Invasive crayfish are therefore a formidable threat to both crayfish biodiversity and freshwater ecosystems in the Great Lakes and worldwide (Lodge et al., 2000a).

Invasive crayfish in the Great Lakes region are described in the guide at the end of the lesson. They negatively impact 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 the spread of crayfish, through release of classroom science organisms, live fishing bait, pets, etc.

An **invasive species** is defined as any non-native organism that causes harm to the environment, economy, or human health ("Invasive Species in the Great Lakes," EPA). 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 Council).

**Introduction pathways** of invasive species are presented with visuals as cards at the end of this lesson. Additional information about native and invasive crayfish is found in the "Common Native and Invasive Crayfishes of the Great Lakes Region" guide and the "Expand Knowledge + Skills" section at the end of the lesson.

## Materials

- Copies of the following for each student or group of 3–4 students (found after lesson):
  - "Common Native and Invasive Crayfish of the Great Lakes Region"
  - Sets of crayfish roles and introduction pathways cards
- Copies of the "Communicating about Crayfish + Their Impacts" handout for each student
- *Optional:* Colored pencils, markers, and/or crayons for students to share
- *Optional:* Posterboard

## Preparation

1. Ensure all materials above are ready for student use. Cut up cards and separate them into two groups:
   - Crayfish roles, and impacts of invasive crayfish
   - Introduction pathways
2. *Optional:* Learn more about topics addressed in the lesson with the sources listed in the More Resources/References section at end of the lesson to prepare to answer student questions.
3. *Optional:* Arrange for a guest speaker with expertise on freshwater habitat restoration projects to visit your class. Contact us for possible recommendations: invasivecrayfish.org/contact-us.

## Teaching Suggestions in the 5E Model

### *Engage*

1. Engage students by showing them live crayfish (if available) or preserved crayfish. Pass out the "Common Native and Invasive Crayfishes of the Great Lakes Region" guides and ask them to work in small groups of 3–4 students to identify the species, using the guides, prior knowledge, and/or additional research.

### *Explore*

2. After a few minutes, discuss student ideas and how they were able to identify the species.
3. Ask students to take out their science notebooks or blank paper. Invite them to draw a vertical line down a blank page to create two columns of about the same width. Ask them to label the first column "Crayfish Roles" and the second column "Impacts of Invasive Crayfish." Invite them to brainstorm ways native crayfish can benefit their ecosystems and record those ideas in the first column. Negative impacts of invasive crayfish can also be brainstormed in their groups; students can record their ideas in the second column.
4. Circulate through the groups, answering (and asking) questions to help them get started (if necessary). After a few minutes, tell students they will have one more minute to brainstorm and to be prepared to share their best ideas with the class.
5. Allow groups to share their ideas and then pass out the sets of cards that describe crayfish roles and impacts from the end of the lesson. Ask them to work with their groups to try to match the photo cards with the correct descriptions, as well as organize them into groups for the positive roles of natives and negative impacts of invasive crayfish.

### *Explain*

6. Pass out the "Communicating about Crayfish + Their Impacts" handout, one for each student. Ask them to read through the questions together and discuss their ideas. Then invite them to write creatively to complete the activity. Circulate through the room to support students, or you might consider taking them outside to work.
7. After about 15 minutes, tell them they can take a break in two minutes to share one of their creative responses if they would like to do so.
8. After a couple of minutes, invite students to share one of their responses with the class and discuss it.
9. Give students most of the remainder of the class to complete their responses. Tell them that they can also continue writing outside of class time, if desired. Five minutes before the end of class, ask more students to share their responses with the class. Discuss the issues they raise in their funny stories, etc.
10. Close with a discussion of different ways invasive species can be introduced to ecosystems and ways that students can help prevent the problem. You might also ask students to discuss ways they might help to reduce problems of invasive crayfish after they have already been introduced.

## *Enrich/Extend*

- Invite students to choose a native or invasive species from the guide to create posters about them.
    - Pass out posterboard (if available) or students could use backs of used sheets or posters to create colorful, labeled scientific illustrations of the species. Students can annotate the illustrations with descriptions and how they impact their ecosystems.
    - Invite students to conduct additional research, as necessary. They may use the Internet and other available reference sources; they should cite the sources they use for additional information.
- Students can observe live or preserved crayfish and/or their body parts under magnification with a microscope, hand lens, and/or macro lens. You can also use a microscope or macro lens connected to an electronic device and/or data projector to show them to the whole class.
- Invite students to create public service announcement videos about ways to help keep invasive crayfish out of our ecosystems.
- Ask students to use the "Native & Invasive Crayfish of the Great Lakes Region" guide to help them compare a native crayfish species found in your area with an invasive crayfish species that is causing problems in your area. This can be done using a graphic organizer such as a Venn diagram and/or a written analysis.
- 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

## *Evaluate*

- Review student projects and answers to the handout questions.
- Use student participation in class discussion and activities to help determine student understanding.
- Record levels of oral participation and student understanding of native and invasive crayfish and their impacts on freshwater ecosystems, etc.
- 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

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**Videos**

- "The Threat of Invasive Species–Jennifer Klos." TED-Ed: ed.ted.com/lessons/the-threat-of-invasive-species-jennifer-klos
- "What Are Invasive Species?" Explore Nature/National Park Service via YouTube: youtube.com/watch?v=_ZzPM7Dw9Gg

**Lessons/Activities**

- "Bugs Don't Bug Me" and many more aquatic macroinvertebrate lessons, in the "Stream Side Science" program from Utah State Univ. Extension Service: extension.usu.edu/waterquality/educator-resources/lessonplans
- IDAH$_2$O water education resources, including curriculum and videos, Univ. of Idaho Ext.: uidaho.edu/extension/idah2o/resources
- Washington Invasive Species Council curriculum: invasivespecies.wa.gov/educational-materials/teacher-curriculum
- "Watershed Detectives" lesson from Utah State University Ext.: extension.usu.edu/waterquality/files/watershed-detectives.pdf

Name(s): ____________________________________________ Period: ____ Date: _________________

# Communicating about Crayfish + Their Impacts

## Explore the crayfish guide and cards with a small group. Then work individually to . . .

1. **Imagine a new student joins your class on a day you are sampling for crayfish.** How would you explain to them how to identify different native and invasive crayfish species? Include specific characteristics for at least 4 species you might find and differences and similarities between them. You can use sentences and/or labeled illustrations. Feel free to use separate paper or notebooks.

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2. **Imagine you are a crayfish species known to be invasive in the Great Lakes region.** Make up a short funny story about how you and your fellow invaders were able to spread into the area using one of the most common dispersal methods.

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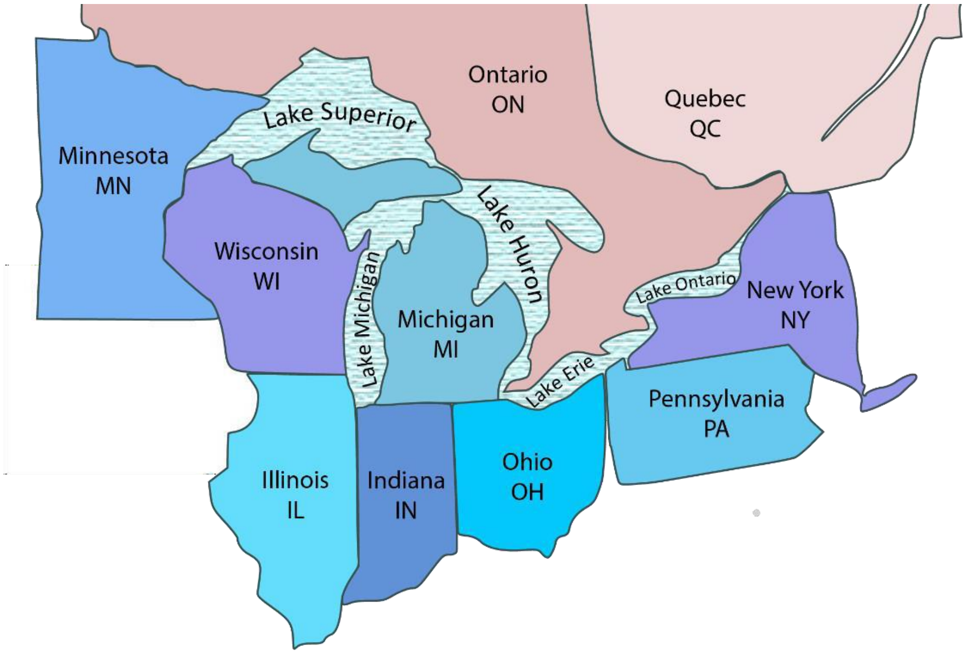
3. **Imagine you are a native crayfish.** Brag to the other aquatic animals about all the positive roles that you and other native crayfish play in aquatic ecosystems.

4. **Imagine you are a native fish or amphibian.** Write about invasive crayfish and all the trouble they are causing you and other native species. What would you recommend scientists and wildlife managers do to solve the problem?

**Learn more:**
"Invasive Crayfish 101." Invasive Crayfish Collaborative: invasivecrayfish.org/invasive-crayfish-101

# *Common Native and Invasive Crayfishes in the Great Lakes Region*




**The Great Lakes region includes the eight U.S. states and two Canadian provinces shown above.**

*Graphic: Rick Reynolds, adapted from map of North America by El bart089 CC-BY-SA 3.0*

| Native Crayfish Species | Invasive Crayfish Species | Other High-Risk Species |
|---|---|---|
| **Big water crayfish**<br>*Cambarus robustus* | **Obscure/Allegheny crayfish**<br>*Faxonius obscurus*<br><br>Photo: Smithsonian Environmental Research Center CC BY 2.0 | **Common yabby**<br>*Cherax destructor*<br><br>Photo: Daiju Azuma CC BY-SA 2.5 |
| **Digger crayfish**<br>*Creaserinus fodiens*<br><br>Photo: Don Henise CC BY 2.0 | | |
| **Calico crayfish**<br>*Faxonius immunis* | **Rusty crayfish**<br>*Faxonius rusticus*<br><br>Photo: Wisconsin Dept. of Natural Resources | **Australian redclaw**<br>*Cherax quadricarinatus* |
| **Northern clearwater crayfish**<br>*Faxonius propinquus* | | **Signal crayfish**<br>*Pacifastacus leniusculus* |
| **Virile crayfish**<br>*Faxonius virilis* | | |
| **Devil crayfish**<br>*Lacunicambarus diogenes* | **Red swamp crayfish**<br>*Procambarus clarkii*<br><br>Photo: Luc Hoogenstein CC BY-SA 4.0 | **Florida/electric blue crayfish**<br>*Procambarus alleni* |
| **Paintedhand mudbug**<br>*Lacunicambarus polychromatus* | | |
| **White River crayfish**<br>*Procambarus acutus* | | **Marbled crayfish**<br>*Procambarus virginalis* |

# NATIVE CRAYFISH SPECIES

## Big Water Crayfish (*Cambarus robustus*)

**A big water crayfish in its rocky habitat.** *Photo: Zack Graham*

**Description**: Big water crayfish are a large species. Carapace lengths can be more than 5 cm long. The overall body color is greenish-brown. They have:

- Large, strong chelae with two rows of tubercules (bumps).
- A long, narrow rostrum with rounded corners.
- An areola that is open and somewhat wide.

**Habitat**: Big water crayfish are commonly found under large, flat rocks. They do not usually burrow, except to survive freezing temperatures or prevent drying out when it is hot. They can live in a wide range of water temperatures and pH levels. They can move short distances over dry land.

**Distribution**:

- Native to the Great Lakes and Ohio River watersheds
- Found from central Michigan to northern Indiana and northern and eastern Ohio
- They are also found throughout southern and central Ontario, as well as throughout Quebec.

**Source:** "Cambarus robustus." USGS: nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=207

## Digger Crayfish (*Creaserinus fodiens*, formerly *Cambarus/Fallicambarus fodiens*)

**Like most crayfish, digger crayfish can survive out of the water for short periods.** *Photo: Zack Graham*

**Description**:

- Heavy-bodied, olive-brown or reddish-tan colored
- A pale, iridescent stripe along the midline of the abdomen
- Dark brown blotches cover the body
- Broad chelae with wide, flattened fingers
- Deep groove at base of moveable finger
- Broad rostrum with a trough-like depression
- No areola

**Habitats**:

- Seasonal wetlands, wooded floodplains, and low-lying fields
- Often lives in burrows up to 3 feet deep

**Distribution**:

- Digger crayfish live in the Mississippi, Ohio River and Great Lakes watersheds.
- Found from southeastern Wisconsin and central Illinois to eastern Ohio and southern Michigan
- They also live throughout southern Ontario.

**Sources**:


- "Digger Crayfish." Missouri Dept. of Conservation: mdc.mo.gov/discover-nature/field-guide/digger-crayfish
- "Digger Crayfish." Illinois Dept. of Natural Resources: dnr.illinois.gov/education/wildaboutpages/wildaboutinvertebrates/wildaboutcrayfish/wacfdiggercrayfish.html

## Calico Crayfish (*Faxonius immunis*)

**Calico crayfish are also called papershell crayfish. They have thin shells.**
*Photo: Chris Lukhaup*

**Description**:

- Calico crayfish have a range of color patterns, from black and brown to mottled green, gray, and brown.
- They sometimes have blue, green, or purple chelae.
- Chelae are large with fairly long fingers. Chelae have large tubercules.
- They have an hourglass pattern on their carapace and tail segments.

**Habitats**:

- Calico crayfish live in many habitats. These include small gravel-bottom streams and slow-flowing creeks, lakes, and ponds with muddy bottoms.
- They can build simple burrows to prevent getting dried out.

**Distribution**:

- Calico crayfish live in clean rivers across the Midwest. They are also found in southern Ontario and throughout Quebec.
- They do not live in northwestern Minnesota, central and northern Wisconsin, and southern and eastern Ohio.

**Sources**:

- "Faxonius immunis." USGS: nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=210
- "Common Crayfishes of the Chicago Region." Field Museum: fieldguides.fieldmuseum.org/sites/default/files/rapid-color-guides-pdfs/981_usa_common_crayfishes_of_the_chicago_region.pdf

## Northern Clearwater Crayfish *(Faxonius propinquus)*

*Photo: Chris Lukhaup*

**Description**:

- A relatively small crayfish with a carapace length of 25–35 mm
- Usually brownish-green with a dark saddle spanning the top (dorsal side) of its abdomen
- Large chelae; the tips are orange or red with black rings
- Areola is open and wide

**Habitats:**

- Found in rivers, swiftly flowing streams, and lakes
- Prefer rocky areas; will seek shelter in shallow crevices

**Distribution**:

- They are found in the Mississippi River and Great Lakes. They are abundant across the upper Midwest east of the Mississippi River.
- They live in eastern Minnesota and Iowa to northern Ohio, in the Wabash River watershed of Illinois and Indiana, and throughout Ontario and Quebec.

**Sources**:


- "Faxonius propinquus." USGS: nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=2249
- "Northern clearwater crayfish." Illinois Dept. of Natural Resources: dnr.illinois.gov/education/wildaboutpages/wildaboutinvertebrates/wildaboutcrayfish/wacfnorthernclearwatercrayfish.html

## Virile (Northern) Crayfish *(Faxonius virilis)*

*Photo: Alan Schmierer CC0*

**Description**:

- Varies in color, from light brown to olive-brown
- Body has dark brown markings on each segment of abdomen
- Long, sharp tubercles along the middle margin of the chelae
- Tips of chelae are orange
- Upper walking legs and chelae can be bluish in color
- Areola is narrowly open

**Habitat:**

- They live in small streams, large rivers, and inland lakes.
- Prefer hard, rocky surfaces but can use areas with plants
- Can live in small burrows in muddy river bottoms.

**Distribution**:

- Native to the Great Lakes, Missouri River, upper Mississippi River, and lower Ohio River
- They are also found in Missouri, Arkansas, Oklahoma, Texas, and New York.
- They occur throughout Ontario, as far north as the James Bay watershed, and in Quebec.
- Non-native introductions have been made in parts of Ohio, Pennsylvania, and New York.

**Sources**:

- "Faxonius virilis." USGS: nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=215
- "Virile crayfish." NatureServe: explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.112669/Faxonius_virilis
- "Faxonius virilis." Smithsonian Environmental Research Center: invasions.si.edu/nemesis/species_summary/97425

## Devil Crayfish (*Lacunicambarus diogenes*, formerly *Cambarus diogenes*)

*Photo: Chris Lukhaup*

**Description**:

- Usually olive or tan in color, without obvious blotches or spots
- Chelae have large knobs and tubercules, as well as long bright red/orange highlights on tips.
- Rostrum is deeply grooved and deep red in color.
- Areola is closed.

**Habitat:**

- Found near streams, ponds, lakes, and ditches
- They burrow and spend most of their time underground. They pile balls of mud at the top of their burrows. They often reveal their presence by these "mud chimneys."

**Distribution**:

- Occur across much of the eastern United States
- They are in every state east of the Rocky Mountains except the New England states.

**Sources**:

- "Devil crayfish." Missouri Dept. of Conservation: mdc.mo.gov/discover-nature/field-guide/devil-crayfish
- "Devil crayfish." Illinois Dept. of Natural Resources: dnr.illinois.gov/education/wildaboutpages/wildaboutinvertebrates/wildaboutcrayfish/wacfdevilcrayfish.html
- "Lacunicambarus diogenes." Georgia Dept. of Natural Resources: georgiabiodiversity.org/portal/profile?es_id=405722&group=crayfish

## Paintedhand Mudbug (*Lacunicambarus polychromatus*)

**Paintedhand mudbug with a tan/olive green coloration**. *Photo: Zack Graham*

**Description**:

- Broad body and reddish-tan to olive green in color
- Segments of the abdomen and tail fan have red edges.
- Chelae are large, often with green, blue, and olive tones. They have red tips.
- Chelae are covered with many small tubercules.
- The rostrum is deeply grooved and highlighted in deep red.
- Areola is closed.

**Habitat:**

- They are widespread and common in wetlands, wet meadows, stream banks, and ditches.
- They spend most of their life in deep, complex burrows.

**Distribution**:

- Occur in the lower Mississippi and Ohio River watersheds
- They are in southern Illinois and northeast through southern Michigan and western Ohio.
- They are also found in southwestern Ontario, in the Detroit River basin in Windsor.

**Source**:

- “Paintedhand mudbug.” Missouri Dept. of Conservation: [mdc.mo.gov/discover-nature/field-guide/paintedhand-mudbug](mdc.mo.gov/discover-nature/field-guide/paintedhand-mudbug)

## White River Crayfish (*Procambarus acutus*)

*Photo: Chris Lukhaup*

**Description**:

- Large-bodied and usually brick red or tan. They have a black wedge on the top (dorsal surface) of the abdomen.
- They have very long and narrow chelae. Their chelae and body are covered with small (usually black and white) tubercles.
- Rostrum is flat. Areola is open.
- Don't mistake them for invasive red swamp crayfish! Red swamp crayfish have red tubercles on their chelae instead of black.

**Habitat:**

- They live in wetlands, ditches, creeks, and lakes.

**Distribution**:

- White river crayfish are found in the southern Great Lakes watersheds to the Gulf of Mexico.
- They also live in the Atlantic Slope (from Maine to Georgia).
- They are an invasive species in Ontario. They are non-native in southeastern Wisconsin and western New York.

**Sources**:

- "Procambarus acutus." USGS: nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=216

# INVASIVE CRAYFISH SPECIES

## Obscure/Allegheny Crayfish *(Faxonius obscurus)*

*Photo: Smithsonian Environmental Research Center (CC BY 2.0)*

**Description**:

- Small-bodied (4–8 cm) with light brown to olive-green coloration.
- Has a dark brown wedge on the abdomen (tail).
- Large chelae with two rows of rounded tubercles along the middle margin. The tips of its fingers are orange with black bands.
- Rostrum curves inward. Areola is open.

**Habitat:**

- They are found in small to medium-sized creeks with rocks, gravel, or sand.

**Distribution**:

- Native range includes the Ohio River watershed in extreme eastern Ohio. Also found in parts of Quebec.
- They are invasive throughout southern and central Ontario.
- Non-native in Lake Huron and Lake Ontario
- Likely introduced to new areas through bait bucket releases. They are a known threat to native crayfish due to competition.

**Sources**:


- "Allegheny crayfish." NatureServe: explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.112938/Faxonius_obscurus
- "Faxonius obscurus." USGS: nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=2243

## Rusty Crayfish (*Faxonius rusticus*)

*Photo: Lake County AIS CC0*

**Description**:

- Olive-green to gray in body color
- Rusty-colored spot on each side of the carapace
- They have black rings around the tips of orange fingers.
- Larger individuals sometimes have chelae with light blue or violet colors.
- Areola is open.

**Habitat:**

- Rusty crayfish can live in many habitat types. These include lakes, ponds, streams, and rivers.

**Distribution**:

- Rusty crayfish are native to the Ohio River basin. This includes parts of Kentucky, Ohio, Indiana, and northern Tennessee.
- Rusty crayfish are one of the most widespread invasive crayfish in the U.S. Non-native populations are in the Great Lakes region, including parts of Canada.
- They have also spread as far west as Oregon and as far east as Maine.
- They have moved into new areas partly due to canals connecting waterways in the upper Midwest and Great Lakes regions.
- Bait bucket releases may have increased their spread.

**Sources**:


- "Rusty crayfish." USFWS: fws.gov/sites/default/files/documents/Ecological-Risk-Screening-Summary-Rusty-Crayfish.pdf
- "Rusty crayfish." USDA: invasivespeciesinfo.gov/aquatic/invertebrates/rusty-crayfish

## Red Swamp Crayfish (*Procambarus clarkii*)

*Photo: Luc Hoogenstein CC BY-SA 4.0*

**Description**:

- Adults are easily identified by their brick red body.
- They differ from most other crayfish species found in the Great Lakes by having chelae that are long and slender.
- Red tubercles on the chelae often extend onto the body.
- Juvenile red swamp crayfish are difficult to identify. They are a variety of tan or brown shades.

**Habitat:**

- They are found in rivers, lakes, ponds, streams, and canals and live in seasonally flooded swamps and marshes and ditches with mud or sand bottoms.
- Can live in a range of temperature, pH, oxygen, and pollution levels

**Distribution**:

- Native to the south central U.S. along the Gulf Coast and along the Mississippi River basin.
- Non-native populations live as far north as southern Illinois and in several other Great Lakes, and mid-Atlantic states.
- They have spread to Idaho, Utah, Arizona, South Dakota, Nebraska, and Georgia.
- They are among the most popular and frequently raised crayfish species in the world. They are found in the bait, aquaculture, and pet trade industries.

**Sources**:


- "Red swamp crayfish." USFWS: fws.gov/sites/default/files/documents/Ecological-Risk-Screening-Summary-Red-Swamp-Crayfish.pdf
- "Procambarus clarkii." USGS: nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=217

# OTHER HIGH-RISK AND PROHIBITED CRAYFISH SPECIES

The following species have not yet been established in the Great Lakes region. However, they are high risk or prohibited based on risk assessments and Great Lakes region crayfish regulations.

## Common Yabby (*Cherax destructor*)

*Photo: Daiju Azuma CC 2.5*

**Description**:

- A very large and aggressive crayfish. They can grow up to 30 cm.
- They have a smooth body and short, stout pincers.
- Their rostrum is short, broad, and triangular.
- Their color ranges from green-beige to almost black. Captive animals are usually blue-grey.

**Habitat:**

- They can live in many environments and habitats. These include springs, lakes, alpine streams, subtropical creeks, swamps, dams, and canals.
- In Australia, they burrow extensively. Burrows can destabilize shorelines.

**Distribution**:

- They are native to Australia.
- They have been transported globally for aquaculture, food markets, and aquariums.
- They are not yet found in the U.S. or in any waters connecting to the Great Lakes. If introduced into the Great Lakes, they may change aquatic food webs. They would compete with native crayfish and could spread diseases, such as crayfish plague.

**Sources**:

- “Yabby (Cherax desctructor)” USFWS: fws.gov/sites/default/files/documents/Ecological-Risk-Screening-Summary-Yabby_0.pdf
- “Cherax destructor.” NOAA: nas.er.usgs.gov/queries/greatlakes/FactSheet.aspx?Species_ID=3648&Potential=Y&Type=2

## Australian Redclaw (*Cherax quadricarinatus*)

*Photo: 5snake5 CC BY-SA 4.0*

**Description**:

- This is a large-bodied and aggressive crayfish. They can grow up to 25 cm.
- Blue-green to green coloration and red/maroon highlights
- Adult males have a bright red patch on the outer margins of their chelae.
- Four long, distinct ridges on the head

**Habitat:**

- Found in freshwater creeks and water bodies in tropical regions of Australia
- Can live in habitats with a wide range of temperatures and dissolved oxygen levels

**Distribution**:

- Native to Australia
- Introduced in parts of California, Nevada, and Texas
- They may impact native species through competition, predation, or habitat changes. They carry diseases that could spread to native crayfishes and shrimps.
- They are a popular aquarium animal because they are colorful and hardy. Aquarium dumps are a possible means of introduction.

**Sources**:


- "Cherax quadricarinatus." USGS: nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=220
- "Redclaw (Cherax quadricarinatus)." USFWS: fws.gov/sites/default/files/documents/Ecological-Risk-Screening-Summary-Redclaw.pdf

## Signal Crayfish (*Pacifistacus leniusculus*)

**Signal crayfish female with eggs on the lower abdomen.**
*Photo: Alaska Region USFWS CC0*

**Description**:
- They are usually bluish-brown to reddish-brown in color on their dorsal side. Average carapace length is 50-70mm.
- The undersides of their claws are bright red. The base of each claw joint has a white or turquoise colored patch.
- The surfaces of the claws and carapace are smooth. They lack the tubercles that are typical of other non-native crayfish.
- Areola is open.

**Habitat:**
- They have moved into many types of habitats. These range from warm coastal waterways to sub-alpine waters.

**Distribution**:
- They are native to the northwestern U.S. They live in the Columbia River Basin and areas of Washinton, Oregon, Idaho, and British Columbia.
- They are now found in the midwestern region of the U.S. Scientists confirmed sightings in Lake Winona, Minnesota in October 2023.
- May spread to new areas due to live bait release, stocking for harvest, or stocking for fish food.

**Sources**:

- "Pacifastacus leniusculus." USGS: nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=200
- "Signal crayfish (Pacifastacus leniusculus)." Minnesota Dept. of Natural Resources: dnr.state.mn.us/invasives/aquaticanimals/signal-crayfish.html

## Florida/Electric Blue Crayfish *(Procambarus alleni)*

*Photo: Chris Lukhaup*

**Description**:

- Wild Florida crayfish can be blue, brown, or red in color. Captive crayfish have been bred to have a brilliant blue color.
- They have dark, circular areas called "headlights" at the base of both antennal glands.
- They have a narrowly open areola.

**Habitat:**

- They tolerate a wide range of habitats. These include seasonal and permanent wetlands, ditches, and small streams.

**Distribution**:

- Native range includes most of central and southern Florida.
- They are not established in the Great Lakes yet.
- There is a high risk of introduction. They are popular in the aquarium trade due to their color. Future introductions may occur through aquarium releases.

**Sources**:


- "Florida Crayfish (Procambarus alleni)." USFWS: fws.gov/sites/default/files/documents/Ecological-Risk-Screening-Summary-Florida-Crayfish.pdf
- "Procambarus alleni." USGS: nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=2812

## Marbled Crayfish (*Procambarus virginalis*)

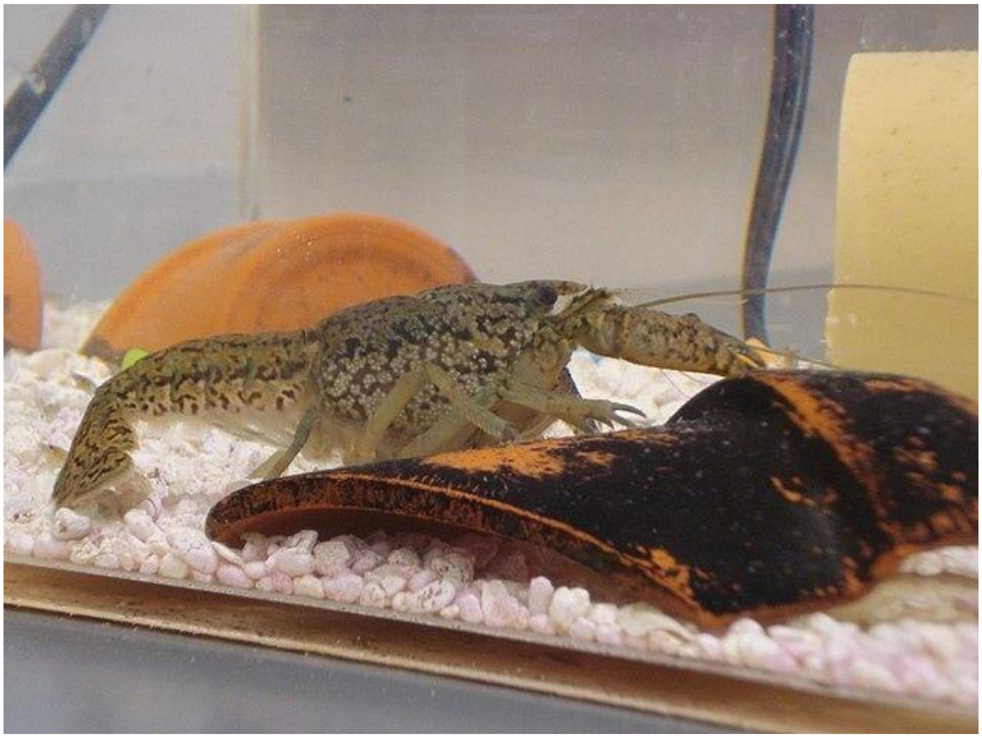


*Photo: Zfaulkes CC0*

**Description**:

- Are usually olive to brown in color when found in the wild
- Have a marbled pattern that covers their entire back and claws
- A dark stripe runs down each side of their carapace and abdomen.
- Male marbled crayfish do not exist. All individuals are female and reproduce by parthenogenesis.

**Habitat:**

- This species does not occur naturally in the wild. They are descended from the slough crayfish, found in the southeastern U.S.
- Their environmental impacts are unknown.

**Distribution**:

- The marbled crayfish is a common species in the pet trade.
- Multiple individuals have been found in the Lake Ontario watershed near Toronto.
- Only one individual is needed to establish a population. Thus, it the potential to be highly invasive.
- Not yet found in the U.S. as of this writing.

**Sources**:


- "Marbled Crayfish (Procambarus virginalis)." USFWS: fws.gov/sites/default/files/documents/Ecological-Risk-Screening-Summary-Marbled-Crayfish.pdf
- "Procambarus virginalis." USGS: nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=3656

# Crayfish Role: **Prey**

*Photo: Brocken Inaglory CC BY-SA 3.0*

- Over 200 animal species eat crayfish, including mammals, birds, reptiles, amphibians, fishes, and insects, like dragonfly larvae (DiStefano, 2005).
- Fish, such as bass, are especially prominent crayfish predators (Probst et al., 1984; Rabeni, 1992).
- A wide variety of other fish species, from brook trout to creek chubs, also consume crayfish (Newsome & Gee, 1978; Gowing & Momot, 1979).
- Crayfish are a vital food source for other important animals in freshwater ecosystems, such as the hellbender, an endangered salamander (Wiggs, 1976).

*Photo: Brian Gratwicke CC BY-SA 2.0*

- Crayfish are also consumed by many land-based animals including minks, raccoons, and wading birds (Baker et al., 1945; Toweill, 1974; Martin & Hamilton, 1985).

# Crayfish Role: **Consumers**

**Crayfish compete with other invertebrates, such as snails, for food. Crayfish also eat them!**
*Photo: Mlogic CC BY-SA 3.0*

- Crayfish are **omnivores**: They eat a wide variety of food items, from tiny phytoplankton to fish.
- Crayfish are also important **scavengers** of dead animals and dead plant matter, such as leaves.
- Crayfish eat producers such as algae (Goldman, 1973) and aquatic plants (Creed, 1994). Crayfish can eat so much algae and plant material that they strongly impact the densities of these organisms (Goldman, 1973).
- Crayfish also feed on many different types of invertebrate prey, including snails (Kreps et al., 2012), insects and their larvae (Parkyn et al., 2001), and even other crayfish (Nakata & Goshima, 2006).
- Crayfish also eat vertebrates such as fish (Rahel & Stein, 1988) and amphibians, especially their eggs and larvae (Axelsson et al., 1997).

## Crayfish Role: **Ecosystem Engineers**

**A burrowing crayfish peeks out of its burrow.**
*Photo: Mlogic CC BY-SA 3.0*

Crayfish can impact habitat quality for other organisms (Reynolds et al., 2013). This can happen through:

- **Burrowing**: Many species of crayfish build burrows. These create spaces that can be used by other organisms (Creed & Reed, 2004). Burrowing can also increase erosion rates (Statzner et al., 2000; 2003). Burrowing crayfish species can construct complex networks of tunnels and chambers deep into the soil. These can help water and gases to move, adding oxygen and draining soils (Richardson, 1983; 2007).
- **Consuming detritus**: Crayfish can also eat large amounts of leaf litter and other dead plant and animal matter (Huryn & Wallace, 1987; Schofield et al., 2001). The processing of detritus by crayfish can change the number of insect larvae, which can be an important food source for fishes and other aquatic vertebrates (Creed & Reed, 2004; Hoopes, 1960). Removing detritus can also help keep water clean.

## Impact of Invasive Crayfish: **Displacement + Loss of Biodiversity**

**An invasive red swamp crayfish**
*Photo: National Park Service CC 0*

Invasive crayfish are aggressive and fast-growing. This threatens native crayfish biodiversity. In fact, the introduction of nonnative crayfish may be the single greatest threat to global crayfish biodiversity (Lodge et al., 2000a).

In the Great Lakes region, invasive crayfish such as the rusty crayfish (*Faxonius rusticus*), have displaced native species from large portions of their natural ranges (Momot, 1996; Taylor & Redmer, 1996; Olden et al., 2006).

## Impact of Invasive Crayfish: **Effect on Other Aquatic Invertebrates**

**A mayfly nymph: important food for fish**
*Photo: National Park Service CC 0*

- Invasive crayfish can cause populations of other aquatic macroinvertebrates (like insect larvae) to decline (Charlebois & Lamberti, 1996).
- Invasive crayfish have also been shown to reduce macroinvertebrate biodiversity in stream ecosystems (Stenroth & Nyström, 2003).
- A long-term study in Wisconsin showed a dramatic decline in snail densities after rusty crayfish were introduced (Wilson et al., 2004). The same study also reported big declines in insect species such as dragonflies and caddisflies.

## Impact of Invasive Crayfish: **Declines in Native Fish Populations**


**Humans and wildlife depend on native fish, like this walleye, for food.** *Photo: Pverdonk CC BY-NC 2.0*

Invasive crayfish can reduce native fish populations by:

- Competing with native fishes for similar prey species.
- Reducing the density of aquatic plants used by young fish as cover (Wilson et al., 2004).

Invasive crayfish may also reduce the breeding success of fish by eating their eggs (Dorn & Mittelbach, 2004).

# Impact of Invasive Crayfish: **Negative Impacts on Amphibians**

**A northern leopard frog**
*Photo: Brian Gratwicke CC BY 2.0*

Invasive crayfish have reduced native amphibian species around the world.

- For example, red swamp crayfish have contributed to the decline of some amphibian species by eating their eggs (Gamradt & Kats, 1996).
- In ecosystems where native crayfish are present, red swamp crayfish can consume amphibian eggs at a higher rate than native crayfish species (Renai & Gherardi, 2004).
- Invasive crayfish can also reduce food availability, which could impact amphibian growth and survival (Cruz et al., 2006).

# Impact of Invasive Crayfish: **Destruction of Aquatic Plants**

**Duckweed: a tiny but important aquatic plant**
*Photo: Mokkie CC BY-SA 3.0*

Aquatic plants provide habitat for fishes, amphibians, and aquatic macroinvertebrates.

- Crayfish can reduce biomass and biodiversity of aquatic plants (Lodge & Lorman, 1987; Wilson et al., 2004; Rosenthal et al., 2006).
- Invasive crayfish consume plant material at a faster rate than some native crayfish species.
- Such changes can strongly affect ecosystem structure and function. This could result in the decline or displacement of other species in freshwater ecosystems.
- Invasive crayfish can also reduce the density of aquatic plants used for cover by young fish (Wilson et al., 2004).

## Impact of Invasive Crayfish: **Disease Transmission**


**Signs warning of the dangers of disease transmission by invasive crayfish in Europe**
*Photo: Kevin Higgins CC BY-SA 2.0*

- Invasive crayfish can transmit diseases to native crayfish species. For example, crayfish plague *(Aphanomyces astaci)* has caused major population declines and range reductions in native European crayfish. The disease was introduced to Europe through invasive North American crayfish *(Lodge et al., 2000a)*.
- While introduced diseases have not yet been reported for native crayfish in the Great Lakes, the potential for disease transmission exists.
- A study in California showed that invasive crayfish lead to more mosquitoes and risk of mosquito-borne diseases: newsroom.ucla.edu/releases/invasive-crayfish-lead-to-more-mosquitoes-and-risk-of-disease-in-southern-california

## Introduction Pathway of Invasive Crayfish: **Bait**

**A bucket of live invasive red swamp crayfish**
*Photo: Defense Visual Information Distribution Service CC 0*

- Invasive crayfish sometimes spread when they are used as bait.
- Live crayfish that are left over after fishing are sometimes released.
- These "bait bucket" introductions are one of the ways non-native crayfish invade new areas (Ludwig & Leitch, 1996).

# Introduction Pathway of Invasive Crayfish: **Aquariums**

**A young blue crayfish in an aquarium**
*Photo: xcalibur8OP CC BY 3.0*

- Crayfish and other freshwater crustaceans have become increasingly popular as pets *(Chucholl, 2013)*. This is partly due to their striking colors.
- Live crayfish are transported across state borders, and even internationally, for the pet trade.
- Some crayfish can grow to a large size quite rapidly, leading to overcrowding or aggression towards other organisms in a tank. For this reason, crayfish pets are often released into nearby water bodies.

# Introduction Pathway of Invasive Crayfish: **Aquaculture**

**A crayfish farm**
*Photo: Natalie Maynor CC BY 2.0*

- Crayfish are grown and sold for a variety of purposes, including for food or for use as bait in recreational fishing.
- Aquaculture facilities that supply crayfish to food and bait vendors can spread invasive species such as red swamp crayfish.
- Facilities farming non-native crayfish can accidentally spread these species to nearby water bodies by overland migrations or during flood events.
- Even facilities that raise other organisms, such as fish in ponds, can risk transporting invasive crayfish if crayfish make their way into the ponds and then are accidentally included with shipments of live animals.

# Introduction Pathway of Invasive Crayfish: **Classrooms**

**Students hold invasive rusty crayfish in a classroom.**
*Photo: Jennifer England*

- Crayfish are used in classrooms as pets or as tools to enrich learning. This can lead to accidental or intentional release of live organisms, negatively impacting local environments.
- Red swamp and rusty crayfish are common in biological supply kits provided to teachers for science lessons. It is estimated that 25% of elementary schools in the US purchase and use live crayfish in their science classes (Patton, 2011).
- It is important to be aware of the alternatives to releasing classroom animals and plants into the wild. Even native crayfish species that are caught in the wild and brought into the classroom should never be re- released into the wild.

Invasive Crayfish Collaborative
Great Lakes

*Lesson 5*

# Collecting Reliable Crayfish Data

**Subjects** Science, Math, Language Arts

**Grade Levels** Ideal for grades 6–12, adaptable for 3–5

**Time** 45 minutes or more + travel time; overnight preparation suggested

**A student safely holds a crayfish by the carapace.**
*Photo: Illinois-Indiana Sea Grant*

## Lesson Overview

Students participate in a scientific field study* and apply what they have been learning about native and invasive crayfish. They first learn to safely collect reliable data from a nearby freshwater ecosystem. Then they analyze the data and present it visually. By participating in the project, students develop an understanding of the power of community science to help monitor invasive and native species and improve watershed health. Students are strongly encouraged to complete prior lessons before beginning this study.

**A scientific collection permit is required for the crayfish study, and approval may take up to 4 months. Plan early to avoid delays.*

## Goals

- Students will demonstrate techniques for safely collecting and then submitting accurate data about the distribution of crayfish species.
- Students will experience the power of monitoring invasive and native species to assist researchers and wildlife managers and improve the health of their local watershed.
- Students will be encouraged to be better stewards of their local watersheds.

## Objectives

- Students will follow a scientific protocol to measure and record data about crayfish specimens in a natural freshwater ecosystem.
- 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

### Building Toward

- MS-LS1-4: Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
- MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
- MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- 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

- Stability and Change
- Structure and Function

## Science & Engineering Practices

- Asking Questions and Defining Problems
- Constructing Explanations (for science) and Designing Solutions (for engineering)
- Obtaining, Evaluating, and Communicating Information

## Core and Component Ideas in the Life Sciences

### LS1: From Molecules to Organisms: Structures and processes

- LS1.A: Structure and Function
- LS1.B: Growth and Development of Organisms
- LS2: Ecosystems: Interactions, Energy, and Dynamics

## Core and Component Ideas in Earth and Space Sciences

### ESS2: Earth's Systems

- ESS2.C: The Roles of Water in Earth's Surface Processes

# Common Core State Standards

## Speaking and Listening Standards for Grade 6

(similar standards for grades 3–5; 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.

**Standard 6.** Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

**Math Standards: Measurement & Data**

- Represent and interpret data

**Math Standards: Statistics & Probability**

- Develop understanding of statistical variability
- Summarize and describe distributions

## Center for Great Lakes Literacy Principles

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

## Teacher Background

This project provides you and your students with the opportunity to support ongoing scientific research. As we have explored in other lessons in this curriculum, a few species of crayfish are negatively impacting other freshwater species at an alarming rate, and your class can play an important role in better understanding and addressing the problem. They should also gain a closer connection to—and appreciation of—your local watershed and its health, for the benefit of people and wildlife. This lesson focuses on collecting data safely in the field and allowing students to begin to explore data through analysis and visualization.

Invasive crayfish pose a substantial threat to aquatic habitats in the Great Lakes region because of their ability to reduce habitat quality, to dramatically alter aquatic food webs, and to outcompete native species. Current efforts to prevent the introduction and spread of invasive crayfish consist largely of reducing the size of existing populations and encouraging people to refrain from releasing crayfish into new bodies of water. The Invasive Crayfish Collaborative (ICC) focuses on improving collective management and outreach capabilities by disseminating novel crayfish research, encouraging collaboration between members, and conducting research and outreach projects with collaborators.

**A group of students prepares to collect crayfish data with waders and nets from the ICC.**
*Photo: Kelsey Berke*

## Materials

Materials needed will vary based on the methods you will be using to collect crayfish. The ICC can help provide your class with equipment. Email invasivecrayfishcollaborative@gmail.com to ask about available resources, such as:

- Overnight crayfish traps (Frabill Torpedo Crayfish Trap or similar) with ropes and/or nets to catch crayfish
- Bait, such as:
    - Dry dog food: 1/2 cup (113 grams) per trap
    - Traps can also be baited with canned cat food (1 can/trap); bring screwdriver or hammer and nail to site to put holes in can(s)
    - Fish or meat scraps will also work for bait
- Seine nets with poles
- Kick nets or D-frame nets
- Crayfish identification books (i.e., *The Field Guide to Crayfishes of the Midwest:* shop.inrs.illinois.edu/inhs-man.html)
- Boots or waders for stream wading

Other materials you might use include:

- GPS device(s) and/or smartphone(s) to collect latitude and longitude data
- Digital camera(s) and/or smartphone(s) to photograph specimens
- Thermometer(s) or probes for testing water and air temperature
- Field map(s) and/or smartphones with Google Maps app (or similar, if you expect to have coverage)
- Copies of these for student groups to share:
    - Crayfish sampling sheets (found after this lesson)
    - "Native and Invasive Crayfish of the Great Lakes Region" reading (found at the end of Lesson 4)
- Pencils
- Rulers or calipers to measure crayfish
- Cooler/ice (to humanely euthanize invasive crayfish, if found)
- Bucket and gallon-size plastic bag(s)
- Sampling permit(s), if required in your area
- Clothing items listed in the Preparation section, below.
- *Optional:* Digital scale and mesh bag
- *Optional (if trapping crayfish in deeper water):* Buoys
- *Optional:* Tablets or smartphones to submit data directly into the "Great Lakes Crayfish" iNaturalist project page: inaturalist.org/projects/great-lakes-crayfish

- *Optional:* Student field journals
- *Optional:* Magnifying devices such as hand lens(es), and/or macro lenses to attach to smart phones/tablets
- *Optional:* Colored pencils, markers and/or crayons for students to share
- *Optional:* Support from a partner to work with your class. Email invasivecrayfishcollaborative@gmail.com for recommendations.

## Preparation

1. **Obtain a scientific collection permit** if required in your area to collect crayfish.
    - The Illinois Department of Natural Resources requires each classroom participating in this program in Illinois to complete a free "Scientific Collecting Permit" here: dnr2.illinois.gov/ScientificPermit/SciPermit

      If you will be collecting on State of Illinois land you will also need to fill out the "Illinois Site Permit:" naturalheritage.illinois.gov/permits/permit-for-state- sites.html
    - Other Great Lakes state and provincial permits: Scientific collector permits for Indiana, Michigan, Minnesota, Ohio, New York, Pennsylvania, Wisconsin, Ontario, and Quebec can also be found at the end of the Expand Knowledge + Skills section at the end of this lesson.
    - All states: You can likely find the scientific collector permit for your respective state at its respective Department of Natural Resources website. Public sites will likely require completed permits or official approval processes through the landowner (e.g., McHenry County Conservation District, Lake County Forest Preserve). Note that it may take a few weeks to a few months to obtain a state permit for scientific research. Approval for sampling on private property should also be gained from the landowner. If you have questions or need assistance with this process, contact your state fish and wildlife department. You or they can also contact us with questions at invasivecrayfish.org/contact-us.
2. **Visit the "Great Lakes Crayfish" iNaturalist project page** to prepare to submit data: inaturalist.org/projects/great-lakes-crayfish.
3. **Prepare to safely sample crayfish** in aquatic habitats (e.g., streams, rivers, ponds) and share the safety rules below with students:
    - Tell students that they should be prepared to work at a waterbody where they may step on rocks, mud, and other slippery things. To maximize safety, they should wear:
        - Close-toed shoes
        - Layers of clothing
        - These can also be worn or brought to the site, some of which may be provided by contacting invasivecrayfishcollaborative@gmail.com:
            - Waders/tall rubber boots
            - Protective gloves
            - Waterproof pants

- Wading may be difficult for younger students. Grade 3-5 educators should either collect crayfish for their students or have students help set and retrieve overnight traps.
- We highly recommend that all participants apply bug spray prior to entering the site to prevent any mosquito or tick bites that may pose a health risk. Sunscreen should also be applied.
- Inform students of important rules/safety tips, which include:
    - Always work in groups of at least two people.
    - Do not enter a waterbody unless the depth is lower than the knee of the shortest participant. A meter stick or other tool can be used to check depths before moving further into the water. Tell students to be prepared for sudden drop offs in rivers. This is especially important if they will be wearing waders, which can quickly fill with water and become dangerous weights.
    - Look where you are stepping and move slowly. There may be tripping hazards (e.g., boulders, dead trees, roots, etc.) or crayfish at the bottom of the waterbody.
    - In slow-moving streams and stagnant ponds with fine substrate (e.g., mud/muck), there is a risk of stepping in and having your foot sink deeper than you expect.
- You may want to ask students to bring water bottles and snacks for the trip.

4. **Choose an ideal location to collect crayfish**:
    - Ask around in your community and/or use the "American Crayfish Atlas" to identify species near you and where you might find them: findmycrayfish.web.illinois.edu. Click "Map" then select "All Species" to see the data points appear. Zoom in with the "**+**" button in the lower-right.
    - Visit the location(s) prior to field studies to determine if the area(s) is/are safe and accessible for your students.
    - Determine if the location is a suitable environment for crayfish sampling. (Coarse and rocky substrates are most ideal for crayfish sampling.)
    - Begin testing different sampling methods to determine what methodology will work best with your supplies, time available, and level of comfort.
5. **Ensure students return signed permission forms.** There is one listed at the end of this educator's guide.
6. Unless you are taking students to set overnight traps on one field trip, then collecting the traps on a field trip the next day, **we highly recommend that you set traps the afternoon or evening before you want the students to collect them.** If possible, travel to the research site with a small group of students to throw out the traps in a river or stream far enough apart from each other that the lines will not get tangled. You could also wait another day to collect the traps, if necessary.
7. *Optional:* Review the information about native and invasive crayfish at the end of lesson
    - Additional sources are listed in the Expand Knowledge + Skills section at end of the lesson, which could also help you prepare to answer student questions.

## Teaching Suggestions in the 5E Model

### *Engage*

1. Tell students they will be able to collect important data about the native and invasive crayfish species found nearby. The data will be shared with university researchers and wildlife managers in states around the Great Lakes region.
2. Ask students to form groups of 2–4. Show them the available equipment, such as traps, nets, and waders, and ask them to think about what specific techniques they could use to catch crayfish safely based on what they have learned about crayfish and freshwater ecosystems.
   - Ask them to quickly brainstorm their ideas, recording them in science notebooks or with an electronic device.
   - Circulate through the room to answer (and ask) questions. Tell students when they have one more minute to brainstorm and be ready to share their best ideas.
   - Ask the groups to share their ideas and demonstrate possible techniques to the class.
3. *Optional if time allows:* Ask the groups to think of questions about crayfish that may live nearby and where they might be easy to find.
   - Ask them to brainstorm and record their ideas.
   - Circulate through the room to answer (and ask) questions.
   - Ask the groups to share their ideas and discuss how they will now be able to apply everything they've been learning about crayfish to do actual field research in a nearby freshwater ecosystem.
4. You and/or experienced students can demonstrate recommended techniques for how to use the equipment such as crayfish traps and nets. This can be done in the classroom and/or in the field.
   - If traps will be used, explain how to tie a rope to the trap clip. If you are using cat food for bait, explain that before they toss in traps, they will punch holes in the top of a can with a nail or screwdriver and attach it to the inside bottom of the trap. Or they will add a half cup (113 grams) of dog food per trap. It is recommended that leaves, sticks or other vegetation also be added to traps to provide cover for any trapped fish and crayfish and help them avoid predation.
   - Tell students that the most important step in throwing traps into a waterbody is to always remember to hold the end of the rope! They need to completely submerge the traps under water. Then they should tie the rope to something secure on shore, such as a tree.
   - If buoys (or empty plastic bottles) will be used with traps, show how to add your name, contact information, and permit number (if applicable) to them. That information can also be displayed on a card attached to the other end of the rope.

5. **Safely handling crayfish and reducing risk of harm to them and their ecosystems:**

   Ask students how they think they should hold live crayfish.

   - Discuss how they should hold them from the back of the carapace to avoid being pinched and/or avoid hurting the crayfish.
   - Tell students they should return native specimens to the waterbody where you caught them after photographing and identifying them. **Explain that they should never release any organisms into areas from which they did not originate.** If you or your students find an invasive crayfish, please **do not** return it to the waterbody. Instead, place it in a plastic bag and euthanize it by placing it in a freezer overnight. Tell students that by doing so, they are helping the rest of the organisms in the ecosystem.
   - Tell students that if they need to handle crayfish for more than a few minutes, they can dunk the crayfish in water to allow them to rewet their gills.
   - Explain that crayfish may shed their chelae (claws) as a defense mechanism if they are held by their tips, so students should be very careful not to do that.

6. **Photographing crayfish:**

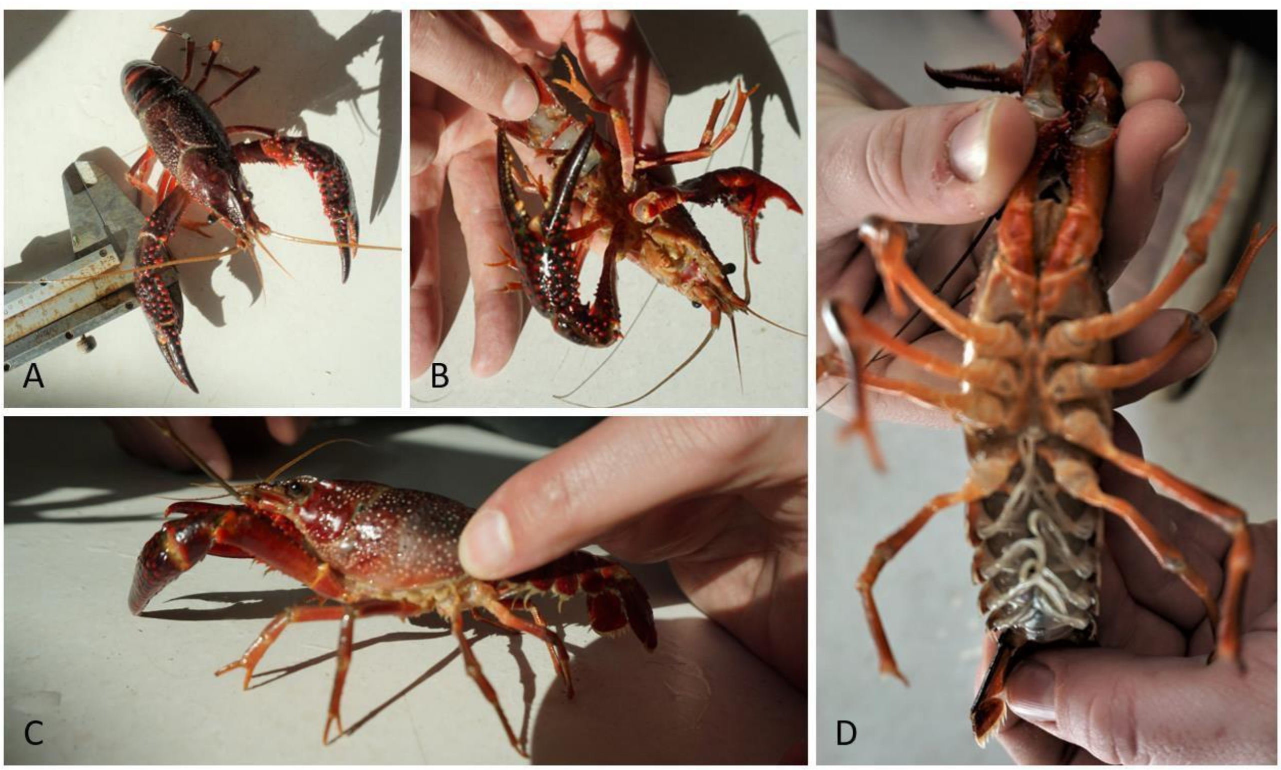
   Guide students through the process of correctly photographing crayfish as shown in the photos below and described here:

   A. From above with a ruler or coin for scale

   B. Close up on chelae (claws)

   C. From the side

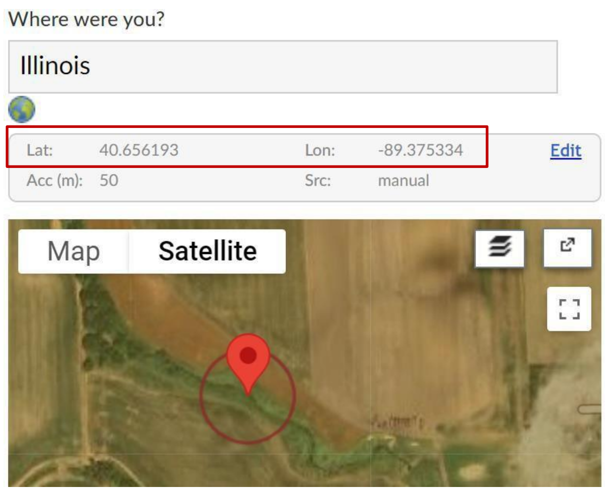
   D. From the underside (ventral view) to clearly see the reproductive structures, also known as gonopods in males




**Exemplar crayfish photos, described above.** *Photos: Illinois-Indiana Sea Grant*

When photographing more than one crayfish, include a numbered note card and/or numbers or letters added with a computer in one or more of the photos. This will help to keep track of the crayfish when reporting on iNaturalist. Additional tips for taking pictures of crayfish can be found on the "How to Photograph Crayfish for iNaturalist" here: inaturalist.org/journal/dan_johnson/16497-how-to-photograph-crayfish-for-inaturalist.

7. Discuss with students how to record location information:
   - You might first ask students what they know about latitude and longitude and why these coordinates are useful. Then ask how they might find that information. Discuss their ideas and clarify any misunderstandings. Details and clear visuals about latitude that you might add are at oceanservice.noaa.gov/facts/latitude.html. Note the "What is longitude?" button on the right. Depending on the level of your students, you could share more technical details during the Explain part of the lesson (after your field study), when discussing the student's location data.
   - Tell students that latitude and longitude coordinates are reported for this scientific study through the iNaturalist platform, which uses the decimal degree format. When submitting observations, click on the map to see the latitude and longitude coordinate information at the top:




   - Other options to find the data include using Google Maps, a smart phone, or a GPS device. Different formats for latitude and longitude are included below. Decimal Degree is the format used by iNaturalist (D= degrees, M= minutes, S=seconds, H=hemisphere)
     - Decimal Degree–DDD.DDDDDD°
     - Degree Minute Second–DDD° MM' SS.SS'' H
     - Minute Decimal–DDD° MM.MMM'
   - If you need to convert location information, you can use online conversion resources such as fcc.gov/media/radio/dms-decimal.
   - Feel free to contact invasivecrayfishcollaborative@gmail.com with questions.

8. Discuss behavior expectations for the trip, and how this field investigation is a special privilege that they should enjoy and not want to lose. If desired, ask the class to form research teams of 2–4 students with whom they will work to collect data (or you can choose the groups).

## Explore

9. Ask students to help you carry the equipment to the research site. Pass out data sampling sheets to student groups (found at the end of the lesson). If traps were set the night before, students can pull them in and collect and record the data on the sheet.
10. Demonstrate the use of other available equipment, such as:
    - **Seine nets, which are** used to catch crayfish stirred up from the stream bottom. Attach seine net ropes to poles. The seine net should be oriented as pictured below.

      **A group collects crayfish with a seine net.**
      *Photo: Illinois-Indiana Sea Grant*

      This method requires two people in the stream to hold a seine net downstream while one or more people upstream disturb the stream bottom by shuffling their feet or flipping rocks.

      - Have two people, one person holding each pole, spread the net out across the stream with the weighted side on the bottom of the stream and the floats above the water.
      - Seine net holders should stand 1–2 feet downstream from one or more feet-shufflers.
      - Feet-shufflers should walk upstream of the net, dragging their feet to stir up the stream bottom as the net-holders walk slowly upstream behind them.
      - Use your best judgment on the amount of time and distance for seine netting. We recommend about five minutes or 15 feet. Record the number of shufflers, time spent shuffling, and distanced shuffled.
      - Once finished, remove nets and their contents from the stream by scooping the weighted bottom of the nets up towards upstream.
      - Place the net with the contents right-side-up on the stream bank. Collect crayfish by hand and place them in buckets. If many crayfish are caught, placing some pieces of PVC pipes in the buckets will give them a place to

hide and reduce their stress. Note: You might catch fish and other invertebrates with this method. Place other species you wish to view in a bucket separate from any crayfish or return them to the stream. (Placing other species in a separate bucket is important to eliminate the risk crayfish will predate upon them.)

- Identify crayfish and collect data using the "Seining for Crayfish" data sheet at the end of the lesson.

**Kick nets:** Similar to seine nets, crayfish are stirred up from the bottom of a stream into a net downstream that is usually held by two people. The net is then carefully lifted out of the stream. Contents are observed and sifted through by hand as described above.

A very low-cost kick net can be created by stapling synthetic window screen to two dowels or other light pieces of wood:

**A simple kick net made by stapling window screen to scrap wood.**
*Photo: Deb Berg*

- **D-nets:**

Participants can hold D-nets on poles to catch crayfish or work with a partner to catch them:

- As with the other methods using a net, it should touch the bottom of the stream. If one person is collecting, they can stand upstream and shuffle their feet, kicking up rocks and substrate.
- If two or more people are collecting, they can hold the net so it is facing upstream while the other participant(s) shuffle(s) their feet, kicking up rocks and substrate.

**A student catches crayfish with a D-net.**
*Photo: Illinois-Indiana Sea Grant*

- Sift through the contents by hand and pick crayfish out and place them in a bucket or tray. If many crayfish are caught, placing some pieces of PVC pipes and/or leaves and sticks in the buckets will give them places to hide and reduce their stress.
- Identify crayfish and collect data. See the "Kicknet Sampling for Crayfish" data form at the end of the lesson.
- We recommend using this method in addition to baited traps or seine/kick netting so that more students can have a hands-on experience. You should also collect more crayfish data!

- **Hand catching:** Crayfish can also be caught by hand. Tell students that crayfish will attempt to escape by jetting backwards with a fast swish of their tail, so they should be approached from the back, which should also keep students from being pinched!
- **Safety reminder:** Whenever participants enter the water, the stream water should be no higher than knee height of your shortest participant.

11. Tell students that they should fill a bucket with enough water from the stream to submerge crayfish.
12. *Optional:* If you have access to tablets and/or smartphones with internet, students can use them to submit data directly to the iNaturalist form: inaturalist.org/observations/new?project_id=36381.
13. Rotate through the groups, answering questions and helping students to correctly measure and record the data about the crayfish specimens.
14. After all the data is recorded and specimens have been photographed, students can also record any additional observations and/or illustrations in field journals.
15. Baited traps can be tossed back in if another sample is desired. Since crayfish are generally nocturnal, it may be necessary to leave the traps overnight before another sample can be collected. More samples will result in more reliable data, but whatever data you are able to collect is helpful.
16. Tell students that counting zero crayfish in a trap is also important data that can be recorded. A trap could be pulled out empty many times, so students should be prepared

with this expectation and know that they did not do anything wrong. However, they may wish to try a slightly different location for their next trap toss—near more rocks that crayfish can use for cover, in a shady area protected from the sun, in deeper water farther out in the stream, etc.

17. Work with students to ensure all the materials are collected. Travel back to the classroom.

## *Explain*

18. Ask the groups to share their data and observations. Crayfish data can be recorded in a table such as the one below, either on the board, in a shared spreadsheet, etc. If students were not sure of species or gender, photographs can be shared with you and other groups to reach consensus about the two important data points.

| **Crayfish Data** | **Crayfish 1** | **2** | **3** | **4** | **5** | **6** | **7** |
|---|---|---|---|---|---|---|---|
| **Species** | | | | | | | |
| **Gender** | | | | | | | |
| **Length of carapace** (cm), from tip of rostrum to end of cephalothorax | | | | | | | |
| **Body length** (cm), from tip of rostrum to end of telson *(optional)* | | | | | | | |
| **Weight** *(optional)* | | | | | | | |

19. Ask students to work with their group to analyze the data and present it visually. See the "Native + Invasive Crayfish" lesson in this curriculum for strategies to facilitate the process, but we recommend that this activity be an opportunity for students to first work together without your help to explore the data and improve their data analysis and visualization techniques. Tell students they should be able to share at least two interesting visualizations of their crayfish data and be ready to discuss them with the class. *Visualization ideas: Younger students could draw a crayfish and add body length data. Older students could graph the relationship between carapace length and weight.*

20. Circulate through the groups, answering (and asking) questions to help students arrive at their own conclusions. After about 15 minutes, or whenever groups start to finish, tell students they will have two more minutes to work and ask them to be prepared to show and explain their best data visualization(s). If time allows, you can also ask students to explain their visualizations in writing.

21. Allow the groups to share their graphs and ideas. Discuss their findings, then ask them to use the "American Crayfish Atlas" to match their findings with those of crayfish scientists and other data collectors: findmycrayfish.web.illinois.edu.

    - Show them how they can click "Map" then select "All Species" to see the data points. Point out how they can zoom in with the "**+**" button in the lower-right to locate the sampling location(s) they visited.

    - Have them compare their observations with those documented on the map. Ask them to develop a list of species that they believe their collected crayfish may be (if they have not yet been identified).

22. Close with a discussion about what was learned about the native and/or invasive crayfish at the site and what your research findings might indicate about the health of the freshwater body. If time allows, discuss strategies that can be used to help make the ecosystem healthier.

## *Enrich/Extend*

- If they have not yet done so, ask students to work with a partner to submit their data to the "Great Lakes Crayfish" iNaturalist project: inaturalist.org/projects/great-lakes-crayfish. First demonstrate the process, then circulate through the groups to answer questions and ensure the data and photos are submitted correctly. This process can also be managed by select trained students.
- Invite students to dissect crayfish specimens, which is an especially good option if you euthanized invasive crayfish. Note that it might get messy when dissecting frozen crayfish. You might want to wear gloves and use hand sanitizer before, during, and after dissection. Preserved crayfish can also be purchased from companies such as Carolina Biological. You can show one of the videos below to guide students through the process, or use one or more resources, such as:
    - "Crayfish Dissection" page from Biology Junction: biologyjunction.com/crayfish_dissection.htm
    - "Crayfish Dissection" video: youtube.com/watch?v=W7F0jZgdc8A
- Students can view the crayfish specimens and/or their body structures under magnification with a microscope, hand lens, and/or macro lens. You can also use a microscope or macro lens connected to an electronic device and/or data projector to show them to the whole class.
- Ask students to record their specimen observations in writing in field journals, labeling illustrations in detail, etc. You can also ask them to write a summary of what they have learned about native and invasive crayfish, using illustrations to better illuminate their points.
- Students can create detailed, labeled scientific illustrations of the crayfish species they observe. Photographs they took can be used for reference.
- Show one or more short video clip(s) about crayfish and/or data collection techniques, such as:
    - "Crayfish Anatomy," which has an explanation with visuals of how to determine crayfish sex: youtube.com/watch?v=qPc8XFaIbTM
    - "Seining at the River." Kick net/seine net demonstration: youtu.be/Rh6nF-kFKf4
- Invite students to create public service announcement videos about invasive crayfish and ways to keep them from spreading.

## *Evaluate*

- Ask students to summarize in writing the process of collecting reliable data for the crayfish study. This could be done in bullet points and/or paragraph form.
- Review tables of crayfish measurements, data visualizations, and analyses.
- Assess levels of oral participation and student understanding of native and invasive crayfish, how to record scientific data about them and their impacts on freshwater ecosystems.
- Students can be asked 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

- Bowling, Terra (2023). "Great Lakes Crayfish Regulation." See the link at: invasivecrayfish.org/publications
- "Crayfish Biology." Biological Surveys and Assessment Program. University of Illinois: publish.illinois.edu/biologicalsurveys/research/crayfish-biology
- "Identifying Crayfish." Illinois Natural History Survey: hmdc.mo.gov/sites/default/files/2020-07/crayfish_ID_brochure_6-08_0.pdf
- "Rusty Crayfish: A Nasty Invader." Univ. of Minnesota Ext.: bonelakewi.com/docs/LakeStewardship/RustyCrayfishNasty.pdf
- "How one scientist enlisted a lakeside community to study (and eat) invasive crayfish" Cascade PBS: cascadepbs.org/2019/09/how-one-scientist-enlisted-lakeside-community-study-and-eat-invasive-crayfish

#### Data Collection Guidance/Lesson Plans

- Larson, E.R. and Olden, A.D. (2016). "Field Sampling Techniques for Crayfish." In book: *Biology and Ecology of Crayfish*, pp.287-324: depts.washington.edu/oldenlab/wordpress/wp-content/uploads/2013/01/Crayfish_Chapter2016.pdf
- "Introducing Biodiversity and BioBlitz." National Geographic: media.nationalgeographic.org/assets/activity/assets/introducing-biodiversity-and-bioblitz-1.pdf
- "Analyzing BioBlitz Data." National Geographic: media.nationalgeographic.org/assets/activity/assets/analyzing-bioblitz-data-1.pdf
- "Connecting Students to Citizen Science and Curated Collections." North American Network of Small Herbaria: collectionseducation.org
- *Crawfish Educational Materials for Grades K-8 & High School Biology*. Louisiana Crawfish Promotion and Research Board: lsuagcenter.com/NR/rdonlyres/4884B6D1-62E6-4ED1-9964-77F2A3CB834A/46487/CrawfishLessonPlanK8HSLab1.pdf
- "COSIA Outreach Activities- Crayfish Investigations." Lawrence Hall of Science: marestage.lawrencehallofscience.org/college-courses/COSIA/outreach-activities
- "Seining at the River." Kick net/seine net demonstration: youtu.be/Rh6nF-kFKf4

**Invasive Species**

- "GLANIS: Great Lakes Nonindigenous Species Information System." NOAA–Great Lakes Environmental Research Laboratory: glerl.noaa.gov/glansis
- "Invasive Species." U.S. Fish & Wildlife Service: fws.gov/invasives
- "Transport Zero." Be A Hero campaign: transportzero.org

**Scientific Permit Applications and Resources for Great Lakes States and Provinces**

- **Illinois**: dnr2.illinois.gov/ScientificPermit/SciPermit

  Illinois state sites: naturalheritage.illinois.gov/permits/permit-for-state-sites.html

- **Indiana**: in.gov/dnr/nature-preserves/research-and-collecting-permits

  Indiana state sites: in.gov/dnr/state-parks/science-and-natural-resources/research-and-collecting

- **Michigan**: survey123.arcgis.com/share/f57a024af3a84432b045c218fb3f140e

  More info: michigan.gov/dnr/managing-resources/wildlife/wildlife-permits/scientific-collectors-permits-wildlife

- **Minnesota**: dnr.state.mn.us/permits/scientific-research.html
- **New York**: extapps.dec.ny.gov/docs/wildlife_pdf/lcpsci2013.pdf
- **Ohio**: ohiodnr.gov/buy-and-apply/special-use-permits/collecting-research/scientific-collecting-wild-animals

  How to apply in Ohio: ohiodnr.gov/static/documents/wildlife/permits/Scientific%20Collection%20and%20Education%20Permits%20-%20Applying%20in%20OWLS.pdf

- **Pennsylvania**: fishandboat.com/Forms-Permits/Documents/SciColl_InterimSolution_Application_Form.pdf

  PA parks and forests: research.dcnr.pa.gov/ResearchApplication/Application

- **Wisconsin**: dnr.wisconsin.gov/topic/endangeredresources/permits

  Contact DNRTEAMWMWildlifeSwitchboard@wisconsin.gov for State Natural Areas.

- **Ontario and Quebec:** pac.dfo-mpo.gc.ca/fm-gp/licence-permis/scientific-scientifique-eng.html

  Contact your local ministry at ontario.ca/page/ministry-natural-resources-and-forestry-work-centres and find more information about Quebec permitting at mrnf.gouv.qc.ca.

# KICKNET SAMPLING FOR CRAYFISH

<table>
<tr><td colspan="4">Use this data sheet for kicknet sampling. To calculate “catch per unit effort,” use a new datasheet for each group of students working together with one piece of equipment. Fill out as many lines under “crayfish” as crayfish you have caught with that net. * Starred fields are required.</td></tr>
<tr><td>* Date:</td><td colspan="2">* Coordinates:</td><td>* Number of students sampling today:</td></tr>
<tr><td colspan="4">Notes on location:</td></tr>
<tr><td>Net #:</td><td>Time spent kick netting on this sampling effort:</td><td># crayfish caught:</td><td># people kick netting on your net:</td></tr>
<tr><td colspan="4">General notes:</td></tr>
</table>

## CRAYFISH

| **Crayfish Photo #s** (or name) | *** Photos** (check after photos taken) | **Species** | **Sex** | **# Chelae (claws) Missing** | **# Other Legs Missing** | **Carapace Length (cm)** | **Notes about Crayfish** |
|---|---|---|---|---|---|---|---|
| | ☐ top ☐ side<br>☐ under ☐ claw | | ☐ male<br>☐ female<br>☐ unknown | | | | |
| | ☐ top ☐ side<br>☐ under ☐ claw | | ☐ male<br>☐ female<br>☐ unknown | | | | |
| | ☐ top ☐ side<br>☐ under ☐ claw | | ☐ male<br>☐ female<br>☐ unknown | | | | |
| | ☐ top ☐ side<br>☐ under ☐ claw | | ☐ male<br>☐ female<br>☐ unknown | | | | |
| | ☐ top ☐ side<br>☐ under ☐ claw | | ☐ male<br>☐ female<br>☐ unknown | | | | |
| | ☐ top ☐ side<br>☐ under ☐ claw | | ☐ male<br>☐ female<br>☐ unknown | | | | |
| | ☐ top ☐ side<br>☐ under ☐ claw | | ☐ male<br>☐ female<br>☐ unknown | | | | |
| | ☐ top ☐ side<br>☐ under ☐ claw | | ☐ male<br>☐ female<br>☐ unknown | | | | |
| | ☐ top ☐ side<br>☐ under ☐ claw | | ☐ male<br>☐ female<br>☐ unknown | | | | |
| | ☐ top ☐ side<br>☐ under ☐ claw | | ☐ male<br>☐ female<br>☐ unknown | | | | |
| | ☐ top ☐ side<br>☐ under ☐ claw | | ☐ male<br>☐ female<br>☐ unknown | | | | |
| | ☐ top ☐ side<br>☐ under ☐ claw | | ☐ male<br>☐ female<br>☐ unknown | | | | |

# SEINING FOR CRAYFISH

| | | | |
|---|---|---|---|
| Use this data sheet when you are sampling for crayfish with your seine nets. Use a new datasheet for each round of seining that you complete to get an accurate "catch per unit effort." *** Starred fields are required.** | | | |
| *** Date:** | *** Coordinates:** | *** Number of students sampling today:** | # crayfish caught in this net: |
| Notes on location: | | | |
| Seine #: | Time spent seining with this sampling effort: | | # people shuffling feet: |
| General notes: | | | |

# CRAYFISH

| **Crayfish Photo #s** (or name) | *** Photos** (check after photos taken | **Species** | **Sex** | **# Chelae (claws) Missing** | **# Other Legs Missing** | **Carapace Length (cm)** | **Notes about Crayfish** |
|---|---|---|---|---|---|---|---|
| | □ top □ side<br>□ under □ claw | | □ male<br>□ female<br>□ unknown | | | | |
| | □ top □ side<br>□ under □ claw | | □ male<br>□ female<br>□ unknown | | | | |
| | □ top □ side<br>□ under □ claw | | □ male<br>□ female<br>□ unknown | | | | |
| | □ top □ side<br>□ under □ claw | | □ male<br>□ female<br>□ unknown | | | | |
| | □ top □ side<br>□ under □ claw | | □ male<br>□ female<br>□ unknown | | | | |
| | □ top □ side<br>□ under □ claw | | □ male<br>□ female<br>□ unknown | | | | |
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| | □ top □ side<br>□ under □ claw | | □ male<br>□ female<br>□ unknown | | | | |
| | □ top □ side<br>□ under □ claw | | □ male<br>□ female<br>□ unknown | | | | |
| | □ top □ side<br>□ under □ claw | | □ male<br>□ female<br>□ unknown | | | | |

# TRAPPING FOR CRAYFISH

| Use this data sheet for trapping crayfish. Traps must be set out overnight. It is best to collect traps within 24 hours, so that the crayfish in that trap do not run out of food and are not predated upon. Use one datasheet for all traps. Starred fields are required. | | | |
|---|---|---|---|
| ***Coordinates:** | | ***Number of students sampling today:** | |
| Notes on location: | | | |
| # Traps set: | # Crayfish caught in traps: | ***Time/date traps were set:** | ***Time/date traps were received:** |
| General notes: | | | |

## CRAYFISH

| **Crayfish Photo #s** (or name) | *** Photos** (check after photos taken | **Species** | **Sex** | **# Chelae (claws) Missing** | **# Other Legs Missing** | **Carapace Length (cm)** | **Notes about Crayfish** |
|---|---|---|---|---|---|---|---|
| | □ top □ side □ under □ claw | | □ male □ female □ unknown | | | | |
| | □ top □ side □ under □ claw | | □ male □ female □ unknown | | | | |
| | □ top □ side □ under □ claw | | □ male □ female □ unknown | | | | |
| | □ top □ side □ under □ claw | | □ male □ female □ unknown | | | | |
| | □ top □ side □ under □ claw | | □ male □ female □ unknown | | | | |
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| | □ top □ side □ under □ claw | | □ male □ female □ unknown | | | | |

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**

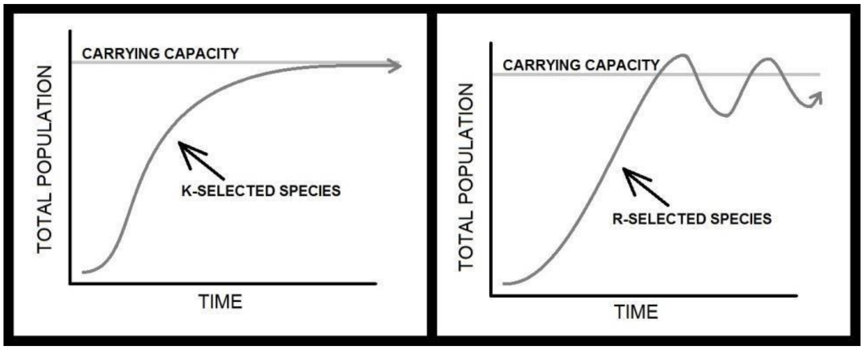
  This is an evolutionary advantage of a particular species. Adaptations allow individuals to thrive in their environment and alter their physiology or behaviors to survive certain changes to that environment. There are numerous examples of adaptations in all organisms including fungi, protists, bacteria,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

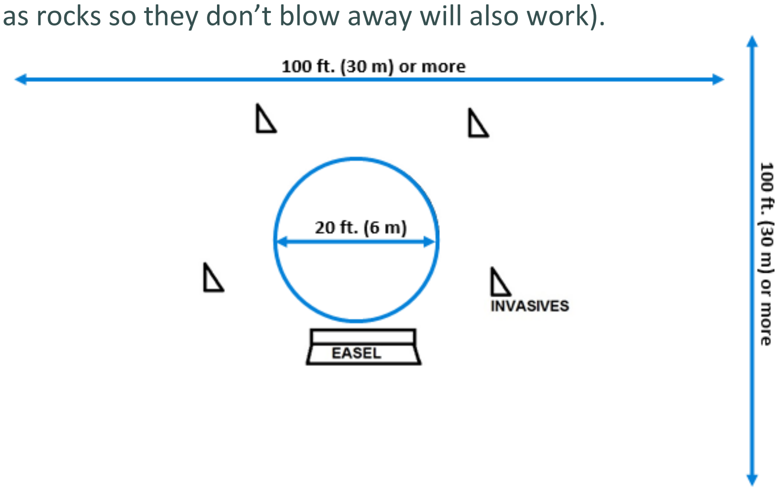
## Materials

- 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-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

Invasive Crayfish Collaborative Great Lakes

*Lesson 7*

# Crayfish as an Indicator Species

**Subjects** Science, Language Arts, Art

**Grade Levels** Ideal for grades 8–12, adaptable for 6–7

**Time** 45 minutes or more

## Lesson Overview

Students will first read about a hypothetical mysterious phenomenon about crayfish disappearing from a river, then work in small groups to develop plans to investigate the issues. The plans should be based on the available information presented in the scenario and what they have learned throughout the unit about crayfish and freshwater ecosystems. We suggest having students first create a visual model, followed by a written explanation.

Lesson options are listed in the "Enrich/Extend" section, including ways to do water quality field investigations.

**A white river crayfish (*Procambarus acutus*): Its presence, as well as the clear water, may indicate high water quality.**
*Photo: Chris Lukhaup*

## Goals

- Students explore water quality issues by working together to solve a mystery about crayfish disappearing.
- Students become aware of how their actions, and those of others in their community, can impact the health of their local watershed, encouraging them to be more environmentally aware.
- Students' understanding of the roles of crayfish and other macroinvertebrates in freshwater ecosystems is increased.

## Objectives

- Students will read about a hypothetical situation and use the information to problem solve and construct possible solutions to the issues.
- Students will create visual models that illustrate their plan to solve the mystery and improve water quality.
- Students will effectively communicate their ideas in writing.
- Students will be able to explain how human activities can benefit, as well as harm, living systems.

## Next Generation Science Standards

### Performance Expectations

#### Building Toward

- MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
- MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- HS-LS2-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- HS-ETS1-4: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

### Crosscutting Concepts

- Cause and Effect: Mechanism and Explanation
- Structure and Function
- Stability and Change
- Systems and System Models

### Science & Engineering Practices

- Developing and Using Models
- Asking Questions and Defining Problems
- Constructing Explanations and Designing Solutions
- Obtaining, Evaluating, and Communicating Information

### Core and Component Ideas in the Life Sciences

#### LS1: From Molecules to Organisms: Structures and processes

- LS1.A: Structure and Function
- LS1.B: Growth and Development of Organisms

#### 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

- ESS2.C: The Roles of Water in Earth's Surface Processes

## Common Core State Standards

### 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.

**Standard 6.** Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

**College and Career Readiness Anchor Standards for Writing**

**Standard 6.** Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

**Standard 7.** Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

## Center for Great Lakes Literacy Principles

**Principle 5.** The Great Lakes support a broad diversity of life and ecosystems.
**Principle 6.** The Great Lakes and humans in their watersheds are inextricably interconnected.
**Principle 8.** The Great Lakes are socially, economically, and environmentally significant to the region, the nation and the planet.

## Teacher Background

Like other aquatic macroinvertebrates, crayfish are sensitive to water quality, and are therefore helpful as an indicator species, in addition to being very important in aquatic food webs. Degraded water quality as a result of human activities such as elevated metal concentrations may contribute to crayfish declines. Crayfish are gill-breathing invertebrates that live in the lowest level of a body of water and feed on plant matter, animal matter, and detritus, thus increasing their exposure and subsequent susceptibility to pollutants such as metals. Crayfish have been shown to bioaccumulate metals associated with mining waste and these metals may negatively impact their populations (Allert et al 2010; Snyder 2010).

Explore "The Mystery of the Disappearing Crayfish" and the other resources listed at the end of the lesson for more information about water quality components, how to test it, and the role of crayfish and other macroinvertebrates as indicator species.

## Materials

- Copies of the following for each student (found after lesson):
  - "The Mystery of the Disappearing Crayfish" (ideally duplexed, to save paper)
  - "Water Quality Improvement Plan Rubric"
  - *Optional:* "Crayfish May Help Restore Dirty Streams, Study Finds"
- Markers, crayons, or colored pencils for students to share
- *Optional:* Posterboard
- *Optional:* Support from an expert partner to work with your class.

## Preparation

1. Ensure all materials above are ready for student use.
2. *Optional:* Learn more about topics addressed in the lesson with the sources listed in the More Resources/References section at end of the lesson to prepare to answer student questions.
3. *Optional:* Arrange for a guest speaker with expertise on freshwater habitat restoration projects to visit your class. Contact us here for possible recommendations: [invasivecrayfish.org/contact-us](invasivecrayfish.org/contact-us)

## Teaching Suggestions in the 5E Model

### *Engage*

1. Engage students and encourage them to apply prior knowledge by asking them what they would do if they discovered that crayfish and many other organisms were disappearing from a nearby stream. Ask them to think about what tests they might conduct to get more information, who they might talk to, what other problems might be related to the issue, etc. Tell them they will have just a couple of minutes to brainstorm their ideas with a neighbor or record them on paper or with an electronic device in words and pictures.

2. Circulate through the groups, answering (and asking) questions to help students arrive at their own conclusions. After a minute or two, tell students they will have one more minute to brainstorm and to be prepared to share their best ideas with the class.
3. Allow the groups to share. Tell them that they will be working in groups to solve a similar realistic scenario that includes more information to help them decide on the best possible solutions to the problem.

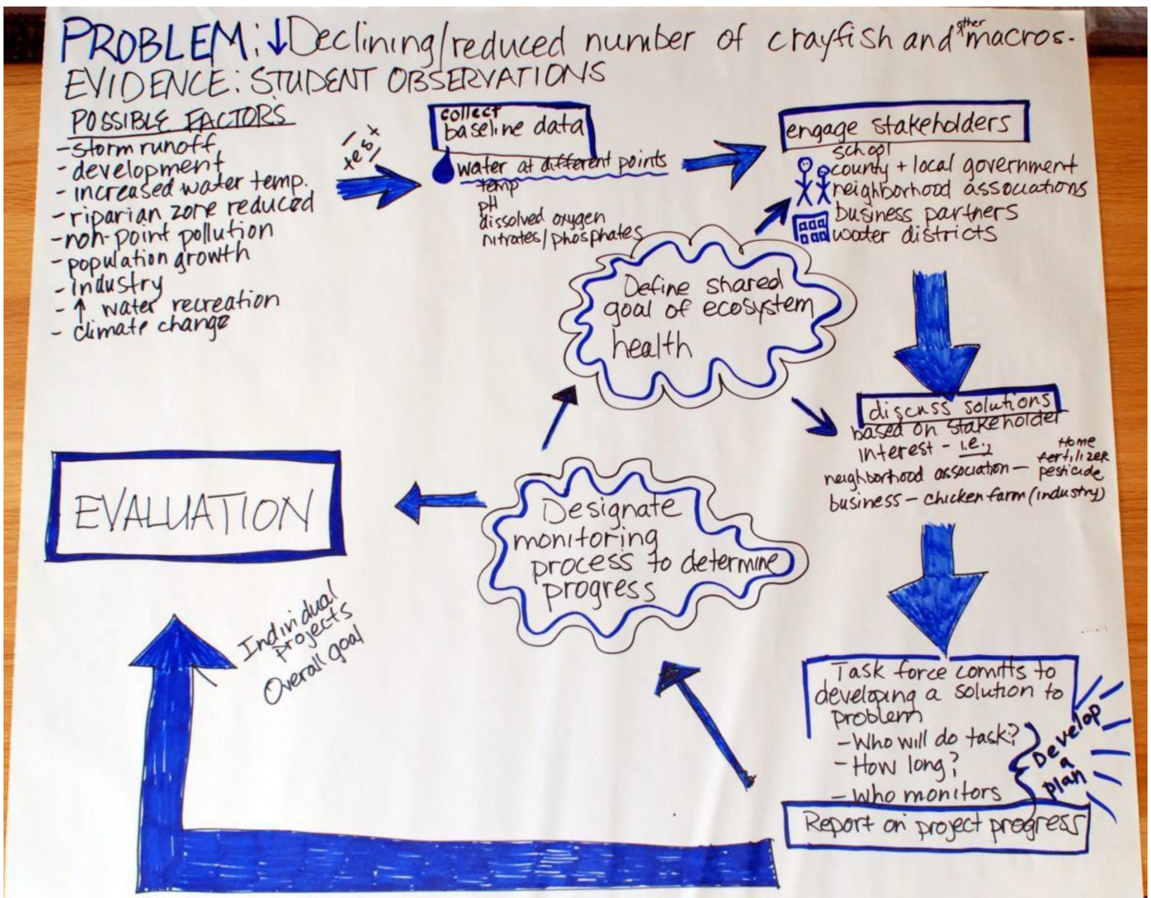
## *Explore*

4. Ask students to form groups of 2–4 while you pass out the "Mystery of the Disappearing Crayfish" and ask them to first read through the whole scenario. Explain that after they finish reading, they should work together to create plans that address the possible problems as explained in the "Your Challenge" section. Tell students they should conduct additional research, as necessary, using the Internet and other available reference sources; they should cite the sources they use for additional information. Explain the available options for visuals: posters, computer-aided diagrams, etc., and show students available materials and/or technology/software with which they can work.


**A visual water quality improvement plan created using Mindomo (free for up to 40 topics). Other software options include FreeMind, MindManager, Illustrator, Google Slides, and PowerPoint.**

## *Explain*

5. Circulate through the room answering (and asking) questions, helping the groups get started. When all the groups have started working on their plans, pass out the "Water Quality Improvement Plan Rubric" so they know how they will be assessed. Explain that they should complete the "Group Self Score" column of the rubric before turning in the rubric with their visual model and written plan. We recommend that you have each student write a written plan to help them process the information and practice their skills arguing from evidence in writing. But, one per group is fine, too, or even just the visual model with a quick oral presentation if time is limited. Either way, tell students that they should also be prepared to present their plans and visual models to the class.
6. Allow students time to complete their plans outside of class, if necessary.
7. Allow students time to present their projects. Discuss the recommendations in their plans for how to improve water quality for macroinvertebrates like crayfish, as well as for humans and every other organism in the aquatic food web.




**Group-created diagram showing the process of investigating declining populations of crayfish and other macroinvertebrates**

## Enrich/Extend

- Discuss the concept of point and nonpoint source pollution, perhaps as preface to the scenario. Good resources to help teach the concept include:
    - "Get to the Point! Nonpoint Source Pollution" lesson plan (grades 9–12). NOAA: [mrbdc.mnsu.edu/sites/mrbdc.mnsu.edu/files/public/org/lakecrystal/activites.html](mrbdc.mnsu.edu/sites/mrbdc.mnsu.edu/files/public/org/lakecrystal/activites.html)

- "Lesson 1: Watersheds and Nonpoint Source Pollution Basics." Groundswell Communities for Clean Water. PBS Learning Media: illinois.pbslearningmedia.org/resource/ee8c197f-9bd5-4017-8ab0-54db41fbf88e

- For younger and/or less experienced students, consider reading through the scenario as a class and answering questions before forming groups to work on the project.
- Investigate the biodiversity of macroinvertebrates in a nearby stream to evaluate water quality based on the prevalence of different species. You can also help improve water quality by doing a service project, such as planting native plants or removing trash. Good activities to support this field work are found in:
  - "Stream Side Science" lesson plans from Utah State Univ. Extension Service: extension.usu.edu/waterquality/educator-resources/lessonplans
  - SOLVE's *Environmental Service-Learning Curriculum:* engagingeverystudent.com/project/solve-environmental-service-learning-curriculum
- Explore the concept of a watershed in-depth with your students. See the "Introduction to Watersheds and Riparian Restoration" lesson in the SOLVE curriculum linked above and/or other online lessons, such as:
  - "Watersheds to Whales" in the "Exploring Ocean Mysteries" curriculum from NOAA: sanctuaries.noaa.gov/education/teachers/ocean-mysteries
  - "Discovering the Watershed" from Purdue Extension: extension.purdue.edu/extmedia/FNR/FNR-476-W%20Discovering%20the%20Watershed%2013.pdf

- Conduct water quality sampling activities with your students. Partners may be able to support your work, including your state university Extension Service, park district, or local watershed council.
- Ask students to read the article "Crayfish May Help Restore Dirty Streams, Study Finds" found at the end of the lesson and discuss the findings.
- If time allows, give students the option of creating dioramas to engineer engaging 3D models of their plans. They could construct areas of habitat restoration along the river, show ways to balance the needs of wildlife and humans, create bioswales, etc.
- Have students create public service announcement videos about ways to keep our water resources healthy for the benefit of both wildlife and humans.

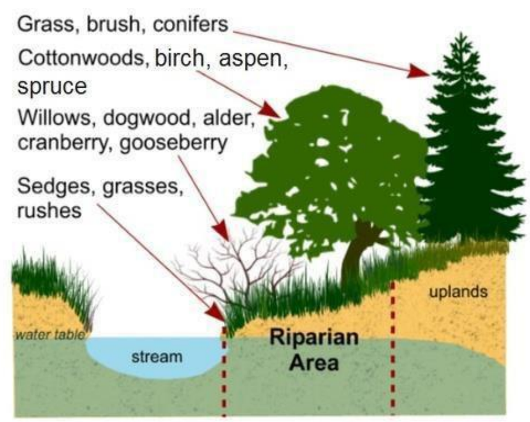
## *Evaluate*

- 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.
- Use completed student diagrams to evaluate student understanding of the concept of freshwater ecosystems.
- Review the short research projects about an organism from freshwater ecosystems and its interactions with other freshwater organisms.
- Use student participation in class discussion and activities, including the simulation of a freshwater web of life, to determine student understanding.

## Expand Knowledge + Skills

### Science/References

- Allert, A.L et al. (2010). “Effects of mining-derived metals on riffle-dwelling crayfish and in-situ toxicity to juvenile *Orconectes hylas* and *Orconectes luteus* in the Big River of southeast Missouri, USA.” USGS: link.springer.com/article/10.1007/s00244-012-9797-9
- “Crawfish Water Quality and Management.” The Fish Site: thefishsite.com/articles/crawfish-water-quality-and-management
- Helfrich, L.A. and DiStefano, R.J. “Sustaining America's Aquatic Biodiversity–Crayfish Biodiversity and Conservation.” Dept. of Fisheries and Wildlife Sciences, Virginia Tech: pubs.ext.vt.edu/420/420-524/420-524.html
- Kilpatrick, Molly. “Water Quality: Lessons From a Crayfish.” Auburn University: sustain.auburn.edu/water-quality-lessons-from-a-crayfish
- “Meet our Grad Student Scholars: Kathryn Mudica.” IISG Graduate Student Researching Crayfish as Bioindicators: iiseagrant.org/meet-our-grad-student-scholars-kathryn-mudica
- “What are Riparian Zones or Areas?” Tanana Valley Watershed Association: tvwatershed.org/riparian-zone-information



***Model of a healthy riparian area from the Tanana Valley Watershed Association***

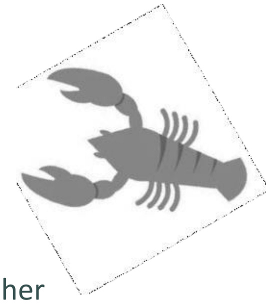
### Lessons/Activities

- “A Very Impervious Situation: An Introduction to Stream Runoff” lesson plan by Great Lakes Aquarium: https://glaquarium.org/resources/a-very-impervious-situation-an-introduction-to-stormwater-runoff/
- “Bugs Don’t Bug Me” and many more aquatic macroinvertebrate lessons, in the “Stream Side Science” program from Utah State Univ. Extension Service: extension.usu.edu/waterquality/educator-resources/lessonplans
- IDAH$_2$O water education resources, including curriculum and videos, Univ. of Idaho Ext.: uidaho.edu/extension/idah2o/resources
- “Stormwater and Green Infrastructure Curriculum for Boston Public Schools.” Boston Water and Sewer Commission: bwsc.org/sites/default/files/2019-01/stormwater_gi_curriculum_grade_7.pdf
- “Watershed Detectives” lesson from Utah State University Ext.: extension.usu.edu/waterquality/educator-resources/lessonplans

### 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

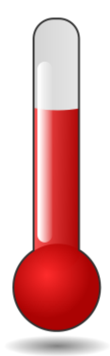
# Mystery of the Disappearing Crayfish



***Scenario:*** Students from Great Lakes School have been studying the crayfish and other macroinvertebrates in Clear Creek, which flows nearby. Classes have enjoyed doing this for many years, but almost every year they find fewer and fewer crayfish and other "macros." They have contacted local agencies to share their data and find out if there is an explanation for the phenomenon, but the agencies were unaware of the problem. However, through their research and their close observations of the river, the students have gathered these important clues, which could help them solve the mystery of the disappearing crayfish:

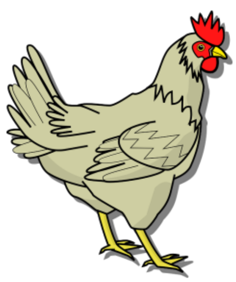
- Crayfish and other macroinvertebrates are considered "**indicator species**." The number of them found in a body of freshwater can indicate the water quality, as measured by many factors, including levels of:
    - **Dissolved oxygen**: aquatic animals need it to breathe; crayfish do best with dissolved oxygen levels of 2 ppm (parts per million) or higher, although they are more tolerant of low levels of oxygen than some other aquatic organisms, such as most fish species
    - **Nutrients**: includes nitrogen and phosphorus that we apply as fertilizer to help plants in our lawns, gardens, and crops to grow; too many nutrients can cause aquatic organisms like algae and bacteria to grow very quickly, and when they die, all the dissolved oxygen can be used up

    - **pH**: the measure of the number of hydrogen ions (which are acidic) in the water compared to the number of hydroxide ions (which are basic)
        - Neutral pH is 7, and crayfish prefer a range of 7.5–8.5. Most aquatic organisms prefer a range of 6.5 (slightly acidic) to 9 (a little basic).
        - Macroinvertebrates are generally quite sensitive to changes in pH.
    - **Sediment**: loose sand, clay, silt and other soil particles that settle on the bottom of a body of water
        - Sediments can build up to unhealthy levels when erosion increases on riverbanks and in the surrounding watershed.
        - Sediments can also be stirred up by rapidly flowing water and human activities.
    - **Toxic substances**: pollution such as ammonia, metals, and oil-based products
    - **Temperature**: amount of heat energy contained in a substance (such as water or air); more oxygen can dissolve in cooler water and be available for animals to breathe
    - **Turbidity**: clarity (clearness) of the water; clearer water is generally healthier
    - **Bacteria** such as fecal coliform, *E. coli*, and enterococci

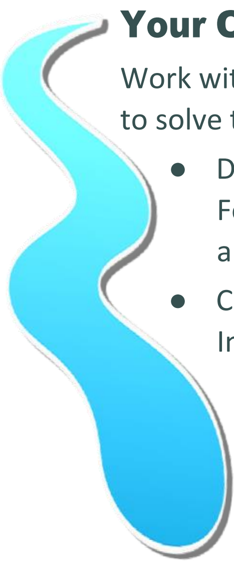


- **More clues the students have gathered:**
  - The sewer system has sometimes been overwhelmed during big storms in recent years. At those times, large amounts of untreated sewage flows into Clear Creek.
    - There has been a lot of development in the area recently, including many new buildings and parking lots. Native plants, such as trees and willows, have been removed from riparian areas (those near rivers and streams). This includes many areas along Clear Creek near the school.

    - Student tests in the river have found that water temperatures have been getting warmer in recent years.
    - Many people who live near the river have lawns that they fertilize and water regularly. The students have also observed homeowners and lawn crews spraying pesticides and herbicides to kill insects and weeds.
  - There has been a reduction of shade plants such as trees and shrubs along the river and in some streams that drain into it.
  - Many more cars are driving in the watershed now, and there are many more parking lots.
  - Some community members have been advocating for the creation of bioswales to reduce stormwater runoff into the rivers and streams.



    - A large chicken farm and processing facility is upriver from the school. The students can often smell it, and the students have heard that waste from the facility is being disposed of on the property, which is right next to the river.
    - More people are using the river recently for activities such as waterskiing and jet skiing.
    - Most climatologists (scientists that study long-term weather patterns) believe that human activities, such as the burning of fossil fuels, are the main cause of the increase in global temperatures over the last century. They expect the trend to continue unless significant changes are made soon. Warmer water will mean less dissolved oxygen for aquatic organisms, such as fish and crayfish.



## Your Challenge

Work with your group to develop a plan to conduct additional tests, if necessary, and take action to solve the mystery of the disappearing crayfish.

- Discuss factors that might explain the declines in crayfish and other macroinvertebrates. For example, how might factors, such as possible pollution sources, loss of native plants, and development be affecting water quality and organisms' ability to survive?
- Create a water quality improvement plan to address issues for crayfish and human needs. Include both a visual model and written description of your plan:
  1. Illustrate your ideas on a large sheet of paper, a computer, or tablet. Label the parts of your model.
  2. Explain your plan in detail, in writing. Include details about how your plan will help crayfish and other macroinvertebrates that are so important in aquatic food webs. **Important:** You should also include a discussion of how the success of your plan can be monitored over time. See the "Water Quality Improvement Plan Rubric" for details about how your plans will be assessed.

Name(s): ______________________________ Period: _______ Date: ____________________

# *Water Quality Improvement Plan Rubric*

| Project Component | Maximum Points Possible | Self-Score (fill out before presentation) | Teacher Score |
|---|---|---|---|
| **Part 1: Background** | | | |
| Problem(s) explained | 10 | | |
| Goal(s) of plan identified | 10 | | |
| **Part 2: Plan Development** | | | |
| Habitat needs of crayfish and other aquatic species identified | 10 | | |
| Areas of human development accurately evaluated for their likely impacts on water quality | 10 | | |
| Riparian areas (those near rivers and streams) accurately evaluated for potential as habitat and to help improve water quality | 10 | | |
| **Part 3: Plan Implementation** | | | |
| Appropriate practices for water quality improvements included | 10 | | |
| Effect of various practices on habitat and aquatic species described | 10 | | |
| **Part 4: Plan Evaluation** | | | |
| Realistic methods for monitoring success of plan presented | 10 | | |
| **Part 5: Format of Visual and Written Plan** | | | |
| Visual clearly demonstrates plan with all necessary labels | 10 | | |
| Written plan is well-written, organized, and easy to understand; grammatical and spelling conventions followed | 10 | | |
| **TOTAL:** | **100** | | |

Teacher Comments:

# *Crayfish May Help Restore Dirty Streams, Study Finds*

*Stroud Water Research Center study finds crayfish may benefit insects, reduce sediment settling in impaired streams*

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While macroinvertebrates are a tasty food source for crayfish, a new study reveals a surprising finding: When crayfish were present in in-stream experimental enclosures, macroinvertebrate density was higher, not lower.

Stroud Water Research Center's lead fluvial geomorphologist Melinda Daniels, Ph.D., and Lindsey Albertson, Ph.D., a postdoctoral researcher and ecology professor from Montana State University, conducted the study in Valley Creek. The creek is an urbanized and degraded tributary of the Schuylkill River in King of Prussia — a Philadelphia suburb.

The scientists placed wire-mesh enclosures, some with crayfish inside and some without, in the creek. At the conclusion of the 2-week experiment, populations of macroinvertebrates such as caddisflies, which can indicate better water quality, were higher in the crayfish enclosures despite being a food source for crayfish. The crayfish enclosures also featured reduced settling of fine sediment pollution on the surface of the streambed. As the crayfish disturbed the rock and gravel bottom with their claws, they agitated and increased suspension of fine sediments, presumably allowing more sediments to flow downstream.

"We were surprised," Albertson admitted. "We thought the crayfish would eat the macroinvertebrates and reduce their populations, but we found the opposite. Macroinvertebrate density was higher in the crayfish enclosures. So even if the crayfish were eating some of the macroinvertebrates, we think that all of the fine sediment that had been suspended and washed away created a more macroinvertebrate-friendly habitat."

Many macroinvertebrates don't like to live in streams with high sediment loads. It's a type of pollution that degrades freshwater streams and can be traced to land-use changes like agriculture and development.

Daniels said, "Crayfish show the potential to alleviate some of the problems seen in impaired streams. Every organism has its part in an ecosystem, and we're still learning what the individual roles are."

The study, "Effects of Invasive Crayfish on Fine Sediment Accumulation, Gravel Movement, and Macroinvertebrate Communities" (2016), was published in *Freshwater Science*.
It can be accessed at [www.journals.uchicago.edu/doi/abs/10.1086/685860](http://www.journals.uchicago.edu/doi/abs/10.1086/685860).
For more information contact Melinda Daniels, Ph.D., Associate Research Scientist, 610-268-2153, ext. 268; [mdaniels@stroudcenter.org](mailto:mdaniels@stroudcenter.org).

Invasive Crayfish Collaborative
Great Lakes

Lesson 8

# From Mental Maps to GIS: Modeling Data with Visualization and Mapping

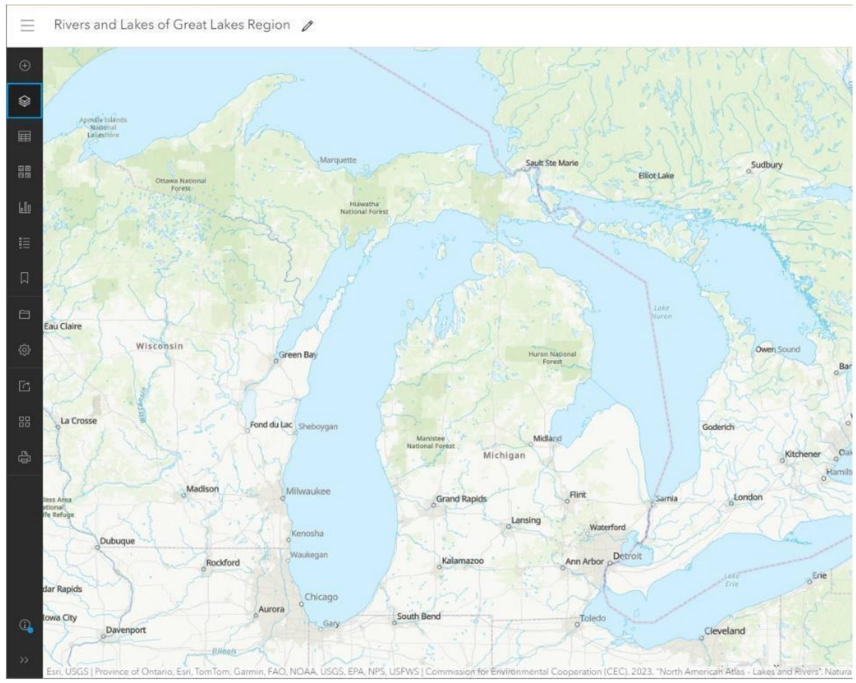
**Subjects** Science, Language Arts, Social Studies, Art

**Grade Levels** Ideal for grades 6–12, adaptable for grade 5

**Time** 45 minutes or more

## Lesson Overview

Students are engaged by creating mental maps of their local watershed or the larger watershed they live in, such as the Ohio River basin. They briefly share their maps with each other, then the teacher shows a GIS-created map of the area, explaining that the students will next be able to help to create a map using GIS technology. Students submit their crayfish data if they have not yet done so, then analyze it and compare to other groups visually.




**A map showing rivers and lakes created with ArcGIS Online**

## Goals

- Provide students with the opportunity to model the crayfish data they collected and share it with researchers, wildlife managers, other school groups, and the community at large.
- Provide students with the experience of creating mental maps about their region.
- Give students the experience of using powerful GIS software to better understand the scientific study they have been participating in and its findings.
- Increase students' understanding of the native and invasive crayfish found in their watershed and encourage them to be more environmentally aware.

## Objectives

- Students will submit the data they collected (see previous lessons), analyze it with ArcGIS Online, and compare it to the data collected by other groups.
- Students will create mental maps related to their watershed and compare it to a map created with GIS software.
- Students will express orally and/or in writing what they have learned about native and invasive crayfish through the activities in the lesson and the others in this unit about crayfish and freshwater ecosystems.

## Next Generation Science Standards

### Performance Expectations

#### Building Toward

- MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.
- HS-LS2-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

### Crosscutting Concepts

- Stability and Change

### Science & Engineering Practices

- Asking Questions and Defining Problems
- Obtaining, Evaluating, and Communicating Information

### Core and Component Ideas in the Life Sciences

#### LS2: Ecosystems: Interactions, Energy, and Dynamics

### Core and Component Ideas in Earth and Space Sciences

#### ESS2: Earth's Systems

- ESS2.C: The Roles of Water in Earth's Surface Processes

## Common Core State Standards

### Speaking and Listening Standards for Grade 6

(similar standards for grades 2-5; 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.

**Standard 6.** Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

### Math Standards: Measurement & Data

- Represent and interpret data

### Math Standards: Statistics & Probability

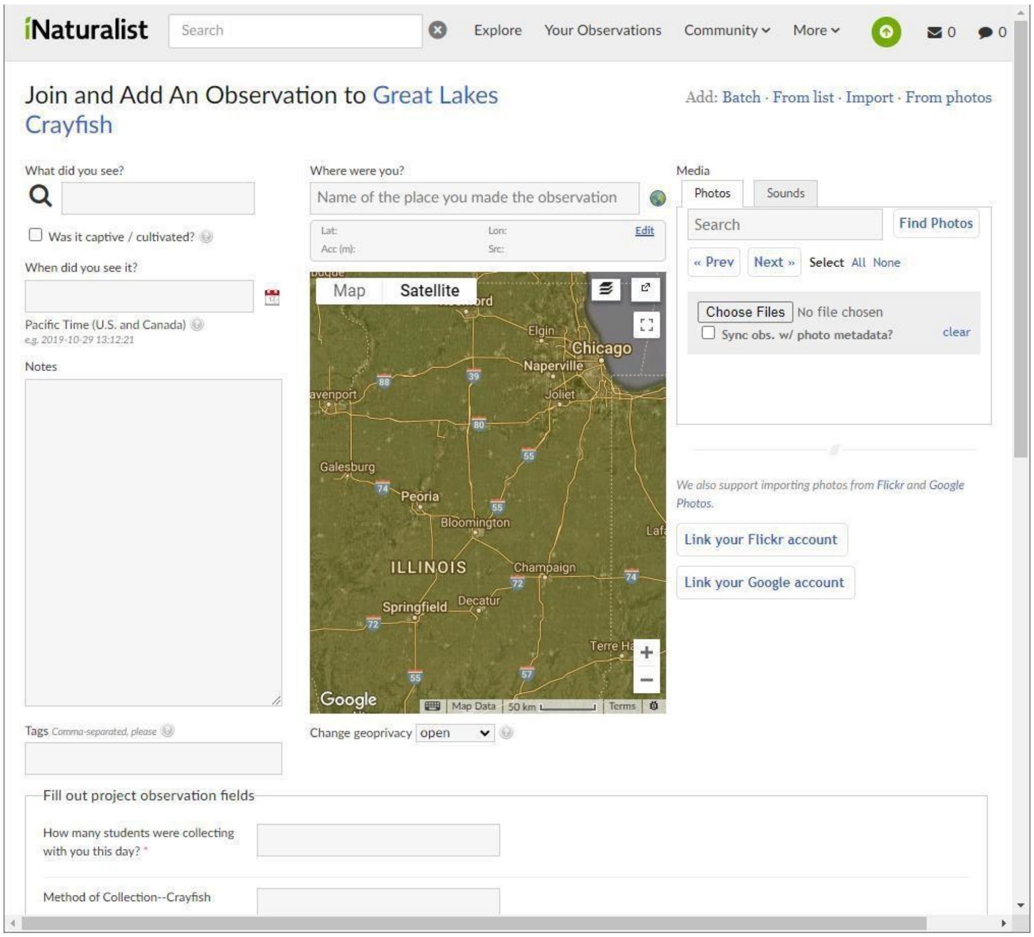
- Develop understanding of statistical variability
- Summarize and describe distributions

## Center for Great Lakes Literacy Principles

**Principle 5.** The Great Lakes support a broad diversity of life and ecosystems.
**Principle 6.** The Great Lakes and humans in their watersheds are inextricably interconnected.

## Teacher Background

The Invasive Crayfish Collaborative (ICC) and partners have been using GIS tools from iNaturalist and Esri to collect and analyze crayfish population data and water quality to measure the health of our watersheds. As explained in previous lessons, scientific protocols are followed to reliably collect data from such a large area. It can then be submitted with the online tools. See the "American Crayfish Atlas" to identify species near you and where you might find them: findmycrayfish.web.illinois.edu. The ICC can help provide your class with equipment. Email invasivecrayfishcollaborative@gmail.com to ask about available resources.




**Part of the crayfish observation form**

### ArcGIS and ArcGIS Online

ArcGIS is the leading Geographic Information System (GIS) software, used by professionals, such as urban planners and scientists, to create maps, which model data visually in countless ways. ArcGIS Online is a simplified version of the software that works in any modern web browser and integrates with the desktop version, if desired. It retains the software's core functionality and a subscription is free for schools, by request. It is surprisingly easy to use for such powerful software with so many data visualization tools. The website "Get Started with ArcGIS Online" is a good place to begin if you are unfamiliar with the software: learn.arcgis.com/en/projects/get-started-with-arcgis-online. Additional resources are listed in the Expand Knowledge + Skills section at the end of the lesson.

## Materials

- ArcGIS Online access: arcgis.com

  Free "ArcGIS for Schools Bundle" at: esri.com/en-us/industries/education/schools/schools-mapping-software-bundle

- Pencils
- Paper (or student journals or field guides)
- Colored pencils, markers, and/or crayons for students to share
- Data projector, computer, and screen
- *Optional:* Print copies of the "Career Connections: Alex Towne, GIS Specialist" article and the "Could you work in GIS?" activity for students found at the end of the lesson
- *Optional:* Document camera

## Preparation

1. Ensure the software and other materials listed above are ready for student use.
2. *Optional:* You can get support from partners by contacting invasivecrayfishcollaborative@gmail.com.

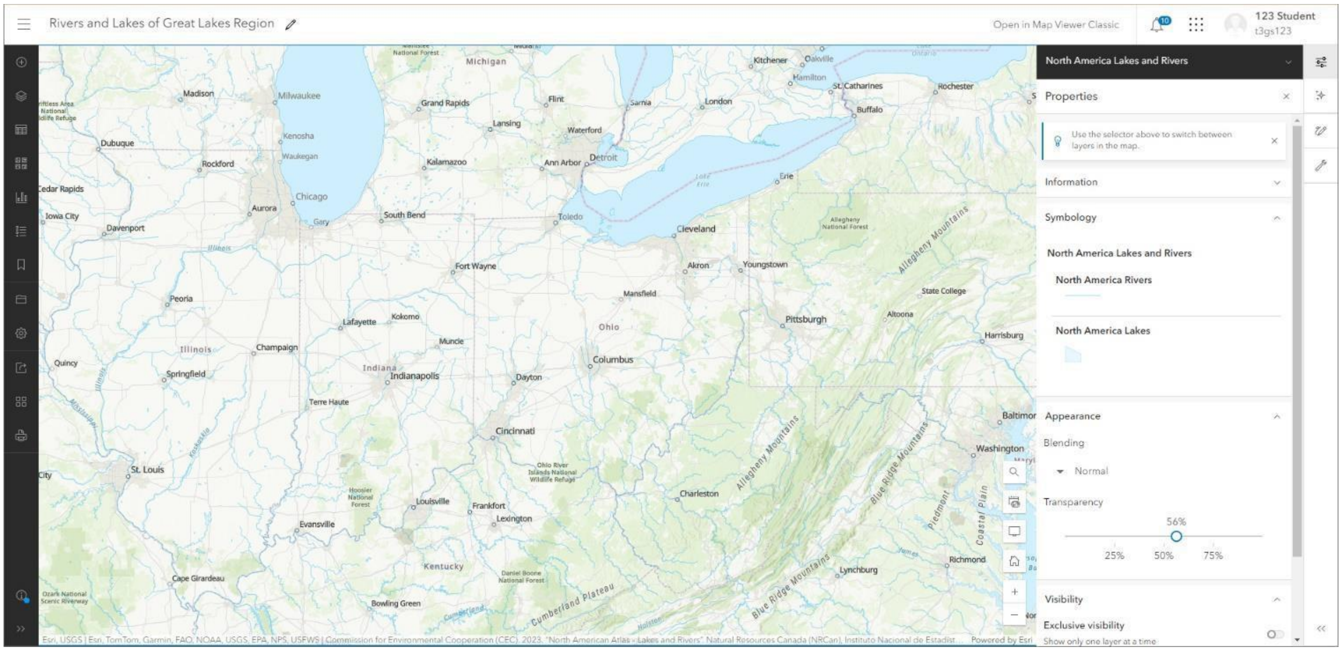
## Teaching Suggestions in the 5E Model

### *Engage*

1. Engage students by asking them to draw a map of the Great Lakes region or a river in your area, from memory. They should use a full sheet of paper and make their maps as accurate as they can without looking at any references. Ask them to try to include the details such as those below:
   - State and/or country boundaries
   - Rivers and streams
   - Boundary line of an entire river basin: the area of land that drains into it
   - Labels and/or a map legend
2. Pass out materials, if necessary, and circulate through the room to answer (and ask) questions. After about five minutes, or whenever students start to run out of ideas to add to their maps, ask the students to show their maps to a neighbor and discuss them briefly. After a minute, ask for a volunteer to share their mental map with the class using a document camera if one is available, or a digital image of it displayed via a computer/device and a data projector.

## Explore

3. Show students an ArcGIS Online-created map of the Great Lakes region, or you could choose a map of a local watershed. Lead an interactive discussion about the states and/or provinces shown, rivers shown, etc. Then explain that the students will be able to add their own data points on a similar interactive map to help professional researchers, wildlife managers, and the community at large.



**A map created with ArcGIS Online showing the "North American Lakes and Rivers" layer with transparency.**

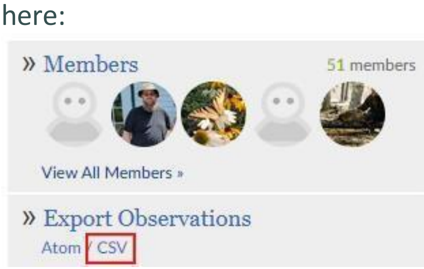
4. Demonstrate for students how they submit their data through the iNaturalist form for the Crayfish Study if they have not yet done so: inaturalist.org/observations/new?project_id=36381. Explain that once all of the groups submit their data, they will be able to use the online map to help compare their data with that of other groups.

## Explain

5. Show students how to access the data using your ArcGIS Online account, as shown in the "Exploring Data with ArcGIS Online" handout at the end of the lesson.

   You can download the data from iNaturalist and add it to your ArcGIS Online maps:

   - Go to the iNaturalist Great Lakes Crayfish community homepage: inaturalist.org/projects/great-lakes-crayfish
   - Scroll down just a bit and click **Export Observations > CSV** on the right side of the screen. "CSV" is in smaller type, as outlined in red here:



- When the data has been exported, extract the data from the zip file in your file explorer.
- Go back to ArcGIS Online, click the "**+**" symbol, then "Add layer from file." Click on the downloaded iNaturalist CSV file. Click "Next" for the next few screens and then "Create and add to map."

6. Demonstrate how students can work with their group to analyze the data and present it visually. If they have never used the software, you should either provide them with a brief tutorial, or you might suggest they work through one or more tutorials online, such as those presented here: learn.arcgis.com/en/projects/get-started-with-arcgis-online.
    - Students can change basemap layers, customize symbol styles, or use the Find Hot Spots tool to identify areas with higher crayfish sampling activity. See more ideas at: esri.com/en-us/industries/k-12-education/your-role/teachers
7. Tell students they should be able to share at least two interesting visualizations of the crayfish data and be ready to discuss them with the class. For example:
    - How did their observations differ in different parts of the waterbody where they sampled?
    - How far away they are from a larger waterbody.
    - They could also calculate distance from the school or see how it compares with the other crayfish found in the area (according to the iNaturalist page or the American Crayfish Atlas).
8. Circulate through groups, answering (and asking) questions to help students better use the software and arrive at their own conclusions. After about 15 minutes, or whenever groups start to finish, tell students they will have two more minutes to work. Ask them to be prepared to show and explain their best data visualization(s). If time allows, you can also ask students to explain their visualizations in writing.
9. Allow groups to share and close with a discussion about how the crayfish your class found compares with those found by other groups, such as other classes, U.S. Geological Survey (USGS), and/or the U.S. Fish & Wildlife Service. Include what students have learned about native and invasive crayfish, as well as freshwater ecosystems, in the complete unit. You could also discuss additional research that might add to your understanding of the health of the watershed.

## *Expand/Enrich*

- After doing the mental maps activity, allow students to use sources to create more realistic maps of your local watershed or regional watershed. They can add your city/town, research site(s), etc. Satellite photographs available via ArcGIS Online or sites like Google Maps can also be used for reference.
- Ask students in grades 6–12 to read the "Career Connections: Alex Towne, GIS Specialist" article at the end of the lesson and then complete the "Could you work in GIS?" activity that follows it in discussion with a partner.

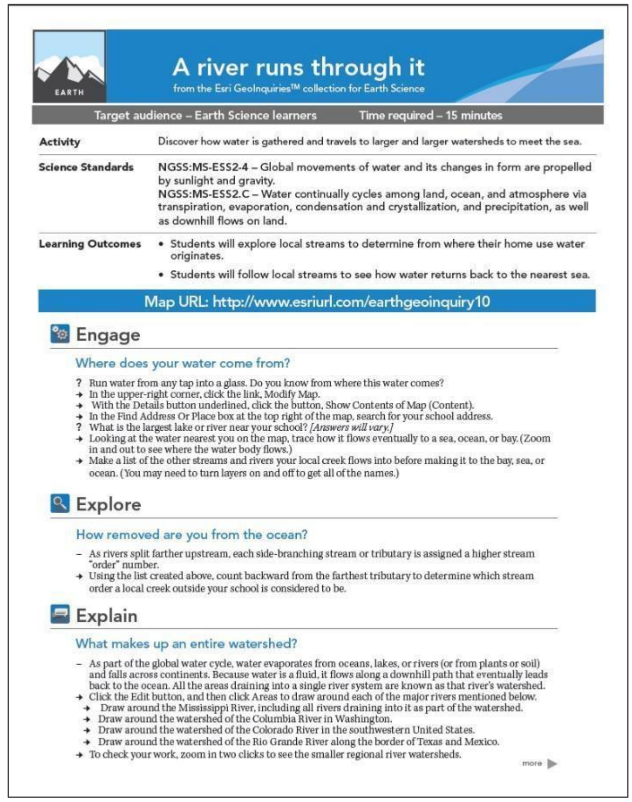
- Show one or more short videos about ArcGIS Online, such as:
    - “A Basic Introduction to ArcGIS Online:” youtube.com/watch?v=1ks6bk5AC9Y
    - “Introduction to ArcGIS Online:” youtube.com/watch?v=N-5FCICaMyM
- Ask students to write in journals or notebooks about what they learned about your area, ArcGIS Online, native and invasive crayfish, etc. throughout the lesson and unit.
- Have a more robust discussion about the concept of a watershed (basin). For instance, discuss how each term describes an area of land that drains precipitation to a river, lake, ocean, etc. Ask questions to get students thinking more about their role in the watershed, such as:
    - Where do oil and trash go after it rains?
    - How are organisms impacted by humans?
    - What can we do for a future with more life?
- Obtain maps of a smaller watershed around your school and ask students to color in the watershed. Good sources of this information include your local soil and water conservation districts and USGS.
- Do one or more of the ArcGIS lessons listed in the “Expand Knowledge + Skills” section below.

### *Evaluate*

- Review student mental maps related to their watershed and those they created with the software, their analyses of the crayfish data, etc.
- Review completed “Could you work in GIS?” activities and provide feedback.
- Assess levels of oral participation and student understanding of the concept of a watershed, how ArcGIS Online can be used to visualize and interpret data about it, etc.

## Expand Knowledge + Skills

- Esri GIS Education Instructional Materials: education.maps.arcgis.com. Search and/or browse the many lessons, maps, and other resources, including these lesson plans:
    - "Where does the water go? (watersheds):" education.maps.arcgis.com/home/item.html?id=b536a8723fd5410d8a246f884e0af1c4
    - "A river runs through it:" education.maps.arcgis.com/home/item.html?id=483ee42fb7d2437aa30b60c4e68466d0
    - "Investigating biodiversity:" education.maps.arcgis.com/home/item.html?id=4ff12184f747412093cf4aecf9628fe8
    - "Down to the last drop:" education.maps.arcgis.com/home/item.html?id=2c4e31fd3157489d807290d341723771
- "Get Started with ArcGIS Online:" learn.arcgis.com/en/projects/get-started-with-arcgis-online
- ArcGIS Skillbuilder Activities for Education: community.esri.com/ccqpr47374/attachments/ccqpr47374/k12-instruction-docs/3/3/AGOskillbuilder.pdf
- DiBiase, D. "The Nature of Geographic Information: An Open Geospatial Textbook." Penn State University: e-education.psu.edu/natureofgeoinfo



A river runs through it

from the Esri GeoInquiries™ collection for Earth Science

Target audience – Earth Science learners — Time required – 15 minutes

| | |
|---|---|
| **Activity** | Discover how water is gathered and travels to larger and larger watersheds to meet the sea. |
| **Science Standards** | NGSS:MS-ESS2-4 – Global movements of water and its changes in form are propelled by sunlight and gravity. NGSS:MS-ESS2.C – Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. |
| **Learning Outcomes** | • Students will explore local streams to determine from where their home use water originates. • Students will follow local streams to see how water returns back to the nearest sea. |

Map URL: http://www.esriurl.com/earthgeoinquiry10

Engage

Where does your water come from?

? Run water from any tap into a glass. Do you know from where this water comes?
→ In the upper-right corner, click the link, Modify Map.
→ With the Details button underlined, click the button, Show Contents of Map (Content).
→ In the Find Address Or Place box at the top right of the map, search for your school address.
? What is the largest lake or river near your school? *[Answers will vary.]*
→ Looking at the water nearest you on the map, trace how it flows eventually to a sea, ocean, or bay. (Zoom in and out to see where the water body flows.)
→ Make a list of the other streams and rivers your local creek flows into before making it to the bay, sea, or ocean. (You may need to turn layers on and off to get all of the names.)

Explore

How removed are you from the ocean?

– As rivers split farther upstream, each side-branching stream or tributary is assigned a higher stream "order" number.
→ Using the list created above, count backward from the farthest tributary to determine which stream order a local creek outside your school is considered to be.

Explain

What makes up an entire watershed?

– As part of the global water cycle, water evaporates from oceans, lakes, or rivers (or from plants or soil) and falls across continents. Because water is a fluid, it flows along a downhill path that eventually leads back to the ocean. All the areas draining into a single river system are known as that river's watershed.
→ Click the Edit button, and then click Areas to draw around each of the major rivers mentioned below.
→ Draw around the Mississippi River, including all rivers draining into it as part of the watershed.
→ Draw around the watershed of the Columbia River in Washington.
→ Draw around the watershed of the Colorado River in the southwestern United States.
→ Draw around the watershed of the Rio Grande River along the border of Texas and Mexico.
→ To check your work, zoom in two clicks to see the smaller regional river watersheds.

more ▶

**One of the many free lesson plans available from Esri GIS Education**

### 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

# Exploring Data with ArcGIS Online

1. **Login to Esri's ArcGIS Online**: arcgis.com

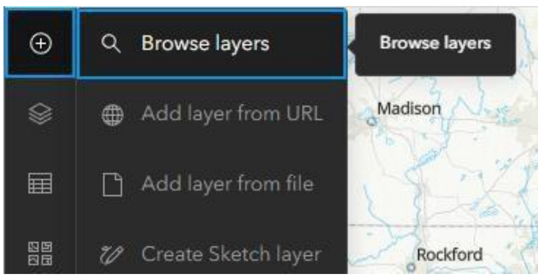
   Get it free for schools: esri.com/en-us/industries/k-12-education/schools-software

   Your school's IT team may need to apply for the School Bundle if you don't have it already.

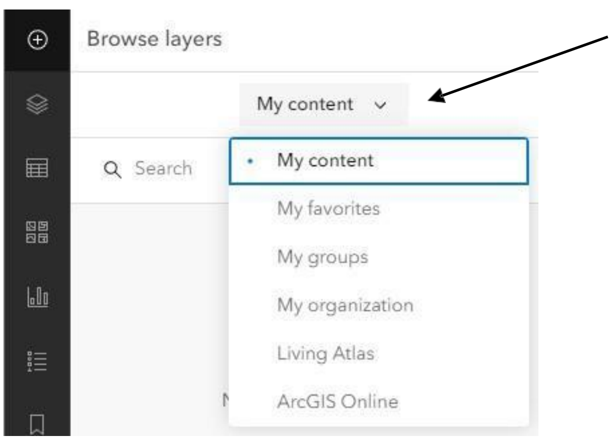
2. Click **Map** at the top of the ArcGIS Online site.

3. Add data to your map:

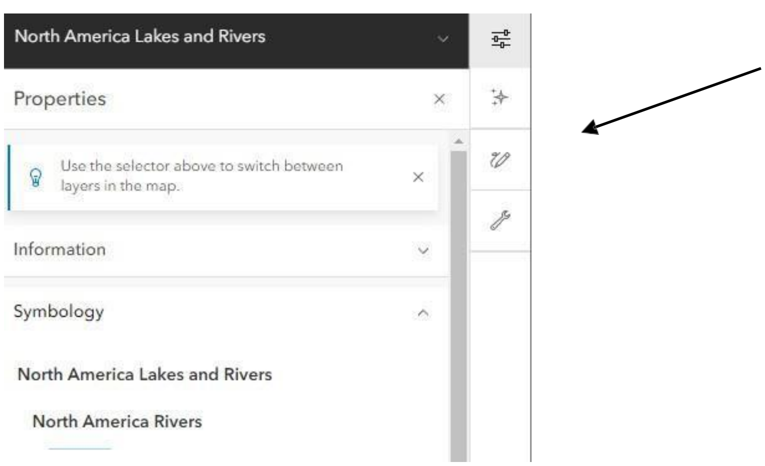
   i. Click the "**+**" button in the upper left to **Add/Browse layers**:



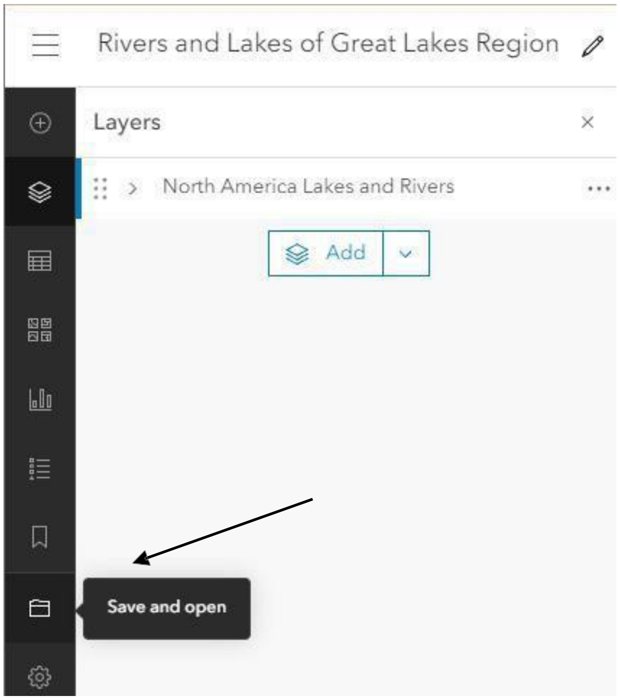

   ii. Click the down arrow to search sources such as **Living Atlas** and **ArcGIS Online**:



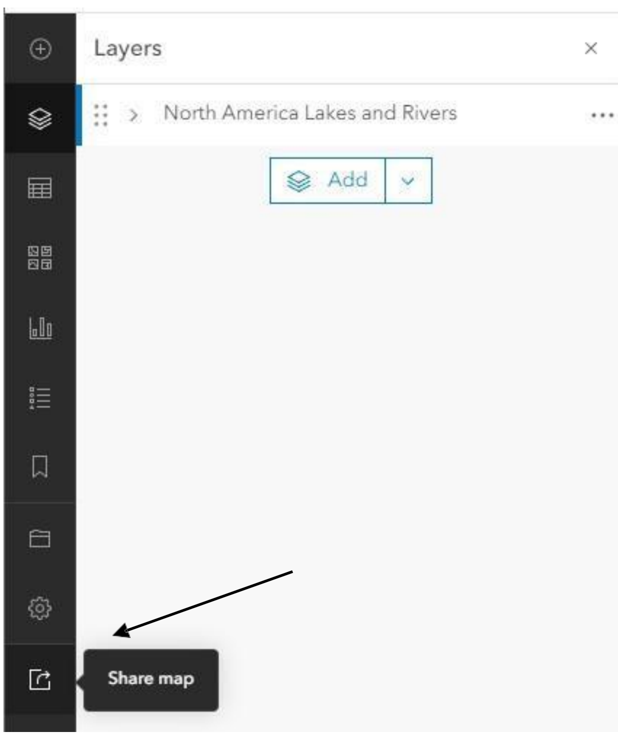

   iii. Use the **tools on the right** to add labels, icons, descriptions, etc. to maps:



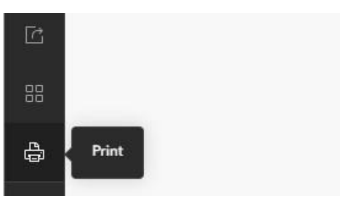
**4.** Click the folder icon on the left to **Save** your map:




**5.** Click the **Share** button on the right to get a link to a map:




**6.** Click **Print** to prepare a map for printing:



# *Career Connections*

# Alex Towne, GIS Specialist

**Alex Towne** is passionate about her career in **geographic information systems (GIS)**. As a GIS specialist, she creates maps, analyzes data, and develops models to help make land use decisions. She even gets to pilot drones!

**Alex Towne pilots a drone for use in GIS.**
*Photo: Grand Ronde Model Watershed*

Alex has loved maps and geography since great teachers got her excited about them as she grew up in rural northeast Oregon. She loved exploring the wide-open landscapes, riding horses, and shooting cans in a beautiful, remote canyon. There were more rattlesnakes in this area than people, with a population of just 175 humans! Alex was deeply influenced by her time spent outdoors. She remembers nights as a child checking on the cows with her dad (she liked to point the spotlight), hiking in the Eagle Cap Mountains with her mom, and spending countless summer days swimming in Wallowa Lake.

Alex earned a Bachelor of Arts degree in geography from Portland State University. She chose her major in part because of intriguing GIS courses. This interest motivated her to further her education with a graduate certificate in GIS from Oregon State University (OSU), where she became proficient with tools like ArcGIS Pro.

**Alex enjoys working in a STEM career in rural Eastern Oregon, where she grew up.**
*Photo: Grand Ronde Model Watershed*

Alex's favorite book as a child was a large atlas (book of maps). "I really like the power maps have to display data in such a user-friendly way, and that geographic reasoning applies to every subject," she said. Alex's love of maps serves her well in her position with the Grand Ronde Model Watershed (GRMW), where she provides map making and data analysis services for the organization and its many partners. These include the U.S. Forest Service, Oregon Department of Fish and Wildlife, The Confederated Tribes of the Umatilla Indian Reservation, The Nez Perce Tribe, Trout Unlimited, the Bonneville Power Administration, and others.

Alex enjoys working with GRMW because, “I believe in the work that is being accomplished, and what better place to do that than a place I love so much.” As a Wallowa County native, Alex brings insight and a unique perspective to her projects, such as the Wallowa County Atlas Project.

Alex’s favorite part of her job is assisting with field data collection, including piloting a drone to collect aerial imagery. She assists with habitat monitoring projects and pre- and post-project assessments. For instance, she does imagery classification to make models that describe what colors in an image represent different types of land cover. That helps her determine the acres of vegetation, how much area is in a floodplain, and how habitat for endangered fish species (Chinook salmon and steelhead) changes over time. An important goal is keeping water high up in streams longer, so the watershed doesn’t dry out as quickly. Increasing riparian areas (buffer zones with native plants along rivers), helps slow water and erosion and provides shade to benefit fish and other wildlife. This is a critical goal of her work.

Alex sees many opportunities for others to pursue careers in GIS no matter where they live. “It’s used in every field now, including healthcare and social services, not just natural resources,” she added. She also loves to write, which helps her produce a newsletter, *Ripples in the Grande Ronde*. You can read it and learn more about GRMW’s work at [grmw.org](grmw.org).

When she’s not working, Alex is outside with her husband Keith, hunting, fishing, hiking, rafting, swimming, and playing with their dogs, Bailey and Bobby, and their cat, Bo. She enjoys a healthy lifestyle and working to protect the environment. Instead of sitting at her desk, she stands, with a reusable water bottle at the ready. She holds tightly to her roots.

She observes the world around her with a curious mind and uses GIS to discover patterns that can benefit people and natural ecosystems.

RIPPLES IN THE GRANDE RONDE

FALL EDITION 2021

RIVERS UNITING NEIGHBORS·QUARTERLY NEWS FROM THE GRANDE RONDE MODEL WATERSHED

## The Wallowa River - McDaniel Project

### A Passion for Rivers and a Continuing Legacy

by Winston Morton, *Oregon Department of Fish & Wildlife*

**A Passion for Rivers**

When Doug McDaniel was a boy growing up in Wallow County, he spent a lot of his free time in the river bottoms of the Lostine and Wallowa Rivers. Whether it was with his fishing pole or with a shotgun, these rivers were places of wonder and beauty for him.

A lifetime later, Doug reminisced about those times along the river as he told me about climbing along a wood jam and over the pool created by the wood to get to a better fishing spot and finding a large Chinook salmon resting in the pool. With an ear-to-ear grin, he talked about that fish and mentioned that he would often find them in these types of locations resting after their arduous journeys returning from the ocean to the stream of their birth. After being born in these rivers, these iconic fish travel hundreds of miles to the ocean, spend two or three years in the waters feeding and becoming mature, and return by the very same path to their natal waters. This journey fascinated him.

By the time I met Doug in 2004, he had led a full life and had "retired" to cattle ranching. He also had turned his interests to the section of the Wallowa River on which he lived. The Wallowa River running through his and Gail Hammack’s place just outside of Lostine had a decent riparian area with some tall black cottonwoods. Although the area was narrow, these trees and other riparian vegetation provided shade that keeps water temperatures cooler, maintaining preferred conditions for the river’s salmonid inhabitants. The stream channel itself particularly caught Doug’s attention. It had been relocated from its historical location and channelized, held in place with a levee. It was clear to him that the river was missing the type of habitat he remembered the adult Chinook utilizing. The mile of river running through their property was just one giant riffle. There were neither

*Continued on page 2,* PASSION

**The late Doug McDaniel fishing a restored section of the Wallowa River on his and Gail Hammack’s ranch outside of Lostine, OR. (Photo: Gail Hammack)**

**Alex Towne creates this newsletter as another fun part of her work with the Grande Ronde Model Watershed.**

**Alex Towne hiking on top of Ruby Peak in the Wallowa Mountains where she works.**

Name(s): ______________________________ Period: ____ Date: _______________

# Could You Work in GIS?

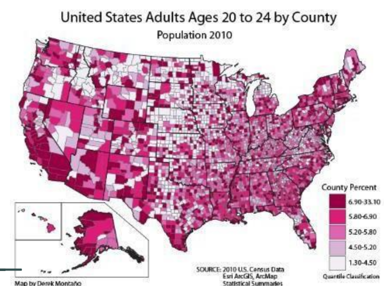
Read about Alex Towne's career to help you decide if GIS could be part of your own future!

1. What does the acronym GIS stand for? ________________________________________

2. What are some career fields that use GIS? ______________________________________

   ________________________________________________________________________

3. Imagine that you were hired as a GIS specialist. What kinds of projects might you work on? What kinds of maps might you make? Some different types are explained here: youtu.be/VgeMUpK-qXM




**A choropleth map created with GIS**

*Photo: Wikimedia Commons*

   ____________________________________________________________

   ____________________________________________________________

   ____________________________________________________________

   ____________________________________________________________

4. Do you think you would enjoy a career as a GIS specialist? Why or why not?

   ________________________________________________________________________

   ________________________________________________________________________

   ________________________________________________________________________

5. What other career paths might you enjoy? Are any in STEM (science, technology, engineering, and mathematics)? Describe what appeals to you about these career options.

   ________________________________________________________________________

   ________________________________________________________________________

   ________________________________________________________________________

   ________________________________________________________________________

Lesson 9

# Community Presentations + Engagement

**Subjects** Science, Language Arts

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

**Time** Will vary

**A student presents about her research project.**
*Photo: U.S. Dept. of Agriculture*

## Lesson Overview

Students learn about effective science communication strategies and make presentations and/or create videos about their crayfish research project(s). In this way, students strengthen their understanding and skills and magnify their impact in the community.

## Goals

- Students will create presentations and/or videos that engage the community.
- Students will increase their skills of organizing information, presenting it to others, and working collaboratively as teams.

## Objectives

- Students will create effective presentations and/or videos that educate the community about their work to investigate native and invasive crayfish and their ecosystems in your area.
- Students will effectively present their work to peers and the broader community with the assistance of multimedia technology.

## Next Generation Science Standards

### Performance Expectations

#### Building Toward

- MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

### Crosscutting Concepts

- Stability and Change
- Structure and Function
- Systems and System Models

### Science & Engineering Practices

- Constructing Explanations (for science) and Designing Solutions (for engineering)
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

### Core and Component Ideas in the Life Sciences

#### LS1: From Molecules to Organisms: Structures and processes

- LS1.B: Growth and Development of Organisms

### Core and Component Ideas in Earth and Space Sciences

#### ESS2: Earth's Systems

- ESS3.C: Human Impacts on Earth Systems

## Common Core State Standards

### Speaking and Listening Standards for Grade 6

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

**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.

**Standard 6.** Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

### College and Career Readiness Anchor Standards for Writing

**Standard 6.** Use technology, including the Internet, to produce and publish writing to interact and collaborate with others.

**Standard 7.** Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

## Center for Great Lakes Literacy Principles

**Principle 6.** The Great Lakes and humans in their watersheds are inextricably interconnected.

**Principle 8.** The Great Lakes are socially, economically, and environmentally significant to the region, the nation and the planet.

## Teacher Background

This lesson provides guidance on conducting presentations and effectively communicating science to the public. Presenting their accomplishments strengthens students' understanding and skills and magnifies their impact in the community. Audiences could include city or town leaders, parents, the rest of the school including administration, and/or another school, as well as restoration partners, landowners, and the community at large. The exercise helps students further reflect on what they have learned throughout their study of crayfish and freshwater ecosystems, understand that their work is important to the public, further educate others on what they have learned, and develop their public speaking and presentation skills.

## Materials

- Computer access and software such as PowerPoint, Google Slides, Keynote, Prezi, and/or iMovie to create multimedia presentations and/or videos
- Display screen
- Copies of the "Presentation Rubric" at the end of the lesson, one for each student
- *Optional:* Tables for students or partner organizations to display information

## Preparation

1. Schedule an event well in advance and, if desired, work with partners to invite community members such as funders, parents, and administrators, as well as partner organizations, such as governmental agencies and nonprofit organizations interested in crayfish (e.g. Invasive Crayfish Collaborative), freshwater ecosystems, and/or water quality.
2. Encourage students to dress appropriately when it is time to present to the public.
3. Consider encouraging students to incorporate props into their presentations which will better engage the audience and help convey their points.
4. Make copies of the Presentation Rubric, one for each student.

## Teaching Suggestions in the 5E Model

### *Engage + Explore*

1. Start by asking students why they think it's important for the public to understand science. Discuss the potential consequences when people lack access to accurate scientific information. Talk as a group and then brainstorm different ways science can be shared with the community.
   - Provide students with examples of science communication formats, such as infographics, posters, street murals, and social media posts. Resources can be found in the Expand Knowledge + Skills section.
2. Tell students that your class will be planning a community event where they will have the chance to present their own data and work. Students will decide as a class what the event will look like, who should be invited, and how they will present their work.

3. Talk with students about ideas for the format of the community presentations and/or videos. This will give them the opportunity to incorporate their ideas for the event(s) and have more "buy-in" and enthusiasm for it.
4. Have students discuss their ideas in small groups before sharing them out in a whole class discussion.

## Explain

5. Depending on what you decide as a class, explain to students what will be expected of them. For example, tell them that they will be working with small groups to create 5–10-minute-long oral presentations or videos about their project. Engaging multimedia content should be incorporated using software such as PowerPoint, Google Sheets, Keynote, or Prezi, or videos can be created using software such as iMovie. Encourage students to conduct additional research to enhance their presentations/videos and bolster their arguments.
6. Discuss or provide students with a sample outline they can use to help them structure their presentations and videos. For example, instruct students to include details such as:
    - All the elements of the Crayfish Study, including visuals (see lesson 5)
    - The native and invasive crayfish species found in their state
    - The anatomy, life cycle, and importance of crayfish
    - What they learned during their field work and/or classroom activities
    - How their field work enhanced what they learned in the classroom
    - How they changed because of this project

    Details such as these are especially important if community partners, funders, and/or school administrators will be in the audience.
7. Pass out copies of the "Presentation Rubric" at the end of the lesson (or your own rubric) to guide student learning and let them know how they will be assessed. Tell students that they will complete the "Self-Score" portion of the rubric and turn it in to you before they present.
8. If desired, work with partner organizations to develop an agenda for the community presentations. Consider inviting other organizations to attend who can staff tables and offer volunteer opportunities after the presentations are complete.
9. Offer students the opportunity to practice their presentations beforehand. A "dress rehearsal" in the space where students will be presenting publicly is helpful.
10. On the day of the event, sit back and watch students shine!

## Enrich/Extend

- Collaborate with grade level English/Language Arts teachers to support standards that have been taught in the students' English classes. Students could do a joint project in which they work on science and literacy together in both their English and science classes.
- Students can present to younger students to teach them about their work.
- Present one or more awards to outstanding class members, either individuals or groups. Awards could be for exceptional additional volunteer efforts, the most outstanding restoration plan, etc.

- Identify students who have photography and/or film experience and ask them to use a camera(s) and/or video camera(s) to document the community presentations. Students can then share their presentations via YouTube, the school website, social media, etc., as allowed by school and district policy.

## *Evaluate*

- Evaluate group presentations/projects using the rubric.
- Record levels of oral participation and group participation throughout the project.
- Ask students and community members to provide feedback about your event so it can be used to improve future events.

## Expand Knowledge + Skills

- Invite professionals to serve as keynote speakers for community presentation events. This can help enhance everyone's understanding of freshwater ecosystems.
- Encourage students in the audience to ask questions after each presentation. Questions can be answered by presenting students, as well as professionals.

### Science Communication and Presentation Skills

- "10 Forms of SciComm for Everyone" by Aimen Arshad: fancycomma.com/2023/02/11/10-forms-of-scicomm-for-everyone/
- McGivern, H. "An Introduction to Science Communication: Translating Your Research for a Non-Specialist Audience", Oxford University Hospitals:bodleian.ox.ac.uk/sites/default/files/bodreader/documents/media/iskills-introduction-science-communication.pdf
- "Science Murals, Communicating and Visualizing Science via Public Art", Art + Bio Collaborative: artbiocollaborative.com/sciencemurals
- "How She Teaches Presentation Skills" by How She Teaches: howsheteaches.com/2023/02/27/how-she-teaches-presentation-skills/

### 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

Name: ____________________________ Period: _______ Date: _______________________

# Presentation Rubric

**Name of Organism:** ____________________________________________

| **Presentation Component** | **Maximum Points Possible** | **Self-Score** (fill out before presentation) | **Teacher Score** |
|---|---|---|---|
| **Content** | | | |
| Subject and purpose of presentation clearly introduced | 10 | | |
| Key concepts identified and clearly explained in well-organized way | 10 | | |
| Ideas supported by examples, data, graphs, etc.; All information accurate and obtained from reliable sources | 10 | | |
| Conclusion summarizes key points in persuasive way; Questions answered thoroughly and accurately | 10 | | |
| **Delivery/Audience Engagement** | | | |
| Speech delivered clearly at appropriate volume and speed (not too fast, slow, loud, or soft) | 10 | | |
| Speed, volume, and voice inflection are varied to engage audience and emphasize key points | 10 | | |
| Speaker connects with audience through eye contact and does not spend too much time looking at notes or screen | 10 | | |
| Speaker demonstrates enthusiasm for topic throughout presentation; audience is persuaded by speaker about important role(s) in ecosystem | 10 | | |
| **Visual(s)** | | | |
| Visuals help to clearly explain concepts | 10 | | |
| **Writing Conventions** | | | |
| Grammatical and spelling conventions followed | 10 | | |
| **TOTAL:** | **100** | | |

Teacher Comments:

# Glossary

**Adaptation** — Process in which an organism changes over many generations to better fit its habitat

**Abdomen** — End section of crayfish and other **arthropods**; area of **vertebrates** with digestive organs (belly)

**Algae** — Many species of simple, nonflowering plants that are generally found in aquatic ecosystems; includes single-celled species, seaweeds, and other varieties, none of which have true stems, roots, or leaves

**Algae and other aquatic plants form the base of freshwater food webs. They are referred to as producers, or autotrophs.**

**Antenna** — One of two long sensory organs at front of crayfish (**antennae**: two or more)

**Antennule** — One of two short antennae

**Anus** — End of digestive tract; in crayfish, located on lower part of **telson**

**Appendage** — A part of an animal (or something else) that projects out; on crayfish, these include **walking legs**, **chelipeds**, **antennae**, and **maxillae**

**Aquatic** — Living in or frequenting water

**Areola** — Space between the two carapace plates

**ArcGIS** — Popular software created by Esri for developing **GIS** applications and maps

**Cyanobacteria (blue-green algae) blooms can be harmful. They are caused by too many nutrients entering the water. When the organisms die, levels of dissolved oxygen drop.**
*Photo: Tom Archer, NASA*

**Arthropod** — An animal from the vast phylum *Arthropoda* with jointed limbs, no backbone, and a body covering made of chitin; includes arachnids like spiders, **crustaceans** like crayfish, insects, and myriapods like centipedes

**Autotroph** — Organism that creates its own food from **photosynthesis** (plants) or **chemosynthesis** (chemical reactions—done by microbes around hydrothermal vents in oceans)

**Bacteria** — Single-cell organisms that can have positive and negative impacts; harmful bacteria found in **freshwater ecosystems** include fecal coliform, *E. coli*, and enterococci

**Behaviors** — Actions of an organism (things it does)

**Biodiversity (biological diversity)**
The variety of life and the interrelationships among various levels of living things

**Biology** The study of living things

**Burrow** Digging for shelter, food, etc.; many crayfish species burrow with their **chelipeds** for shelter and to keep their **gills** moist

**Camouflage** Ways an organism blends in with its **environment**; includes color, patterns, materials, and light

**Carapace** Upper protective **exoskeleton** (shell) of cephalothorax

**Carnivore** Meat eater; animal that eats other animals

**Cervical Groove** Indentation in carapace between head region and thorax region

**Cephalothorax** Combined head and thorax; contains the heart, gills, stomach, and other organs

**Chela** One of two big claws used for defense and food handling (**chelae**: two or more)

**Cheliped** One of two long legs with a **chela**

**Chitin** Substance most abundant in the **exoskeletons** of **arthropods** like crayfish; also forms the cell walls of fungi

**Chlorophyll** Green pigments that allow plants and cyanobacteria to use light for **photosynthesis**

**Classification** In biology, a method to group and categorize organisms

**Climate** The average weather conditions of a place, such as temperature and rainfall levels, over a long period of time

**Common name** A name by which a species is known, rather than its scientific name; can vary by region or country, unlike a **scientific name**

**Community** All the organisms in a habitat that interact in a complex food web

**Competition** An interaction between organisms or species for a limited supply of one or more resources (such as food, water, and space) that are used by both

**Compound eye** Two eyes made up of many small eyes; located on **eye stalks** in crayfish

**Conservation measures**
Actions to preserve, improve, and/or restore habitat for one or more wildlife species and/or future human use

**Conservation strategy**
An approach for protecting a particular species, habitat, or ecosystem

**Consumer** In biology, an organism that eats food created by other organisms; **heterotroph** (animal)

**Contiguous** Connected; meeting or joining at the border

**Crayfish** **Crustacean** found in freshwater ecosystems; relative of lobsters, found in saltwater; there are about 600 species of crayfish in the world and over 400 species in North America, some of which are at risk of **extinction**

| | |
|---|---|
| **Crustacean** | An **arthropod** in subphylum *Crustacea* that includes crayfish, crabs, shrimp, and wood lice (pill bugs); most have two pairs of **antennae** (the smaller called **antennules**) and other paired **appendages** near their mouths |
| **Data** | Evidence, facts, and statistics collected for analysis or reference |
| **Data analysis** | Process of evaluating **data** using statistics, graphs, etc. to determine trends |
| **Decomposer** | Organism that breaks down dead plants and animals, allowing the nutrients to be recycled in the **ecosystem** |
| **Detritus** | Any kind of waste or debris; plant and animal detritus provide important food for crayfish |
| **Digestive tract** | **Internal** organs used by an animal to break down food; starts at **mouth** and ends at **anus** |
| **Dissolved oxygen** | Oxygen in water that most **aquatic** animals need to breathe; crayfish do best with dissolved oxygen levels of 2 ppm (parts per million) or higher, although they are more tolerant of low levels of oxygen than some other aquatic organisms, such as salmon |
| **Diversity** | A variety of different things; the number of different species, communities, or habitats; can also apply to human communities |
| **Dorsal** | Refers to upper side (back) of an organism |
| **Ecosystem** | The plants, animals and other living organisms interacting together and with their environment, which includes nonliving things like water, air, and sunlight; often thought of as a functioning unit |
| **Ecosystem services** | The life-sustaining functions of healthy, diverse ecosystems, such as flood control, food, and water/air purification |
| **Egg** | Round or oval object produced by female animals for reproduction; crayfish females hold eggs in their **swimmerets** after they have been fertilized by males |
| **Endangered species** | An organism that is in danger of extinction throughout all or a significant part of its range |
| **Endangered Species Act of 1973** | Federal law designed to protect species at risk of extinction and the ecosystems on which they depend; administered by the U.S. Fish & Wildlife Service and the National Oceanic and Atmospheric Administration |
| **Environment** | Surroundings of an organism; includes all the other living and nonliving things |
| **Erosion** | The process of moving rock, soil, or minerals by water, wind, or other natural processes; can reduce **water clarity** and quality in **freshwater ecosystems** |
| **Evolve** | To change gradually over time |
| **Evolution** | Process by which organisms change over time through **natural selection** |

**Exoskeleton** Outside shell that protects and supports the body of crayfish and other **arthropods**

**Exotic** Not native, introduced

**External** Outside of something, such as the **exoskeleton** of a crayfish

**Extinct** A species that no longer exists

**Extinction** When a species completely dies out

**Eye stalk** One of two columns that attaches to each crayfish **compound eye**; allows them to have a larger field of view

**Fertilizer** **Nutrients**, such as nitrogen and phosphorus, added to plants to help them grow; can reduce **water quality**

**Field journal** A place to record observations, illustrations, data, and ideas

**Food chain** A series of organisms that depend on each other for food; usually begins with **producers** (plants), followed by **consumers** (animals)

**Freshwater ecosystem** An area of freshwater, such as rivers, lakes, streams, and ponds; includes all the living and nonliving things that interact

**Genital pores** Openings in female crayfish from which eggs exit (and sperm enters)

**Gills** **Internal** feathery **organs** used to get oxygen from the water

**GIS** Geographic information system; way to organize/analyze **data** rooted in geography

**Gonopods** Modified swimmerets of males; used to pass sperm to females

**Green gland** One of a pair of organs used to remove waste products and balance salt levels in blood; two openings to them are on the lower side of the head

**Groundwater** Underground water in soil or permeable rock, often feeding springs and wells

**Habitat** The place or type of site where an organism lives

**Herbicide** A chemical designed to control or destroy plants, weeds, or grasses; can reduce water quality in **freshwater ecosystems**

**Herbivore** Animal that eats plants

**Heterotroph** Organism that cannot create its own food; eats plant and animal matter

**Indicator species** Organism that can provide evidence about the health of an **ecosystem** by its presence, absence, or change of abundance

**Internal** Inside of something, such as the organs inside a crayfish

**Instar** Phase between **molts** for crayfish and other **invertebrates**

**Invasive species** A species, usually nonnative, that spreads and crowds out native species, causing harm to the environment, economy, and/or human health

**Invertebrates** Animal species that lack a backbone, such as crustaceans, insects, snails, and worms; includes 97% of all animal species

**Larva** Immature stage of certain organisms, such as **crustaceans** and insects

**Macroinvertebrates** Animals without a backbone that can be seen without magnification

**Mandible** One of two strong **jaws** used to crush food

**Maxillae** First pair of maxillae helps hold, tear, and pass food to mouth; second pair helps draw water over the **gills**

**Maxillipeds** One of three pairs of feeding appendages; attached to jaws

**Metamorphosis** In biology, the process of changing into an adult; crayfish go through incomplete metamorphosis, because they hatch from eggs into miniature crayfish, they grow through about 11 **instars** (depending on the species) before reaching adulthood

**Microscopic** So small as to be invisible without a microscope

**Mineral** Any natural, inorganic material that can be extracted from the earth

**Mitigation** Steps taken to avoid or minimize negative environmental impacts

**Molt (molting)** Process in which a crayfish or other organism sheds its outer layer before growing a new one; shedding their **exoskeleton** allows crayfish to grow larger

**Monoculture** Area consisting almost entirely of a single plant species

**Mouth** Opening at start of **digestive tract**

**Mutation** A rare change in the DNA of genes that creates genetic diversity

**Native plant** A plant that is naturally found in an area

**Natural selection** The process in which organisms better adapted to their environment survive to produce more offspring

**Native species** An organism that is naturally found in an area

**Natural selection** The process in which organisms better adapted to their environment survive to produce more offspring

**Nocturnal** Being most active at night

**Nonnative (introduced) species** Species brought into an ecosystem by humans (accidentally or intentionally)

**Nutrients** Substances that provide nourishment for growth and life; includes nitrogen and phosphorus applied as **fertilizer**; too many nutrients can cause aquatic organisms like algae and bacteria to grow very quickly, and when they die all the dissolved oxygen can be used up

**Observation** What one notices or pays attention to using their senses

**Omnivore** Animal that consumes food from both plants and animals

**Organism** Individual living thing that can react to stimuli, reproduce, and grow

**Pesticide** A chemical designed to control or destroy insects or other organisms; can reduce water quality in **freshwater ecosystems**

**pH** Measure of the number of hydrogen ions (which are acidic) in the water compared to the number of hydroxide ions (which are basic); neutral pH is 7, and crayfish prefer a range of 7.5–8.5. Most aquatic organisms prefer a range of 6.5 (slightly acidic) to 9 (a little basic). **Macroinvertebrates** are generally quite sensitive to changes in pH.

**Photosynthesis** The process of using energy in sunlight to convert water and carbon dioxide into carbohydrates and oxygen

**Policy** A statement of guiding principles or procedures

**Pollution** Substance with harmful effects on the **environment**

**Predation** When one species (the predator) feeds on another (the prey)

**Predator** Animal that hunts and eats other animals

**Prey** Animal hunted by other animals

**Producers** In biology, organisms that produce food in an **ecosystem**; plants

**Protocol** System of rules that explains procedures that must be followed

**Red swamp crayfish** *(Procambarus clarkii)*
The most common **invasive** crayfish species in the world with red to black coloration and elongated **chelipeds** with **tubercules**; may be expanding its range in the Great Lakes region

**Rehabilitate** To make habitable or useful again; to return to original condition

**Reintroduction** To return members of a species to their historical range

**Restoration** The process of returning a degraded or former habitat to a healthy condition

**Riparian area** The important strip of habitat along rivers and streams where water is more abundant

**Rostrum** Beak-like structure above eyes; also called the **supraorbital spine**

**Rubric** A document that explains expectations for an assignment and the components that will be included in the evaluation of the assignment

**Saline** Containing salt; some crayfish can live in moderately saline water

**Scavenger** Animal that feeds on dead animal or plant matter

**Scientific name** The two-part Latin name assigned to a species; system established by botanist Carl Linnaeus in the 1700s

**Sediment** Loose sand, clay, silt and other soil particles that settle on the bottom of a body of water

**Species** A group of organisms that share a unique set of characteristics and that (usually) can reproduce among themselves

**Species diversity** The number and variety of species present in a community, as well as the relative abundance of each species

**Sternum** Lower protective plates of crayfish abdomen

**Stewardship** Caring for our natural resources in a way that preserves them for future generations

**Structure** In biology, the shape or arrangement of parts of an organism

**Swimmerets** Five pairs of short **appendages** on bottom of crayfish **abdomen** used for swimming; also used by females to hold **eggs** and young crayfish

**Tail fan** The **telson** and four **uropods** of crayfish; used for swimming backwards—fast!

**Telson** Center section of tail fan

**Tergum** Upper protective plates of abdomen of crayfish

**Threatened species**
A species likely to become endangered in the future throughout all or a significant part of its range

**Topography** The earth surface features of a region, such as mountains, plains, or hills

**Toxic substances** **Pollution** such as ammonia, metals, and oil-based products

**Temperature** Amount of heat energy contained in a substance (such as water or air); more oxygen can dissolve in cooler water and be available for animals to breathe

**Turbidity** Measure of amounts of solids in water; provides good measure of **water quality**

**Tubercules** Bumps found on some crayfish species

**Uropods** Two pairs of appendages on **tail fan** that surround the telson

**Ventral** Refers to underside of an organism

**Vertebrate** Animal with a backbone; includes mammals, reptiles, birds, fish, and amphibians

**Walking legs** Four pairs of jointed legs; the gills are attached to them

**Water clarity** Measure of how far down light can travel in water

**Water quality** Measure of water's ability to support life; includes its physical, biological, and chemical characteristics

**Watershed** The land area that drains into a river, stream, or other body of water

**Weed** Any plant out of its native habitat that is unwanted and has an ability to spread

**A student tests for levels of dissolved oxygen, a key component of water quality. Crayfish and other aquatic life depend on dissolved oxygen for survival**.
*Photo: IdaH$_2$0*

# Youth Permission and Waiver Form

Project: ____________________ Site Location: ____________________ Date: ____________________

**ALL PARTICIPANTS UNDER THE AGE OF 18 WHO ARE UNESCORTED BY AN ADULT MUST HAVE A PARENT OR GUARDIAN SIGN THIS PERMISSION AND WAIVER FORM. Escorted youth may be included by their parent, guardian or authorized adult on the adult registration and waiver form.**

**This is a waiver and release. Please read it carefully before signing.** I am the parent or legal guardian of Participant named below and I, the undersigned, enter this Release and Waiver of liability and Assumption of Risk Agreement ("Agreement") on behalf of myself, the Participant, my personal representatives, next of kin, heirs, successors, and assigns and anyone else who may make any claim for or on behalf of the Participant.

- I will **cause the Participant to agree and comply** with the terms of the Agreement and not to take any actions that would assist or cause the Participant to invalidate, renounce, negate, revoke, or disclaim any part of the Agreement.
- I make this Agreement for the benefit of partner organizations, other individual volunteers, project coordinators, sponsors, suppliers, supporters, and all private and public land owners on whose property the project described above may be located (collectively the "Released Parties), including, without limitation, the Released Parties' employees, agents, personal representatives, next of kin, heirs, successors and assigns.
- I make this Agreement in consideration of the Released Parties providing Participant with the opportunity to **participate as a volunteer** in this project.
- I understand that the Project may include **dangerous or hazardous** activities and that the Project may take place on a location or under conditions that may be dangerous to Participant.
- Participant and I **accept full personal responsibility** for all risks arising from or relating to this Project.
- Participant's involvement in this Project is **completely voluntary** and neither participant nor I have received nor expect to receive any compensation for participation in it.
- Participant will read, listen to and follow all **safety instructions and procedures** presented in conjunction with this Project and **use best judgment** based upon physical and mental abilities at all times, and to immediately terminate participation in this Project if activities become too strenuous, difficult or hazardous.
- I agree to **waive all liability** of the Released Parties, **discharge them, and covenant not to sue them** for any liability, claims, sums, costs, or other expenses on my account that may be caused in whole or in part by Participant's involvement in the Project.
- I agree that this Agreement shall act as a **complete bar against all actions or claims** that I might otherwise bring against the Released Parties, including negligence claims, arising from or related to this project.
- I have read this Agreement, fully understand its terms, understand that I have **given up substantial rights** by signing it, and have **signed it freely** and without any inducement or assurance of any nature. I intend this Agreement to be a **complete and unconditional release of all liability** to the greatest extent allowed by law, and I further agree that if any portion of this Agreement is held invalid, then the balance of the Agreement shall continue in full force and effect.
- I understand that a photographer may be present to photograph the activities at the Project and that Participant may be photographed while participating in the Project. I agree that Participant will contact the photographer if he or she does not wish to be photographed.
- I hereby grant the irrevocable and unrestricted right to **use and publish photographs of Participant**, or in which Participant may be included. I hereby release Photographer and his/her legal representatives and assigns and partner organizations from all claims and liability relating to any such photographs.

**Thank you for filling out the form below and signing to give permission for your student to participate in field work. Please print clearly. We would <u>never</u> sell or trade your information.**

| | | | | | |
|---|---|---|---|---|---|
| **Name of Participant** | | ☐ Male ☐ Female ☐ Other/Prefer not to say | | | |
| **Name of Parent/Guardian** | | | | | |
| **Relationship to Participant** | | **Phone** | - - | ☐ Home ☐ Business | |
| **Address** | | | | ☐ Home ☐ Business | |
| **City** | | **State** | | **Zip** | |
| **Age of Participant** | | | | | |
| **Signature of Parent or Guardian** | | | | **Date** | |

**Are you able to chaperone?** ☐ **Yes** ☐ **No** ☐ **Maybe**

If so, please indicate your preferred method(s) of contact.

| | | |
|---|---|---|
| ☐ **Email, using address below** (please write your email address in the boxes below) | ☐ **Mail, using address above** | ☐ **Phone** |
| | | ☐ **Home** ☐ **Business** |

# Student Feedback

## Investigating Crayfish + Freshwater Ecosystems

We want your opinion! Help us find out what was best about the program and what could be improved. There are no right or wrong answers and no one will know your responses.

Please read each statement below and decide if you agree or disagree with the statement.
**Put an X in one box in each row.**

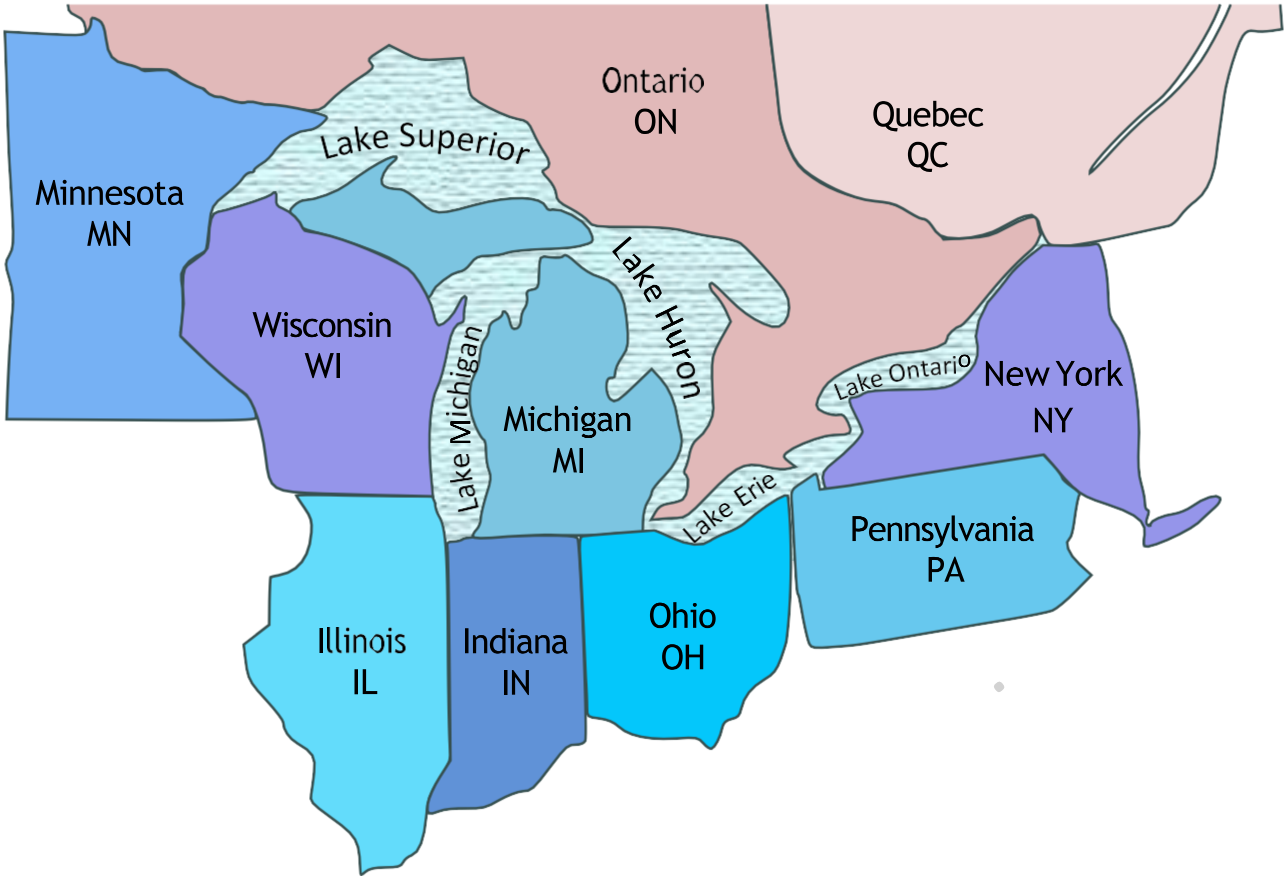
| Statement | Strongly NO | Sort of No | I'm Not Sure | Sort of Yes | Strongly YES |
|---|---|---|---|---|---|
| What I did in this program was interesting. | | | | | |
| I think I will remember the things I learned in this program about crayfish and freshwater ecosystems. | | | | | |
| I see some things differently because of this project. | | | | | |
| I care more about crayfish and freshwater ecosystems than I did before. | | | | | |
| I can see the connection between this program and the other things I am learning in school. | | | | | |
| I might volunteer to help improve wildlife habitat and/or water quality. | | | | | |
| I might like to enter a career in science, natural resources, and/or conservation because of what I have been doing. | | | | | |

**Do you have any suggestions or comments about this program?**

**THANK YOU—Your input helps a lot!**

## Meet the Next Generation Science Standards and Common Core State Standards.

## Help Researchers Learn What Native + Invasive Crayfish are in Your Neck of the Woods!




## Learn more at InvasiveCrayfish.org.

Invasive Crayfish Collaborative
Great Lakes