Investigating Crayfish + Freshwater Ecosystems

Hands-On Science Lessons Adaptable for Grades 2 -12

Aligned to NGSS + CCSS

TRM

The River Mile

Teacher's Guide

Investigating Crayfish + Freshwater Ecosystems

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Grades 2 – 12

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Published by

The River Mile

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Engaging Every Student

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About this Guide
+ The River Mile's Crayfish Study

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

The curriculum will help prepare you and your students to participate in The River Mile (TRM) network's Crayfish Study, an effort to collect data about the native and invasive crayfish found throughout the Columbia River watershed and beyond. TRM is a network of educators, students, resource managers, and scientists exploring the essential question: "How do relationships among components of an ecosystem affect watershed health?" The data students collect is shared through ArcGIS Online, enabling them to compare it with that of other groups. Just as importantly, it provides critical information for researchers and wildlife managers seeking to better understand and manage populations of the various species, as well as assess water quality, since crayfish are an excellent indicator species.

TRM is a participant-driven approach to learning about, researching, and exploring the health of the Columbia River watershed and freshwater ecosystems more broadly. Participants share best practices, lessons learned, examples, links to resources, and real-world scientific data. Students and teachers engage in science education outdoors and explore scientific practices through community-based resource projects. Groups become intimately familiar with their section of the watershed.

Join Us!

Visit therivermile.org to learn more and sign up for our free newsletter and/or join the community. Get updates about the Crayfish Study and other exciting projects, free training, resources, and more available from The River Mile network.

Thank you for your interest in joining the effort and supporting meaningful, place-based learning for our students!

TRM
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Thanks + Appreciation

We greatly appreciate the many generous colleagues who have provided invaluable contributions to this curriculum and supporting resources, especially:

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NATIONAL PARK SERVICE

IDAH2O MASTER WATER STEWARDS

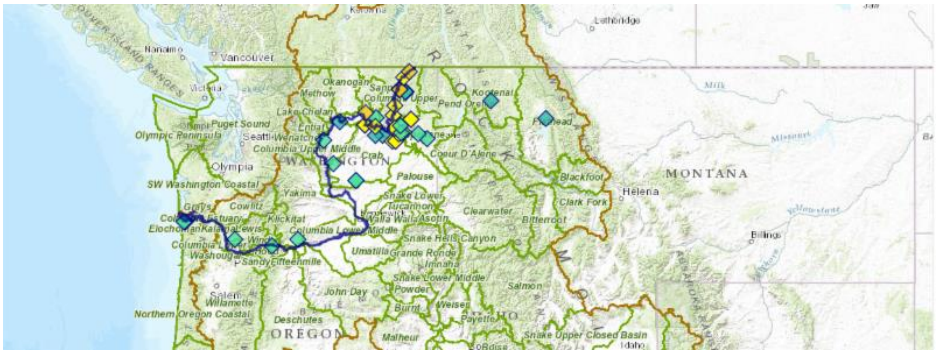
University of Idaho Extension

ILLINOIS

Lake Roosevelt Forum

COLUMBIA HIGH SCHOOL CHS HOME OF THE LIONS

Contents



Introduction to Crayfish in the Pacific Northwest and Beyond

Native and Invasive Species

Signal crayfish are **native** (naturally occurring) in the Pacific Northwest. "This species can be identified by its uniform brownish coloration, white or light coloration of the claw joint, and the smooth surface of its carapace and claws compared to that of nonnative species" (WA Dept. of Fish & Wildlife). They can range in color from lighter brown to darker brown to reddish. They have a lighter colored patch ranging from white to green in the joint of their **chelipeds** (claws).

Signal crayfish *(Pacifastacus leniusculus)*
Public domain image from Wikimedia Commons: commons.wikimedia.org/wiki/File:Signal_crayfish_female_Pacifastacus_leniusculus.JPG

An **invasive species** is defined as any non-native organism that takes 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). bare virile (northern) crayfish *(Faxonius virilus)*, red swamp crayfish *(Procambarus clarkia)*, and rusty crayfish *(Faxonius rusticus)*.

Virile (northern) crayfish *(Faxonius virilis)*
Public domain image by Alan Schmierer: flickr.com/photos/sloalan/7670748928

A few species of crayfish 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 "45 percent of North American crayfish species are considered to be at risk of extinction" ("Menace to the West: Crayfish": seagrant.oregonstate.edu/menacetothewest/species-guide/crayfish). 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.

Rusty crayfish *(Faxonius rusticus)*
Image from Wisconsin Dept. of Natural Resources: flickr.com/photos/widnr/6506232505

Similarly, the signal crayfish itself is an invasive species in some places (such as California and Europe). For instance, the endangered status (and likely extinction) of Shasta crayfish *(Pacifastacus fortis)* in northern California is due primarily to competitive displacement by introduced signal crayfish. Therefore, it is **essential that signal crayfish and other species used in the schools are not moved or released to other places.** Signal crayfish are a threat to other native crayfish in their own genus, in particular, including the Shasta crayfish, pilose crayfish *(Pacifastacus gambelii)*, and Snake

River pilose crayfish *(Pacifastacus connectens)*. We must all work together to protect **biodiversity**.

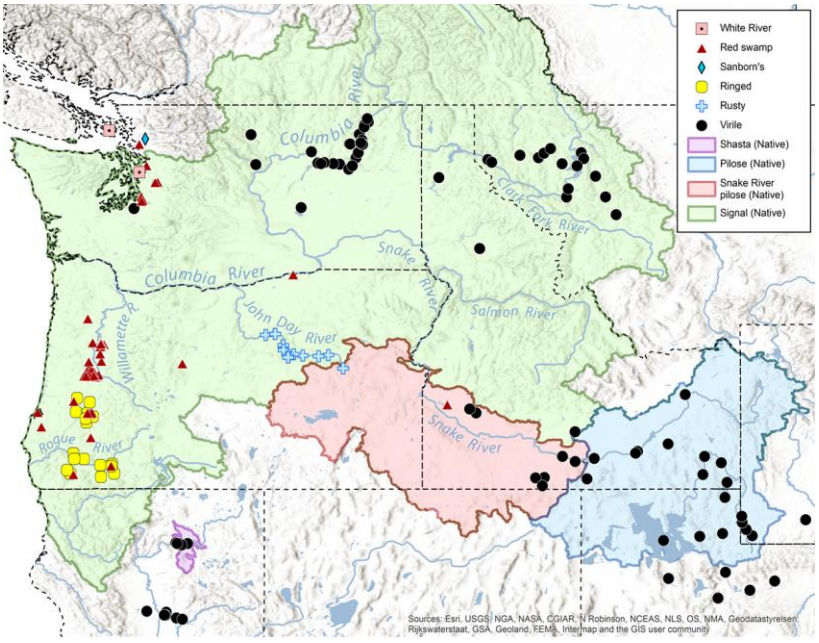
How Do We Know Which Species are Native?

According to Dr. Eric Larson, who is providing expert support for the Crayfish Study, we can reconstruct where signal crayfish were and were not native in some cases through a combination of geologic history, historical records of introductions for stocking, and genetics. We know, for example, when and how many signal crayfish were introduced to California (especially Lake Tahoe) from agency records. He is very confident that signal crayfish aren't native northwards in Puget Sound and in coastal British Columbia, but it remains unclear how far upstream they are native in the Columbia River itself. For instance, we have no records of crayfish at all from remote, wilderness areas of central Idaho, but they could be present there. The Crayfish Study can help provide important data to help answer these questions.

Pilose crayfish *(Pacifastacus gambelii)*
Image courtesy Eric Larson, Ph.D.

Snake River pilose crayfish *(Pacifastacus connectens)*
Image courtesy Eric Larson, Ph.D.

Because of meticulous historical data collected by the Oregon Department of Fish & Wildlife, we know that the commercial harvest for crayfish as food started in the lower Columbia River around Portland in the late 1800s. The signal crayfish there are the invasive signal crayfish we see (by genetics) in California, Japan, Europe, etc. And they are a risk to introduce over other "signal" crayfish that might be undescribed species. For example, when really bright red signal crayfish are found around Lake Roosevelt (often in inland, isolated lakes) that have longer (less round) claws, those are a unique Okanagan Plateau species. According to Dr. Larson, they are very different—farther genetically from signal crayfish than all of the other native western crayfish in the genus *Pacifastacus*; they should unambiguously be described as a different species, just like a similar crayfish in central Oregon, but sufficient research has not yet been done to reclassify them. Dr. Larson notes that we need to be particularly careful with the Okanagan Plateau crayfish, because it does not have expansive known range, and it could be impacted by both virile (northern) crayfish and other, more typical signal crayfish.



Recent data of native crayfish ranges and invasive crayfish occurrences; not shown are areas where signal crayfish are invasive
Map by Eric Larson, Ph.D.

Learn more about crayfish throughout this Teacher's Guide, in the resources listed at the end of each lesson plan, and at therivermile.org. A large "Native + Invasive Crayfish" poster is also available through The River Mile Network.

The River Mile

Lesson 1
Crayfish + Freshwater Ecosystems

Subjects Science, Language Arts, Art

Grade Levels Adaptable for grades 2 – 12 (Ages 7 – 18)

Time 50 – 75 minutes or more

A signal crayfish *(Pacifastacus leniusculus)* in its freshwater ecosystem

Image by Roger Tabor, U.S. Fish and Wildlife Service: flickr.com/photos/usfwspacific/6093365240

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. Students can next act out a simple food chain of different organisms which feed on each other in freshwater ecosystems, followed by a short research project about a freshwater organism and the creation of a more complex model of freshwater food webs with the whole class which demonstrates the resilience that comes with biodiversity.

The suggested lesson closes with a short discussion of the many interdependent relationships in the ecosystem that allow all of the species to survive, including crayfish, which can play especially important roles in freshwater ecosystems. 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 the 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 them 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

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.

Teacher Background

Crayfish

Crayfish are **crustaceans** which 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 which spend much of their time on land, such as raccoons, so they can play important roles in terrestrial ecosystems, as well.

Signal crayfish *(Pacifastacus leniusculus)*

Image by Jeff Benca; used by permission

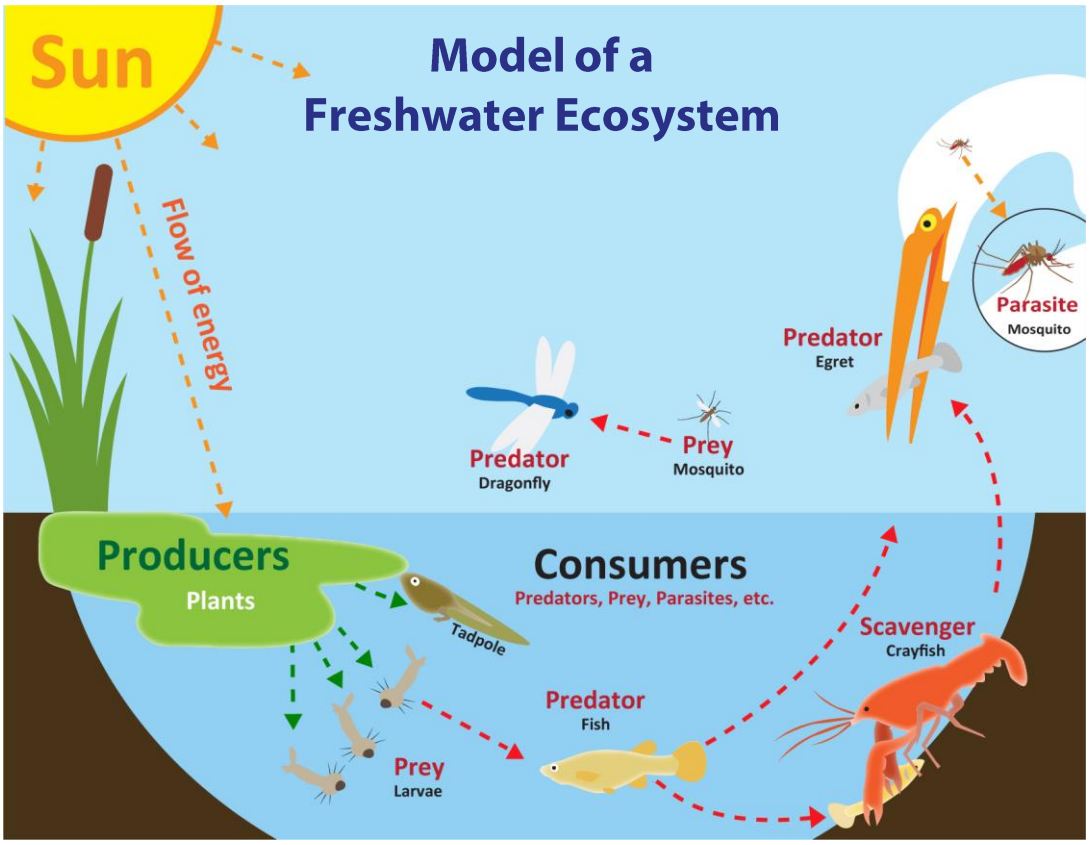
Crayfish are **omnivores** that eat both dead and living plants and animals on river and lake bottoms; their role in reducing decaying matter and filtering the water is especially important for improving water quality. In addition, their habit of burrowing provides additional benefits for water quality, 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, as well. We will explore the positive and negative roles more fully in later lessons.

The vast majority of the world's more than 400 crayfish species are found in North America, especially the Southeastern U.S., although 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 2018).

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 of organisms 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



Graphic created by Eric Engh and Rick Reynolds; used by permission

biodiversity, the more stable the environment and the less it is impacted by changes in the environment. The organisms that interact with each other in their ecosystems are called a **community** (or **ecological community** for high school students).

Some members of a community, such as crayfish, are particularly important to its vitality. For example, crayfish recycle nutrients through the consumption of decomposing organisms. This helps clean the water, and 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 which 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 **food webs** of an ecosystem 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 Their Ecosystems* PowerPoint presentation; available on The River Mile Network resources page: therivermile.org/resources
- 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:* "Curious Crayfish + Freshwater Ecosystems" activity which follows the lesson
- *Optional:* Large pieces of paper or poster board (1 per student or 1 per group; can use backs of used paper/poster board, if available, for this activity which is listed in the Adaptations / Extensions section)

Preparation

1. If possible, identify an expert partner to work with your class. Recommendations for partners such as the National Park Service and University of Idaho Extension Service can be found at therivermile.org/participation/watershed-facilitators-stem-champions or you can email therivermile@gmail.com.
2. Ensure all materials above are ready for student use.
3. 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 the next lesson in the curriculum focuses on fascinating crayfish adaptations, including their structures and functions, as well as their behaviors that help them to survive.

4. *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 More Resources / References section.

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), but first they will get to see 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.

2. Collect the handouts and 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 of 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 5 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.

3. 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 which interactive with them, such as a variety of plants, fish, turtles, or frogs/tadpoles.

Explore

4. Ask the class to arrange their desks in groups of 4, 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 the name of it in large letters in the top 1/3 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 student in each group should choose a plant, because they are so important for almost every ecosystem. *Note:* To help students understand what to do, you can show them the “Rainbow Trout” example which follows the lesson, create your own example, and/or show students samples.

5. Ask the students to create a basic illustration of their organisms below the organisms’ names 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 5 minutes (or however much time you want to allow) to create their illustrations, but that

they will be able to add more detail 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 "Native Plants for Aquatic Gardens and Aquariums." Washington State Dept. of Ecology: fortress.wa.gov/ecy/publications/documents/0603004.pdf

6. Next, have students conduct research about the organisms using the available reference sources to prepare a short (perhaps 1-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. The could also be used as a sample English Language Arts assignment or performance assessment.

Explain

7. While the students finish their illustrations and/or short research projects, ask the groups to choose 2-3 of the species and 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 which eats other animals. Ask the student to try to make themselves look and/or act like the animal they are playing.

8. Ask another group to send a representative to play a different animal which 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 which 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 the words predator and prey.

9. 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 3, 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.

10. 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 3—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.

11. 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 and water to complete the amazing process. Ask the students to say at the count of 3 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 3 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.

12. Explain that all of the other organisms that don't produce their own food are called **consumers**, and write that word below carnivore and herbivore in the middle.

13. 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 do, 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 oxygen dissolved in it for animals to breathe. Also explain that freshwater ecosystems can be very complex, with many hundreds of species of animals and plants, 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.

14. 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--which 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).

15. 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 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 the student to say the name of an organism it interacts with and toss the ball of yarn to the student representing it.

16. 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.

17. 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.

Students create a model of a web of life as a class.

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.

18. Continue this 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 less species, losing one of them had a greater impact on the ecosystem.
        - When certain species that had multiple interactions where 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 the humans don't try to minimize their impact and protect the biodiversity of the ecosystem.

19. 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 of the diverse 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. Write the word community on the board when you say it, and then ask students if they hear that word 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.

20. Extend the lesson with activities such as those listed below and/or pass out the "Curious Catfish + 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 specific 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 Life – 32 Card Set" listed in the Materials 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): edis.ifas.ufl.edu/pdffiles/4h/4h34700.pdf
- 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/greatersagegrouse/education.php
    - *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 first hand, if possible. 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 the interactions in the ecosystem, 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/teacher_resources/crumpled_paper.pdf
- Show a short video clip about crayfish and/or freshwater ecosystems such as:
    - College of Idaho group uses crayfish to study ecosystem toxicology: collegeofidaho.edu/news/c-i-group-uses-crayfish-study-ecosystem-toxicology
    - "Queen Nerdling Presents Freshwater Ecosystems": youtube.com/watch?v=hdeGM65Enko
    - "We Found Crayfish Outside Our Studio in Twin Falls": kezj.com/we-found-crayfish-outside-our-studio-in-twin-falls
- Students can write fictional stories or poems about one or more organisms from freshwater ecosystems.
- Have each student choose an organism from the freshwater ecosystems 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:
    - "Crayfish" by Phillis W. Grimm: www.amazon.com/Crayfish-Early-Bird-Nature-Books/dp/0822530309
    - "The Life Cycle of a Crayfish" by Bobbie Kalman: www.amazon.com/Crayfish-Cycle-Paperback-Bobbie-Kalman/dp/0778707032

Evaluate

- 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.
- Completed student diagrams can be used to evaluate student understanding of the concept of freshwater ecosystems.
- The short research projects about an organism from freshwater ecosystems and its interactions with other organisms in it can be reviewed.
- Student participation in class discussion and activities, including the simulation of a freshwater web of life, can also be used to determine student understanding.

Expand Knowledge + Skills

- "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
- "Crayfish." The Virtual Nature Trail at Penn State Kensington: www.psu.edu/dept/nkbiology/naturetrail/speciespages/crayfish.htm
- "The Crayfishes." Missouri Stream Team: mostreamteam.org/assets/factsheet22.pdf

- Endreny, A. "Crazy about Crayfish." NSTA WebNews Digest. http://www.nsta.org/publications/news/story.aspx?id=51806
- "The freshwater biome." UC Berkeley: www.ucmp.berkeley.edu/exhibits/biomes/freshwater.php
- Freshwater Food Web diagrams:
    - "Aquatic Ecology and the Food Web" diagram from Texas A&M Univ.: agrilife.org/fisheries/files/2013/10/Aquatic- Ecology-And-The-Food-Web.pdf
    - "Aquatic Food Web" from Univ. of Michigan: www.miseagrant.umich.edu/lessons/files/2013/05/Aquatic-Food-Web-GLEP.jpg
    - "Aquatic Food Web" diagram from Texas Aquatic Science: texasaquaticscience.org/wp-content/uploads/2013/07/C5_fig_5.3-aquatic-science-texas.jpg
    - Freshwater food web from Cary Institute of Ecosystem Services: www.caryinstitute.org/sites/default/files/public/downloads/curriculum-project/FRESHWATER_CHANNEL_food_web_0.jpg
- "Freshwater ecosystems filter pollutants before they reach oceans." ScienceDaily: www.sciencedaily.com/releases/2018/04/180430212349.htm
- "Freshwater Lesson Plans." Fresh Water Live: freshwaterlive.org/resources/lesson-plans
- "Freshwater Systems – Rivers and Streams." aboutenvironment.wordpress.com/2010/03/28/freshwater-availability-in-the-world
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- Larson, E. R. and Olden, J.D. "The State of Crayfish in the Pacific Northwest": depts.washington.edu/oldenlab/wordpress/wp-content/uploads/2013/03/Fisheries_2011a_Cray.pdf
- Kaplan, S. "These animals relied on each other for 100 million years. Now climate change is killing them both." Washington Post: www.washingtonpost.com/news/speaking-of-science/wp/2016/05/25/these-animals-relied-on-each-other-for-100-million-years-now-climate-change-is-killing-them-both
- "Native Plants for Aquatic Gardens and Aquariums" (contains photos and details on a number of freshwater plant species). Washington State Department of Ecology (2006): fortress.wa.gov/ecy/publications/documents/0603004.pdf
- 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

Crayfish Trivia!

1. What kind of animals are crayfish? (Circle one)
   a. Amphibians
   b. Crustaceans
   c. Fish
   d. Insects
   e. Molluscs (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 the animals below that crayfish eat.
   ____ 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
   c. Fish
   d. Insects
   e. Molluscs (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 crayfish eat.
   __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. About 550 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

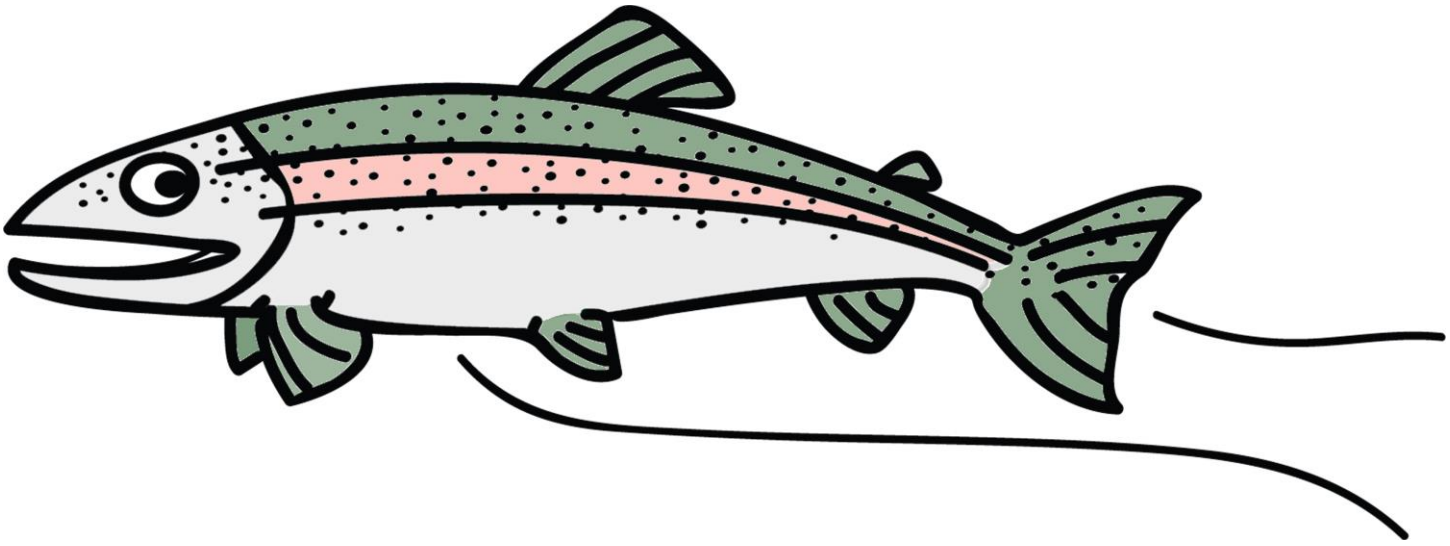
8. Please write all the reasons why you think native or invasive crayfish are better for their ecosystems below and on the back of this paper.

   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 that stay in fresh water)



Details about the organism can be researched and added here and/or on the back of the sheet, such as:

- 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.)

Name: _____ Period: ____ Date: _____

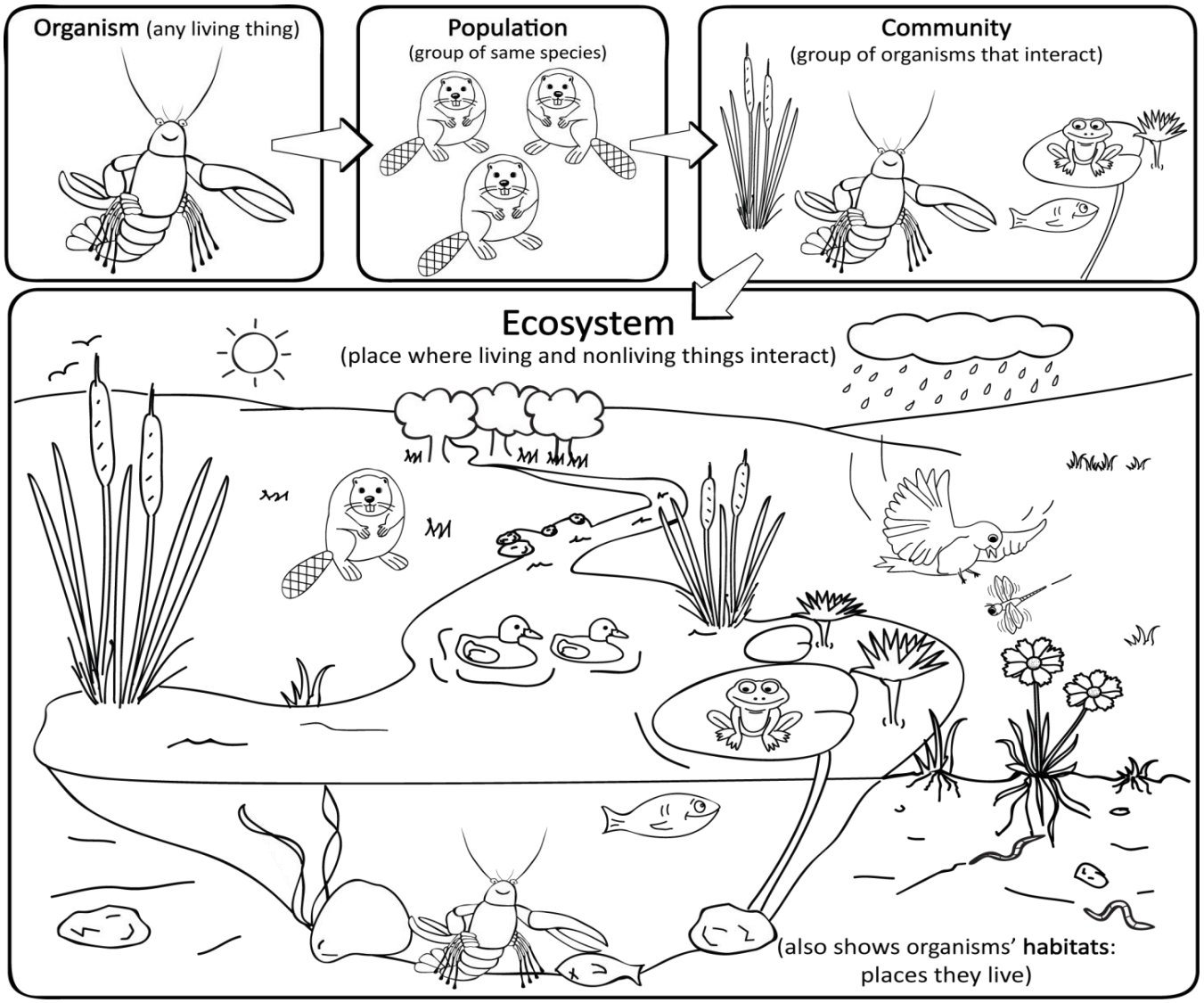
Curious Crayfish + Freshwater Ecosystems

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 _____.

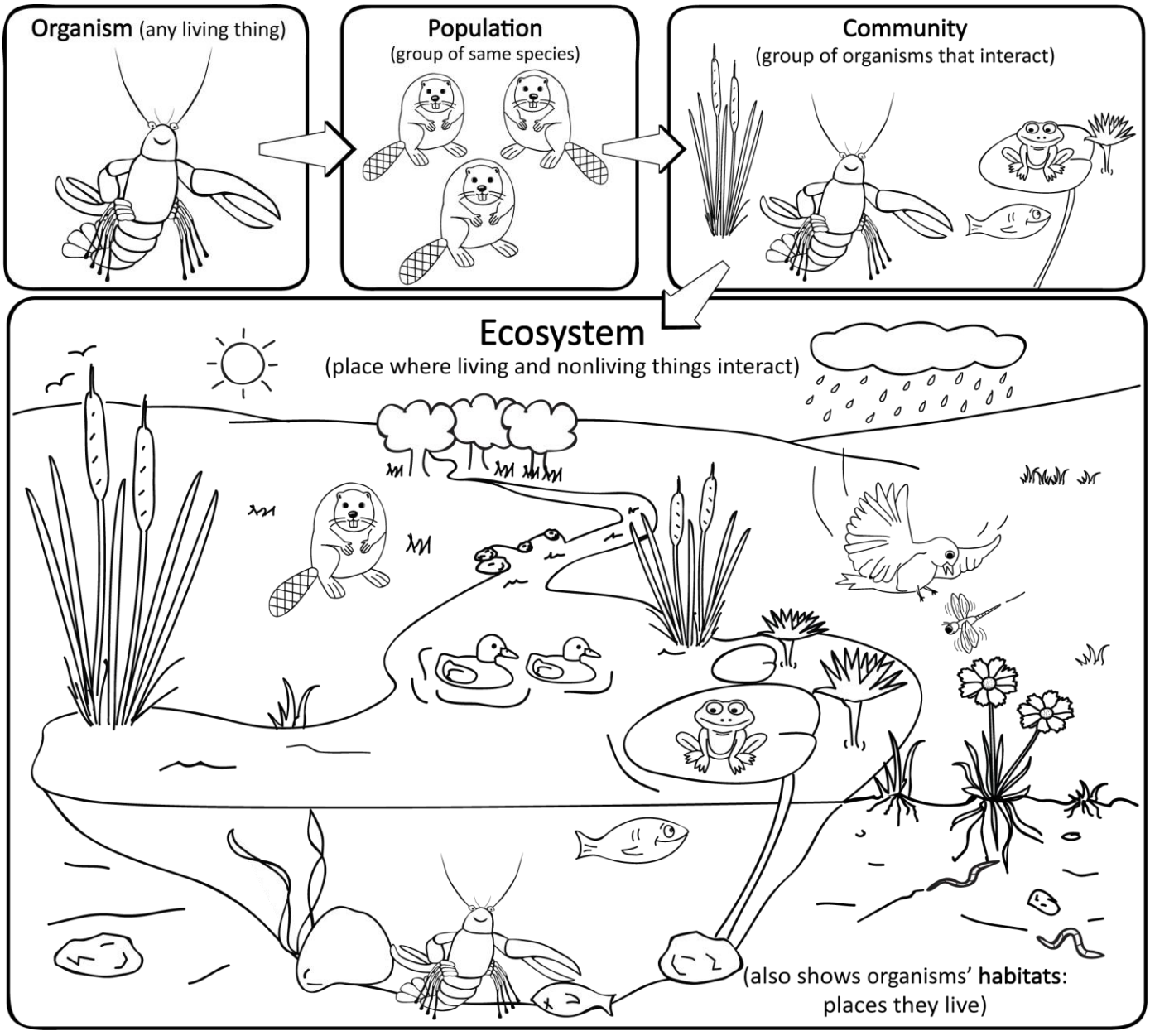


Curious Crayfish + Freshwater Ecosystems

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
Crayfish Adaptations

Subjects Science, Language Arts, Art

Grade Levels 2 – 12 (Ages 7 – 18)

Time 50 – 75 minutes or more

A pilose crayfish *(Pacifastacus gambelii)*, a native of the Pacific Northwest
Image used courtesy of Dr. Eric Larson

Lesson Overview

In this lesson, students explore the adaptations of crayfish which 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. Additional options to "Extend / Enrich" the lesson to engage all learners, including field experiences, are included.

Goals

- Increase students' understanding of crayfish adaptations that help them to survive and reproduce
- Provide students with 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 them 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 it with their peers, gaining feedback which could be incorporated into a new iteration of the design.
- Students will write about how crayfish or their own 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 utilize them.

Next Generation Science Standards

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.A: Structure and Function
LS1.B: Growth and Development of Organisms
LS4.C: Adaptation
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.

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.

Teacher Background

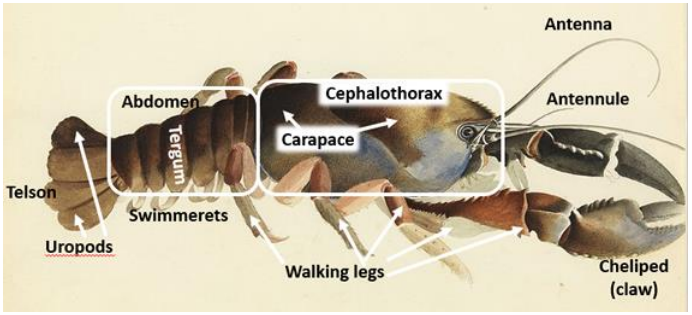
Crayfish Life Cycle and Behaviors

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

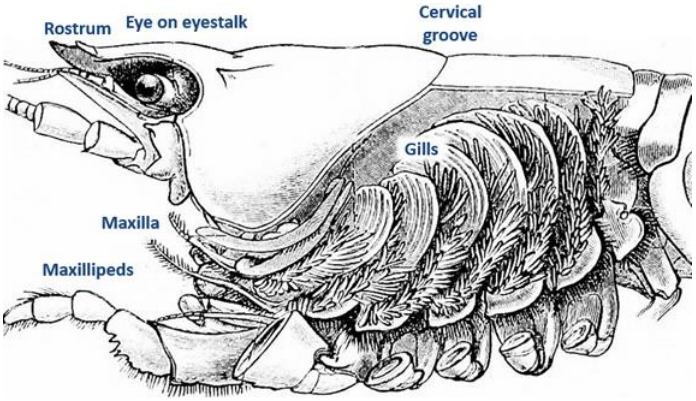
Crayfish go through incomplete **metamorphosis** through their life cycle. Unlike many other **invertebrates**, such as butterflies, which go through complete metamorphosis with distinct larval and pupal stages, they hatch from eggs directly into tiny crayfish and go through roughly 11 **molts**, in which they shed their **exoskeleton** and then replace it with a new one, while they are 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 the shelter beneath rocks or burrows during the day it is in well-shaded areas.

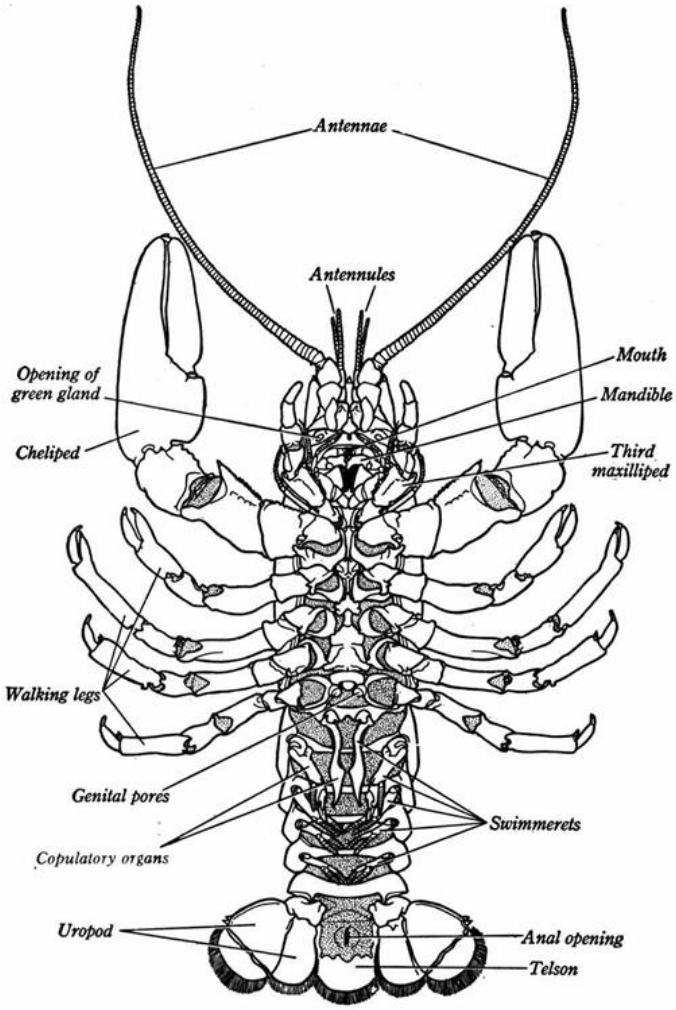
Crayfish Anatomy / Structures



- **Cephalothorax:** joined thorax and head of crayfish and other arthropods
- **Abdomen:** section behind the thorax covered in 6 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; protects the crayfish
- **Antenna:** long organs used for touch, taste, and smell; helps to sense prey and predators in murky water
- **Antennule:** shorter organs also used for touch and taste, as well as balance
- **5 pairs of walking legs** to move along river or pond bottom (locomotion)
- **Cheliped:** Fifth set of legs, enlarged to claws to hold food and provide protection
- **Uropod:** Last pair of abdominal appendages of crayfish and related crustaceans; found on sides of the **telson**, completing the tail fan used for swimming
- **Rostrum:** beak-like projection; ask students what function might be; protects eyes, antennae, and antennules
- **Eyes on stalks:** can be rotated for very large field of view
- **Cervical groove:** indentation that separates head and thorax, which are connected in crayfish



- **Gills:** extracts 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
- **Maxillipeds:** hold food; can touch and taste
- **Genital pores:** used in reproduction



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 River Mile Network resources page: therivermile.org/resources
- Computer access, data projector, display screen, and Microsoft PowerPoint (or other software capable of displaying a .ppt file)
- *Optional:* Modeling clay or Play-Doh and natural materials like dried vegetation, twigs, pine needles, and pine cones for students to share
- *Optional:* 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
- *Optional:* Paper plates on which to construct creatures
- *Optional:* Colored pencils, markers and/or crayons for students to share
- *Optional:* Live native crayfish and/or preserved crayfish specimens
- *Optional:* Microscope(s) and/or hand lens(es)
- *Optional:* Enlarged photographs of crayfish
- *Optional:* "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. Recommendations for partners can be found at therivermile.org/participation/watershed-facilitators-stem-champions or you can email laro_river_mile@nps.gov.
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/adaptions to prepare to answer student questions. Good sources include those listed at the end of the lesson in the More Resources / References 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 them 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 these are traits of crayfish and every other **organism** (living thing) which **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 Anatomy + Adaptations* PowerPoint presentation and you and/or the visitor can lead a brief interactive discussion about it, drawing on the student ideas and information in the slide notes to talk about important crayfish body structures, behaviors, their life cycle, and the functions they all 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 which 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 used 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 organism's adaptation 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
Image courtesy 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 which they devise:
    - Labels can be created with small pieces of card stock and attached to their organisms with toothpicks and tape or another method.
    - They can illustrate their engineering designs on paper, labeling the adaptations which help them to survive. Color can be added with pencils, markers, or crayons.
    - A narrative can be written which explains the organism's adaptations in paragraph form.
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 which help them survive in their aquatic habitats.

Extend / Enrich

- 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 behavior adaptations to those of crayfish, including the different structures of the organisms and the functions of them that help the organisms to survive.
- Ask students to first plan their organisms on paper before they start engineering them with physical materials, labeling the adaptations which 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 via 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 them to the whole class.
- 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
    - "Crayfish Dissection" video, such as youtube.com/watch?v=CmPAACHSZKI

- 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 first hand.
- Classroom centers can be setup 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
    - "We Found Crayfish Outside Our Studio in Twin Falls": kezj.com/we-found-crayfish-outside-our-studio-in-twin-falls
    - College of Idaho group uses crayfish to study ecosystem toxicology: collegeofidaho.edu/news/c-i-group-uses-crayfish-study-ecosystem-toxicology
- For younger grades, read a story or nonfiction book with your class about crayfish. Examples include:
    - "Crayfish" by Phillis W. Grimm: amazon.com/Crayfish-Early-Bird-Nature-Books/dp/0822530309
    - "The Life Cycle of a Crayfish" by Bobbie Kalman: amazon.com/Crayfish-Cycle-Paperback-Bobbie-Kalman/dp/0778707032

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

- "Aquatic Macroinvertebrate Lesson Plans," including "Bugs Don't Bug Me" and many more: extension.usu.edu/waterquality/educator-resources/lessonplans/macro
- Carpenter, M.E. (2017). "Adaptations of the Crawfish." Sciencing: sciencing.com/adaptations-crawfish-10006220.html
- *Crawfish Educational Materials for Grades K-8 & High School Biology*. Louisiana Crawfish Promotion and Research Board: www.fws.gov/uploadedFiles/Region_1/NWRS/Zone_2/Inland_Northwest_Complex/Turnbull/Documents/EE/Crayfish_Dissection/CrawfishLessonPlanK8HSLab.pdf
- "Crayfish Investigations." Lawrence Hall of Science: coseeca.net/files/coseeca/cosia_crayfish_investigations.pdf
- *Crayfish Student Activity Book*: currikicdn.s3-us-west-2.amazonaws.com/resourcefiles/54d26e5197a40.PDF
- "Crayfish Biology." Biological Surveys and Assessment Program. University of Illinois: inhs.illinois.edu/research/biosurveys/crayfish
- "Crayfish Dissection." Biology Junction: biologyjunction.com/crayfish_dissection.htm
- "Crayfish." The Virtual Nature Trail at Penn State Kensington: psu.edu/dept/nkbiology/naturetrail/speciespages/crayfish.htm
- Endreny, A. "Crazy about Crayfish." NSTA WebNews Digest. nsta.org/publications/news/story.aspx?id=51806
- Helfrich, L.A., Parkhurst, J., and Neves, R. 2001. The control of burrowing crayfish in ponds. Dept. of Fisheries and Wildlife Services, Virginia Tech. fishwild.vt.edu/extension/fiw/wildlife/damage/Crayfish.pdf
- "Introduction to Scientific Sketching" lesson plan. California Academy of Sciences: calacademy.org/educators/lesson-plans/introduction-to-scientific-sketching
- Kaplan, S. "These animals relied on each other for 100 million years. Now climate change is killing them both." Washington Post: washingtonpost.com/news/speaking-of-science/wp/2016/05/25/these-animals-relied-on-each-other-for-100-million-years-now-climate-change-is-killing-them-both
- Larson, E.R. and Williams, B.W. Historical Biogeography of Pacifastacus Crayfishes and their Branchiobdellidan and Entocytherid Ectosymbionts in Western North America. 404-447. 10.1201/b18723-21. researchgate.net/publication/275770403
- Larson, E. R. and Olden, J.D. "The State of Crayfish in the Pacific Northwest." depts.washington.edu/oldenlab/wordpress/wp-content/uploads/2013/03/Fisheries_2011a_Cray.pdf
- Water Quality Educator Resources. Utah State University Extension: extension.usu.edu/waterquality/educator-resources
- 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: nextgenscience.org/framework-k%E2%80%9312-science-education
- Common Core State Standards: corestandards.org

Native + Invasive Crayfish
Why do we care?

Subjects Science, Math, Language Arts

Grade Levels 2 – 12 (Ages 7 – 18)

Time 50 – 75 minutes or more

Red swamp crayfish *(Procambarus clarkii)*: one of the most invasive crayfish species
Image from National Park Service: *flickr.com/photos/santamonicamtns/11954193476*

Lesson Overview

In this lesson, students will be encouraged to think critically about native and invasive crayfish species and their roles in freshwater ecosystems. Activity options include having students brainstorm what they already know about native and invasive crayfish, presenting a short interactive multimedia presentation a variety of species, and ways to measure and record data about them. See the "Enrich / Extend" section near the end of the lesson with more ways to engage all learners, including an "Invasive Species Project," invasive species cartoons, crayfish dissections, short videos, field experiences, and more.

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
- Provide students with the opportunity to learn and practice techniques for safely collecting and recording accurate data about crayfish which is helpful to researchers and wildlife managers
- Increase student skills with analyzing and visualizing data they have collected, as well as converting measurements

Objectives

- Students will demonstrate understanding of native and invasive crayfish species, including ways to identify them, their impacts on freshwater ecosystems, etc.
- Students will measure and record data about crayfish specimens (if available).
- 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

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.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 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
- Convert like measurement units within a given measurement system

Math Standards: Statistics & Probability

- Develop understanding of statistical variability
- Summarize and describe distributions

Teacher Background

Signal crayfish are **native** to the Pacific Northwest. "This species can be identified by its uniform brownish coloration, white or light coloration of the claw joint, and the smooth surface of its carapace and claws compared to that of nonnative species" (WA Dept. of Fish & Wildlife). They can range in color from lighter brown to darker brown to reddish. They have a lighter colored patch ranging from white to green in the joint of their **chelipeds** (claws).

An **invasive species** is defined as any non-native organism that takes 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 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 "45 percent of North American crayfish species are considered to be at risk of extinction" ("Menace to the West: Crayfish"). 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.

Additional information and visuals about invasive and native crayfish are found in the PowerPoint presentation listed below and in the "Expand Knowledge + Skills" section listed at the end of the lesson.

A signal crayfish *(Pacifastacus leniusculus)* native to the Pacific Northwest
Image from WA Dept. of Fish & Wildlife: wdfw.wa.gov/species-habitats/species/pacifastacus-leniusculus

Materials

- *Native and Invasive Crayfish* PowerPoint presentation available on The River Mile Network website: therivermile.org/network-projects/the-river-mile-crayfish-study/complete-crayfish-curriculum
- "Native + Invasive Crayfish" poster; available in print from The River Mile Network and for download from the resources page: therivermile.org/resources
- Computer access, data projector, display screen, and Microsoft PowerPoint (or other software capable of displaying a .ppt file)
- *Optional:* Live native crayfish and/or preserved crayfish specimens; these can be gathered from the field or ordered from companies such as Carolina Biological Supply: carolina.com.
  Note: Live invasive crayfish can no longer be transported in some areas, such as Washington state.
- *Optional:* Plates on which to observe, measure, and/or dissect crayfish specimens
- *Optional:* Rubber gloves and/or vinyl tablecloths to protect tables
- *Optional:* Printed photographs of different crayfish species, such as those found in the *Native and Invasive Crayfish* PowerPoint presentation.
- *Optional:* Microscope(s), 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 an expert partner to work with your class. Recommendations for partners can be found at therivermile.org/participation/watershed-facilitators-stem-champions or you can email therivermile@gmail.com.

Preparation

1. Join The River Mile Network community at therivermile.org/community.
2. Once you are a member of TRM Network, you can register for the Crayfish Study and get a "Volunteer ID" used to participate in the study. Then you will also be able to access resources here: therivermile.org/community/groups/crayfish-study.
3. Write the words "Native" and "Invasive" on the board to refer to during the lesson.
4. Ensure all materials above are ready for student use.
5. *Optional:* Learn more about native and invasive crayfish and/or review the information presented in the slide notes of the *Native and Invasive Crayfish* presentation and 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. 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 them in a nearby freshwater ecosystem (if you will be visiting one). Tell students you would first like them to think about what they already know about **native** and **invasive** species. Point to the words on the board and explain to students that they can include their ideas about native and invasive crayfish, plants and/or any other organisms in their brainstorms. Ask them to turn to a neighbor to quickly record all their ideas on a piece of paper in words and/or pictures without worrying about if they are good ideas or not.
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 briefly. Then open the *Native and Invasive Crayfish* PowerPoint presentation and you and/or the visitor can lead a brief interactive discussion about it, drawing on the student ideas and information in the slide notes to talk about native and invasive crayfish and their identifying characteristics, behaviors, etc. If available, you can also show the students live crayfish and/or preserved specimens, keeping in mind that live invasive crayfish are no longer allowed in classrooms in some states, such as Washington.

Explore

4. Next, tell students that they will have the opportunity to practice techniques that can be used to gather data about local populations of native and/or invasive crayfish species. If specimens are available, demonstrate how to gather important data about them which can be recorded on the "Crayfish Observation Form" found after the lesson, such as:
    - **Species name**: Use the information presented in the presentation and the key provided at the end of the lesson. See the More Resources / References section at the end of the lesson for additional resources useful in identification.
    - **Gender**: Male (M) or Female (F); Note how males have gonopods used in reproduction, which are larger, firmer modified swimmerets on the ventral (bottom) side of their

abdomen as shown here: researchgate.net/figure/Ventral-view-of-male-and-female-Procambarus-crayfish-illustrating-sexual-dimorphism-A_fig3_266617669

- **Body Length**, measured in millimeters (mm) from the tip of the rostrum to the end of the telson. A measuring board is helpful for getting more accurate measurements. The rostrum can be lined up touching the front of board, and the uropods can be held down together against the telson to measure the full length.
- **Length of Cephalothorax** in millimeters (mm); measured from tip of rostrum to end of carapace where it meets the abdomen
- **Weight** to the nearest gram: place in mesh bag and hang from digital scale, being sure to zero (tear) scale each time with bag attached before weighing crayfish

Measuring length of a cephalothorax from tip of rostrum to end of carapace

5. If live specimens are being used, tell students that crayfish can be held by the back of the carapace to avoid being pinched and/or hurting the crayfish.
6. Ask students to choose a partner or small group of 3–4 students (if desired, or they can work individually). Then they can measure and record the data of the crayfish specimens. Rotate though the groups of students, answering questions and helping students get started, if necessary. Students can also record in writing how they were able to identify the species they observed, such as coloration, cheliped (claw) length/shape, etc. If the students have time, they can move on to another activity, such as crayfish dissection and/or one of the other options listed in the Enrich / Extend section, below.
7. After about 15 minutes or whenever groups start to complete their measurements, tell them that they have 5 minutes left to work. Explain that you will be looking for volunteers to make a brief presentation to the class about their observations, and ask them to start cleaning up when they are finished. Then the students can record their crayfish data in a table such as the one below, either on the board, in a shared spreadsheet, etc.

Crayfish Data	**Crayfish 1**	**2**	**3**	**4**	**5**	**6**	**7**
Species							
Gender							
Body length (mm)							
Length of cephalothorax							

(mm)							
Weight (g)							

8. When 5 minutes have passed, ask the remaining students to help clean up and add their data to the table.

Explain

9. Ask students to share their ideas about how they identified the species they were observing and about the process of recording the data. Then ask 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. If desired, you can also include a discussion of how measurements can be converted, such as centimeters (cm) to millimeters (mm), mm to cm, cm to inches, etc. This can be done as a class and/or individually or in groups. A good strategy can be to model the processes using one of the categories of data, such as body length, and have students analyze and graph the data from the other categories on their own.
10. Review the data analysis with the class and close with a discussion about native and invasive crayfish and how they can be measured to conduct useful research. If you will be conducting field research, tell students that the next time they record measurements they may have to manage challenges such as weather, collecting and handling live specimens, bringing everything they will need for the day with them, etc. Talk about ways to dress appropriately and the supplies they will need.

Extend / Enrich

- Students can complete the "Invasive Species Project" explained on the handout following the lesson plan, including the creation of "Wanted" posters.
- 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 Oregon Sea Grant website: seagrant.oregonstate.edu/sites/seagrant.oregonstate.edu/files/invasive-species/toolkit/stone-soup-lesson-plan-teachers.pdf
- Ask students to dissect crayfish specimens with the guidance of one or more resources such:
  - "Crayfish Dissection" page from Biology Junction: biologyjunction.com/crayfish_dissection.htm
  - "Crayfish Dissection" video, such as youtube.com/watch?v=CmPAACHSZKI
- 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.
- If you have access to live or preserved crayfish, students can view them and/or their body structures under magnification via 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.
- 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: opb.org/television/programs/ofg/episodes/2210
- "Crayfish Anatomy," which has an explanation with visuals of how to determine crayfish gender: youtube.com/watch?v=qPc8XFaIbTM
- College of Idaho group uses crayfish to study ecosystem toxicology: collegeofidaho.edu/news/c-i-group-uses-crayfish-study-ecosystem-toxicology

- Take students on a field trip to collect and measure crayfish found in your local area. More details are explained in the next lessons of The River Mile's Crayfish Curriculum.
- Students can create detailed scientific illustrations of the crayfish species they observe in the field or the classroom. Printed or online photographs can also be used for reference.
- Ask students to record their observations of specimens in writing in field guides, by labeling illustrations in details, 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.
- Have students create public service announcement videos about invasive crayfish and ways to keep them from spreading.

Evaluate

- Review student tables of crayfish measurements, as well as any data visualizations and/or written analyses which were created.
- Record 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, etc.
- 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

- *Animal Invasive Species Field Guide*. Washington Invasive Species Council: invasivespecies.wa.gov/documents/final_animal_invasive_species_guide.pdf
- "Crayfish as Invasive Species" lesson plan. Office of Superintendent of Public Instruction (OSPI) and Washington State Leadership and Assistance for Science Education Reform (LASER) project. wastatelaser.org/wp-content/uploads/Crayfish_as_Invasive_Species.pdf
- "Crayfish: Species at a Glance." Oregon State University: seagrant.oregonstate.edu/sites/seagrant.oregonstate.edu/files/invasive-species/toolkit/crayfish.pdf
- "Identifying Crayfish." Illinois Natural History Survey: huntfish.mdc.mo.gov/sites/default/files/downloads/crayfish_id_brochure_6-08_0.pdf
- 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
- Larson, E.R. (2018). "Crayfish in the Pacific Northwest: Natural History, Ecology, and Conservation." Presentation available on The River Mile community site: therivermile.org/blog/category/resources/community
- "Menace to the West: Aquatic Invasions" from Oregon State University: seagrant.oregonstate.edu/menacetothewest
    - "Menace to the West: Crayfish": seagrant.oregonstate.edu/menacetothewest/species-guide/crayfish
- "Observing & Collecting Crayfish." Washington Invasive Species Council. k12.wa.us/Science/pubdocs/Crayfishbrochure.pdf
- Olden, J.D. "Brief Guide to Crayfish Identification in the Pacific Northwest": nps.gov/laro/learn/education/upload/crayfish_id_guide-in-the-Pacific-Northwest.pdf
- "Rusty Crayfish: A Nasty Invader." Univ. of Minnesota Ext.: seagrant.umn.edu/ais/rustycrayfish_invader
- "Protect Your Waters!" Ways to prevent aquatic invasions: stopaquatichitchhikers.org//prevention
- *Crayfish Student Activity Book*: currikicdn.s3-us-west-2.amazonaws.com/resourcefiles/54d26e5197a40.PDF
- Larson, E.R. and Olden, J.D. The State of Crayfish in the Pacific Northwest. depts.washington.edu/oldenlab/wordpress/wp-content/uploads/2013/03/Fisheries_2011a_Cray.pdf
- 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: nextgenscience.org/framework-k%E2%80%9312-science-education
- More information about the Common Core State Standards and links to the complete documents: corestandards.org

Crayfish Observation Form

Record all required information and any optional data. There are 2 options for uploading data:

1. On a computer with internet service enter each data sheet 1 at a time; or
2. Enter data in the Excel Data Sheet for the Crayfish Study and submit it through therivermile.org.

***Required Information**

Volunteer ID*: _____ Site ID*: _____

Grade Level(s) *(check all that apply)

_____ 1st	_____ 6th	_____ 11th
_____ 2nd	_____ 7th	_____ 12th
_____ 3rd	_____ 8th	_____ College
_____ 4th	_____ 9th	_____ Other
_____ 5th	_____ 10th	

Date*: _____ Time*: _____

mm/dd/yyyy (ex: 06/11/19) hh:mm (ex: 13:30)

Collection Location*:

Latitude: _____ Longitude: _____

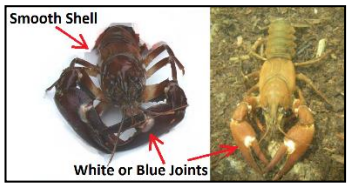
Altitude (in meters): _____ m

Identify the Crayfish Species*

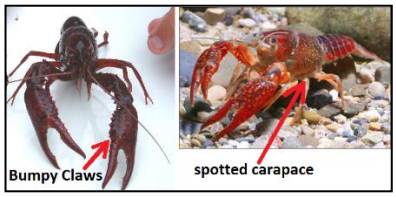
____ **Virile (Northern) Crayfish** *(Faxonius virilis)*

____ **Rusty Crayfish** *(Faxonius rusticus)*

____ **Signal Crayfish** *(Pacifastacus leniusculus)*



____ **Red Swamp Crayfish** *(Procambarus clarkii)*



____ **Other/Unknown: Ideas?** _____

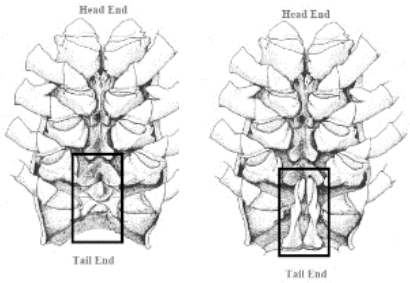
Alive, dead, or partial remains?

___ Alive ___ Dead ___ Partial Remains (pieces)

Crayfish Photo? ___ Yes ___ No

If Yes, Document Number/ID: _____

Gender: ___ FEMALE ___ MALE ___ Unknown



Weight (grams): _____ cm

Length of Cephalothorax* (in cm): _____ cm

Total Length of Body (in cm – optional): _____ cm

Notes:

_____

_____

_____

_____

_____

_____

_____

_____

Name: _____ Period: ____ Date: _____

Invasive Species Project

Adapted with permission from a project in the SOLVE Environmental Service Leaning curriculum by Erin Cole

Your Assignment

Research an invasive species that is impacting an ecosystem near you. Create an "eradication sales pitch" to share your information and warn others about the dangers of these noxious 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 eradicating it NOW!
Some things to think about in your sales pitch:

1. Is your animal or plant one that is already causing widespread damage?
2. Is it one that is not that big a problem in our area yet, but it may become really damaging?
3. Is it causing significant economic damage? Environmental damage? Aesthetic damage?
4. Is it cost-effective to get rid of?
5. Is there an organization which 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 they are native and originally from)
4. Where it can be found now (region, specific place in ecosystem)
5. How they harm humans and ecosystems (Be specific: for example, if they take over land from other plants, HOW do they do it? If they cause economic damage, to what industries or structures?)
6. What humans are trying to do to stop the invasion (Again, be as specific as possible: is there a specific organization which is already trying to stop them? What tools/chemicals/methods are they using, and are there pros and cons to the various methods?)
7. All sources of information, including photos, are cited in MLA format

Formatting and Aesthetic Requirements

1. 4-10 slides created with PowerPoint or another program, including a sources page at the end
2. A title slide with a photo or drawing of the plant or animal that has been stylized to look "evil" or "wanted" (created with graphics software or drawn by hand and scanned)
3. The presentation should last no longer than 3 or 4 minutes and should seem like a "sales pitch," not just an informational session—be persuasive!!!

Evaluation

Your presentations will be scored as follows:

Requirement	Score
Information: All information requirements met, including sources	/ 20
Organization: Presentations are neat and organized, with proper grammar and spelling	/ 5
Creativity: Photo or drawing on first slide has been "evilized" and presentation is persuasive	/ 5
Total	/ 30

Choices Include:

Invasive Animals

1. Zebra and Quagga Mussels
2. Chinese Mitten Crab
3. Nutria
4. European Starling
5. English House Sparrow
6. Asian Carp/Asian Leaping Carp/Silver Carp
7. American Bullfrog
8. Rusty Crayfish
9. Feral Pig/Feral Swine
10. Red-eared Slider
11. Oriental Weatherfish
12. Northern Snakehead
13. New Zealand Mud Snail
14. Yellow Perch
15. Asian Clam
16. European Green Crab
17. Red Swamp Crayfish

Invasive Plants

1. Cheatgrass (Downy Brome)
2. Medusahead
3. Ventenata (North African Wiregrass)
4. Bull, Canada, Musk, and Scotch Thistle
5. Common, Cutleaf, or Fuller's Teasel
6. Russian Thistle
7. Yellow Star Thistle
8. Scotch (Scot's) broom
9. Purple loosestrife
10. Knapweeds
11. Knotweeds (Japanese or other)
12. Thistle and Teasel (various species)
13. Traveler's Joy / Old Man's Beard Clematis
14. Laurel
15. Garlic Mustard
16. English Ivy
17. English Holly
18. Tree of Heaven
19. Indigo Bush/Butterfly Bush
20. Reed Canary Grass

Resources

- MLA citation guide, Purdue Online Writing Lab (OWL): owl.english.purdue.edu/owl/resource/747/02
- USDA Plants database: plants.usda.gov
- *Silent Invasion* documentary film with additional resources: opb.org/programs/invasives
- Oregon Invasive Species Council: oregon.gov/OISC
- USDA Invasive Species resources: invasivespeciesinfo.gov/unitedstates
- Oregon Dept. of Fish and Wildlife (ODFW) Invasive Species resources: dfw.state.or.us/conservationstrategy/invasive_species.asp

Lesson 4
Crayfish as an Indicator Species

Subjects Science, Language Arts, Art

Grade Levels Adaptable for grades 3 – 12 (ages 8 – 18)

Time 45 minutes or more

Janice Elvidge of the National Park Service and The River Mile Network observes a crayfish.

Lesson Overview

Students first read about a hypothetical mysterious phenomenon about crayfish disappearing from a river, then work in small groups to develop plans to address the issues raised in it. 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 near the end of the lesson, including ways to do water quality field investigations and the inclusion of an interesting scientific study which found positive impacts of crayfish on the populations of other macroinvertebrates.

Goals

- Provide students with the opportunity to explore issues around water quality by working together to solve a mystery about crayfish disappearing
- Make students more aware of how their actions, and those of others in their community, can impact the health of their local watershed and encourage them to be more environmentally aware
- Increase students' understanding of the roles of crayfish and other macroinvertebrates in freshwater ecosystems

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 which 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

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.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 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.

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 metals concentrations may contribute to crayfish declines. Crayfish are gill-breathing invertebrates that live in the lowest level of a body of water feeding 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 impact crayfish 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 components of water quality, how to test for them, 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. Recommendations for partners can be found at therivermile.org/participation/watershed-facilitators-stem-champions or you can email laro_river_mile@nps.gov.

Preparation

1. Ensure all materials above are ready for student use.
2. *Optional:* Learn more about the topics address 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.

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, recording 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 1 more minute to brainstorm and to be prepared to share their best ideas with the class.
4. Allow the groups to share and tell them that they will be working in groups to solve a similar realistic scenario which includes more information to help them decide on the best possible solutions to the problem.

Explore

5. 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 do that they should work together to create plans which 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 the cite the sources for additional information. Explain the available options for visuals to students: posters, computer-

aided diagrams, etc., and show students the available materials and/or technology/software with which they can work.

Explain

6. 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 about their plans and visual models to the class.
7. Allow students time to complete their plans outside of class, if necessary.
8. Allow students time to present their projects. Discuss the recommendations in their plans for how to improve the water quality for macroinvertebrates like crayfish, as well as for humans and every other organism in the aquatic food web.

Extend / Enrich

- Discuss the concept of point and nonpoint 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: oceanservice.noaa.gov/education/lessons/get_point.html
  - "Watersheds/Non-point Source Pollution Lessons & Activities." Clean Ocean Action: cleanoceanaction.org/index.php?id=321
- 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.
- Conduct water quality sampling activities with your students. Partners may be able to support your work, such as those in The River Mile Network. For example, the wonderful Vancouver (WA) Water Resources Center has a Watershed Monitoring Network and staff that supports school groups, as well as excellent field investigations available online: cityofvancouver.us/publicworks/page/watershed-monitoring-field-investigations

- 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

- Review water quality improvement plans and written descriptions. You can also record levels of oral participation and student understanding of measures of water quality, their impacts on freshwater ecosystems, how human activities can benefit, as well as harm, living systems, etc.
- 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

- Aquatic Macroinvertebrate Lesson Plans, including "Bugs Don't Bug Me" and many more: extension.usu.edu/waterquality/educator-resources/lessonplans/macro
- "Watershed Detectives" lesson from Utah State University Ext.: extension.usu.edu/waterquality/files-ou/Lesson-Plans/Water-pollution-LPs/watershed-detectives.pdf
- Water Quality Monitoring resources from The River Mile Network: https://therivermile.org/network-projects/water-quality-monitoring/
- Vancouver Water Resources Center Watershed Monitoring Network field investigations: cityofvancouver.us/publicworks/page/watershed-monitoring-field-investigations
- "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
- 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: fws.gov/midwest/es/ec/nrda/SEMONRDA/documents/EffectsMetalsCrayfishInBigRiverMissouriFinalRev10Feb10.pdf
- "A Very Impervious Situation: An Introduction to Stream Runoff" lesson plan by Great Lakes Aquarium: glaquarium.org/wp-content/uploads/2015/10/A-Very-Impervious-Situation-Lesson-Plan.pdf
- "Calculating Stormwater Runoff" lesson plan from the Civic Garden of Greater Cincinnati: civicgardencenter.org/green-learning-station/schools/curriculum-for-bringing-the-gls-back-to-school/stormwater-lessons/calculating-stormwater-runoff
- Snyder, J.L. (2010). "Trace metal concentrations in the signal crayfish, *Pacifastacus leniusculus (Decapoda: Astacidae)*, and the stonefly *Pteronarcys californica (Plecoptera: Pteronarcyidae)* along a downstream gradient of the Umatilla River." Oregon State University: ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/np193d168
- 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: nextgenscience.org/framework-k%E2%80%9312-science-education
- More information about the Common Core State Standards and links to the complete documents: corestandards.org

Mystery of the Disappearing Crayfish

Students from Eagle Feather School have been studying the crayfish and other macroinvertebrates in Salmon River that 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 see if there is an explanation for the phenomenon, but the agencies were unaware of a problem. However, through their research and their close observations of the river, the students have gathered these 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**: 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 salmon
  - **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 river banks 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 Salmon River.

- 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) in the watershed. This includes many areas along the Salmon River 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 kills 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.
- There is a large chicken farm and processing facility 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.
- There have been more people 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 oxygen needed 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 which might explain the declines in crayfish and other macros. For example, how might factors such as possible sources of pollution, loss of native plants, and development be affecting water quality and their 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 which 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.
    3. 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	Group Self Score (fill out before submit project)	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 demonstrated	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		
TOTALS:	**100**		

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 – April 21, 2016

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," was published in *Freshwater Science* and can be accessed at 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

Lesson 5

Collecting Reliable Crayfish Data in the Field

Subjects Science, Math, Language Arts

Grade Levels Adaptable for grades 3 – 12 (Ages 8 – 18)

Time 45 minutes or more + travel time

Lesson Overview

In this lesson, students will have the opportunity to apply everything they have been learning about native and invasive crayfish while doing a place-based educational field study. They will work in groups to collect scientifically reliable and relevant data about them from a nearby freshwater ecosystem, then work together to analyze the data and present it visually.

The River Mile's network of schools and other partners has been helping biologists and wildlife managers by collecting and sharing data about crayfish and water quality. By participating in the project, students can see the power of using science to monitor an invasive species, encouraging them to be better stewards of their local watersheds while they develop their science, math, and language arts skills.

Students remove live crayfish from a trap to observe, identify, and measure them. Then they will submit the data online to share it with researchers and wildlife managers.

Goals

- Provide students with the opportunity to demonstrate techniques for safely collecting and then submitting accurate data about the distribution of crayfish species which is helpful to researchers and wildlife managers
- Give students the power of monitoring an invasive species to improve the health of their local watershed and encourage them to be more environmentally aware
- Increase students' understanding of native and invasive crayfish and their many positive and negative roles in freshwater ecosystems

Objectives

- Students will follow a scientific protocol to measure and record data about crayfish specimens in a natural freshwater ecosystem.
- Students will demonstrate understanding of native and invasive crayfish species, including ways to identify them, their impacts on freshwater ecosystems, etc.
- 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

Crosscutting Concepts

- Structure and Function
- Stability and Change

Science & Engineering Practices

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

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

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

Teacher Background

The River Mile Network's Crayfish Study is a community science project collecting data on species distribution throughout the Columbia River watershed. Dr. Eric Larson, assistant professor in the Department of Natural Resources and Environmental Sciences at the University of Illinois, who earned his Ph.D. from the University of Washington specializing in Northwest crayfish—and is one of the leading experts in the world—supervises the project. Scientists do not know a lot about crayfish, native or non-native, in the Pacific Northwest, and so you and your students can contribute critical data by learning and submitting about the crayfish at your site.

Students work together to setup crayfish traps at stream near their school.

Any K-12 grade school group located in the Columbia River Watershed can participate and submit data about crayfish in their area. The data collected will support ongoing scientific research that Dr. Larson and his colleagues around the Northwest, U.S., and world are undertaking. As we have explored in other lessons in this curriculum, a few species of crayfish are invading freshwater ecosystems at an alarming rate, and your class can play an important role in better understanding and addressing the problem, not to mention gaining 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 the data and allowing students to begin to explore it through analysis and visualization. The next lesson in the curriculum focuses on ways to share your data, including using The River Mile's community site, presenting at regional gatherings, etc.

The River Mile education program seeks to collect data of natural resources throughout the Columbia River watershed. In order to reliably collect data from such a large area, all groups involved in the project must collect consistent data systematically. Uniform testing is the best way to collect any type of data because further study and future researchers may utilize the same techniques yielding compatible data. The protocol which is explained at the end of the lesson describes the methodology used to collect crayfish data. Tablets or smartphones with the Survey 1-2-3 app for ArcGIS from ESRI can be used to collect the data, or it can be submitted via any Web browser, as explained on The River Mile "Data Collection & Submission" page: therivermile.org/network-projects/data-collection-submission.

Students should have a question in mind before going out into the field to collect data. In most cases, scientists are interested in determining a trend of a parameter that is physical, chemical, or biological. A physical example could be what percentage of rock is granite in a given area, while a chemical example would include collecting water samples to test for E. coli, mercury, iron, etc. This lesson focuses on a biological study of native and invasive crayfish, so your question(s) could revolve around

what percentage of crayfish found are native and invasive, etc. Determining changes over time and the direction of that change (positive or negative) is very valuable information for researchers, wildlife managers, and the public at large, so we hope you may be able to continue your crayfish study over multiple months and/or years.

Materials

- Crayfish traps with ropes and buoys
- Canned cat food (1 can/trap)
- Screwdriver or hammer and nail to put holes in can(s)
- 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 the these for student groups to share (found after lesson):
    - "Crayfish Study Data Collection Protocol"
    - "Crayfish Observation Form"
    - "Crayfish Identification Key" (also at therivermile.org/wp-content/uploads/2016/09/Crayfish-ID-Key-PDF.pdf)
- Pencils
- Measuring board/ruler
- Digital scale and mesh bag
- Camera(s) and/or smartphone(s) to photograph specimens
- Cooler/Ice
- Bucket and gallon-size plastic bag(s)
- Sampling permits
- *Optional:* Tablets or smartphones with the Survey 1-2-3 app from ESRI (ArcGIS) installed as explained on The River Mile "Data Collection & Submission" page: therivermile.org/network-projects/data-collection-submission
- *Optional:* Waders
- *Optional:* Student field journals
- *Optional:* Microscope(s), 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 an expert partner to work with your class. Recommendations for partners can be found at therivermile.org/participation/watershed-facilitators-stem-champions or you can email therivermile@gmail.com.

Preparation

1. Obtain a Scientific Collection Permit to collect crayfish and/or a fishing license if required in your area. Oregon does not require a permit or license, but Washington and many other states do. You may also be able to work with a partner in The River Mile network who already has a permit. Contact your state fish & wildlife department with questions, or you can direct them to therivermile@gmail.com. If the class is working with a scientist, ask if they would like any changes in the protocol found at the end of the lesson that should be implemented.
2. Ensure all materials above are ready for student use. Ask students to prepare for a field trip to a nearby stream by wearing layers of clothing and protective foot wear to school on the day of the trip. They can also help to bring in needed materials, and you may want to ask them to bring water bottles and snacks for their use during the field trip.
3. Ensure students return signed permission forms.
4. Unless you are taking students to set the traps on one field trip, then having a field trip the next day to collect the traps, you will need to set the 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. If you are in Washington, note that the individual listed on a Scientific Collection Permit through the WA Dept. of Fish & Wildlife must be on site for trap setting and retrieval.
5. *Optional:* Learn more about native and invasive crayfish and/or review the information presented in the slide notes of the *Native and Invasive Crayfish* presentation and in the sources listed in the "Expand Knowledge + Skills" section at end of the lesson to prepare to answer student questions.

Teaching Suggestions in the 5E Model

Engage

1. Engage students by asking them to think of questions that they have about crayfish that may live nearby. Ask them to turn to a neighbor and quickly brainstorm their ideas, recording them on paper or with an electronic device.
2. Circulate through the room to answer (and ask) questions. After a minute, tell students they have one more minute to brainstorm and that they should be ready to share their best ideas.
3. Ask the pairs to share their ideas and discuss how they will now be able to investigate them and apply everything they've been learning about crayfish to do actual field research in a nearby freshwater ecosystem. They will be collecting important data about the native and invasive crayfish species found there. The data will be shared with university researchers working on a large crayfish study of the Columbia River watershed, as well as wildlife managers in states such as Washington, Oregon, and Idaho.
4. Show students the crayfish traps and explain how they will tie a rope to it and add a buoy (or empty plastic bottle) to it with a name, contact information, and permit number (if applicable) on it. At the stream they will punch holes in the top of a can of cat food with a nail or screwdriver and attach it to the inside bottom of the trap before it is tossed in the stream. Tell students that the most important step with throwing the traps is to always remember to hold the end of the rope! Then they should tie the rope to something secure on shore, such as a tree.

5. Talk about 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 with to collect data (or you can choose the groups).
6. Ask students how they should hold live crayfish; review how it should be by the back of the carapace to avoid being pinched and/or hurting the crayfish.

Explore

7. Travel to the research site with the equipment listed above and pass out copies of the "Crayfish Study Data Collection Protocol," "Crayfish Observation Forms," and "Crayfish Identification Key" for student groups to use. If traps were set the night before, students can pull them in and collect the data following the protocol. If you have access to tablets or smartphones with the Survey 1-2-3 app from ESRI (ArcGIS) installed, students can use them to collect the data as explained here: therivermile.org/network-projects/data-collection-submission.
8. Rotate through the groups, answering questions and helping students to correctly follow the protocol to measure and record the data about the crayfish specimens.
9. After all the data is recorded using techniques explained in the protocol and earlier lessons, including the identification of crayfish (with the help of the "Crayfish Identification Key" and other available resources), and specimens have been photographed, students can also record any additional observations and/or illustrations in field journals.
10. The 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. And you should tell students that counting zero crayfish in a trap is also important data that needs to be recorded. There could be many times that a trap could be pulled out empty, 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 which crayfish can use for cover, in a shady area protected from the Sun, in deeper water farther out in the stream, etc.

Explain

11. Work with students to ensure all the materials are collected. Travel back to the classroom and ask the groups to record their crayfish data 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 other groups and the teacher to reach consensus about the two important data points.

Crayfish Data	**Crayfish 1**	**2**	**3**	**4**	**5**	**6**	**7**
Species							
Gender							
Body length (mm)							
Length of cephalothorax (mm)							
Weight							

12. 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 about ways 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 the crayfish data they gathered, and be ready to discuss them with the class.
13. 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 2 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.
14. Allow the groups to share and close with a discussion about the native and invasive crayfish that you found, including what your research findings might indicate about the health of the body of freshwater. If time allows, discuss strategies that can be used to help make the ecosystem even healthier.

Expand / Enrich

- See the next lesson in the curriculum for how to use ArcGIS and other technologies to submit and analyze your data.
- Ask students to dissect crayfish specimens with the guidance of one or more resources such:
  - "Crayfish Dissection" page from Biology Junction: biologyjunction.com/crayfish_dissection.htm
  - "Crayfish Dissection" video, such as youtube.com/watch?v=CmPAACHSZKI
- Students can view the crayfish specimens and/or their body structures under magnification via 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.
- Show one or more short video clip(s) about crayfish, such as:
  - "Crayfish Invasion." The first part of this Oregon Field Guide episode from OPB: opb.org/television/programs/ofg/episodes/2210
  - "Crayfish Anatomy," which has an explanation with visuals of how to determine crayfish gender: youtube.com/watch?v=qPc8XFaIbTM
  - College of Idaho group uses crayfish to study ecosystem toxicology: collegeofidaho.edu/news/c-i-group-uses-crayfish-study-ecosystem-toxicology
- Students can create detailed scientific illustrations of the crayfish species they observe. The photographs they took can be used for reference.
- Ask students to record their observations of specimens in writing in field guides, by labeling illustrations in details, 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.
- Have students create public service announcement videos about invasive crayfish and ways to keep them from spreading.

Evaluate

- 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, etc.
- 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

- *Animal Invasive Species Field Guide*. Washington Invasive Species Council: invasivespecies.wa.gov/documents/final_animal_invasive_species_guide.pdf
- "Crayfish Biology." Biological Surveys and Assessment Program. University of Illinois: inhs.illinois.edu/research/biosurveys/crayfish
- *Crawfish Educational Materials for Grades K-8 & High School Biology*. Louisiana Crawfish Promotion and Research Board: fws.gov/uploadedFiles/Region_1/NWRS/Zone_2/Inland_Northwest_Complex/Turnbull/Documents/EE/Crayfish_Dissection/CrawfishLessonPlanK8HSLab.pdf
- "Crayfish Investigations." Lawrence Hall of Science: coseeca.net/files/coseeca/cosia_crayfish_investigations.pdf
- "Crayfish: Species at a Glance." Oregon State University: seagrant.oregonstate.edu/sites/seagrant.oregonstate.edu/files/invasive-species/toolkit/crayfish.pdf
- *Crayfish Student Activity Book*: currikicdn.s3-us-west-2.amazonaws.com/resourcefiles/54d26e5197a40.PDF
- "Identifying Crayfish." Illinois Natural History Survey: huntfish.mdc.mo.gov/sites/default/files/downloads/crayfish_id_brochure_6-08_0.pdf
- 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
- Larson, E.R. and Olden, J.D. (2011). "The State of Crayfish in the Pacific Northwest." *Fisheries* 36 (2): 60-73: depts.washington.edu/oldenlab/wordpress/wp-content/uploads/2013/03/Fisheries_2011a_Cray.pdf
- "Observing & Collecting Crayfish." Washington Invasive Species Council. k12.wa.us/Science/pubdocs/Crayfishbrochure.pdf
- "Crayfish Found in Oregon." OR Dept. of Fish & Wildlife: dfw.state.or.us/conservationstrategy/invasive_species/docs/Crayfish_Comparison.pdf
- "Rusty Crayfish: A Nasty Invader." Univ. of Minnesota Ext.: seagrant.umn.edu/ais/rustycrayfish_invader
- 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: nextgenscience.org/framework-k%E2%80%9312-science-education

Crayfish Study
Data Collection Protocol

1. **Check that the following equipment is ready to travel to the study site:**

___ Crayfish traps with ropes and buoys
___ Canned cat food + nail or screwdriver
___ GPS device(s) and/or smartphone(s)
___ Camera(s) and/or smartphone(s)
___ Thermometer(s)
___ Measuring board(s) or ruler(s)
___ Digital scale(s) and mesh bag(s)
___ Cooler with ice
___ Bucket and gallon-size plastic bag
___ Pencils
___ Field map(s) and/or smartphone(s) for maps
___ Copies of the "Crayfish Observation Form"
___ Copies of the "Crayfish Identification Key"
___ Permit to sample (or fish) for crayfish
___ *Optional:* Waders
___ *Optional:* Field journals

2. **Check the weather and dress appropriately**. Ensure data sampling groups all have a minimum of two people—and that everyone is prepared for the field.

3. **Before setting a trap:**

___ Decide where to set it within the sampling location, depending on available habitat and distance from other sample sites

___ Punch several small holes in bottom of can of cat food (seafood-flavored is best)

___ Place can in trap; secure to bottom with zip tie, long twist tie, or carabiner and lock door

___ Attached buoy and rope securely to trap

Record these on Crayfish Observation Form:

___ Site name

___ Names of collectors (group members) and date set

___ Water temperature in Celsius and air temp. (C)

___ Precipitation (Circle Y or N)

___ Bank condition and substrate

4. **Setting traps:**

___ Toss baited trap into water; **be sure to hold end of rope!**

___ Secure rope to shore.

___ Record time set, GPS waypoint, latitude, and longitude on Crayfish Observation Form

5. **Pulling a trap:**

___ Pull out SLOWLY in order traps set (don't accidentally lose crayfish or cut the line!)

NOTE: *A trap may get stuck; try your best to get it unstuck without getting into the water. Tell an adult if you are not able to bring in a trap.*

___ Record time and date on data sheet

___ Unhook buoy line from trap, wind up neatly, and place in mesh bag

6. **Recording crayfish measurements on data sheet:**

___ Carefully remove a crayfish from trap

___ Identify and record its species and gender ("M" for male, "F" for female); if you are unsure of species and/or gender, take several pictures for later identification

___ Measure & record:

- Carapace length in cm
- Total length in cm (hold down uropods together)
- Weight to nearest gram: place in mesh bag and hang from digital scale; Be sure to zero scale each time with bag attached before weighing crayfish

7. ___ **Take picture(s) of crayfish**; record picture number on data sheet

NOTE: *Throughout the trip you should also take pictures and/or video of the site, the crayfish in the traps, your team, etc. Document everything!*

8. **Return native crayfish to water** immediately where they were caught; **place non-native (invasive) species in bucket**
9. Repeat steps 6-8 for each crayfish
10. **Record total number of crayfish** in trap (and its buoy number) on data sheet
11. Repeat steps 5-10 until all traps pulled in and all data collected and recorded
12. Put invasive crayfish in plastic bag and set in cooler with ice to euthanize them
13. Your teacher must properly dispose of them so there is no chance they invade anywhere else!

IMPORTANT: At NO time can any of the crayfish collected be kept as live specimens or pets. They also may not be consumed without written permission of your wildlife agency and the necessary fishing license. It is against the law to transport live crayfish, and it would be a violation of our scientific collection permit to use these crayfish for anything other than what the permit states. If at any time these rules are broken the student(s) or group(s) involved will be immediately banded from the project.

Lesson 6

From Mental Maps to GIS: Modeling Data through Visualization and Mapping

Subjects Science, Language Arts, Social Studies, Art

Grade Levels Adaptable for grades 3 – 12 (Ages 8 – 18)

Time 45 minutes or more

Lesson Overview

Students are engaged by creating mental maps of the Columbia River and using a colored pencil or crayon to color in the area of land that they think is part of the Columbia River Basin (watershed). Students briefly share their maps with each other in a lively discussion, then the teacher shows an ArcGIS-created map of the Columbia, its tributary rivers and streams, and its complete basin, explaining that the students will next be able to help to create an ArcGIS map for the crayfish study happening throughout the watershed. Students submit their data through the Survey123 form if they have not yet done so, then analyze it and compare to other groups visually using ArcGIS.

Map of the Columbia River Basin and schools participating in The River Mile.

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 Lesson 5) to analyze it with ArcGIS.

- Students will create mental maps related to their watershed and compare it to a map created with professional GIS software.
- Students will analyze their crayfish data and compare it to the data collected by other groups with visualizations created using ArcGIS.
- Students will express orally and/or in writing what they have learned about native and invasive crayfish in the Columbia River Watershed through the activities in the lesson and the others in this unit about crayfish and freshwater ecosystems.

Next Generation Science Standards

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

Teacher Background

The River Mile education program has been using ArcGIS Online from Esri to collect and analyze data of crayfish populations and water quality to measure the health of the Columbia River watershed. 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 Survey 1-2-3 app for ArcGIS as explained on The River Mile's "Data Collection & Submission" page: therivermile.org/network-projects/data-collection-submission.

ArcGIS is the leading Geographic Information System (GIS) software, used by professionals such as urban planners and scientists to create maps which model data in a breathtaking range of areas. ArcGIS Online is a simplified version of the software which 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 also surprisingly easy to use for such a powerful piece of 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 More Resources / References section at the end of the lesson.

Materials

- Free "ArcGIS for Schools Bundle" including ArcGIS Online access available at: esri.com/en-us/industries/education/schools/schools-mapping-software-bundle
- Survey 1-2-3 for ArcGIS access: survey123.arcgis.com
- Data projector (to display your computer screen to class)
- Completed copies of the "Crayfish Study Data Collection Protocol" (found after data collection lesson) or another source of data
- Pencils
- Paper (or student journals or field guides)
- Colored pencils, markers, and/or crayons for students to share
- Data projector, computer, and screen
- *Optional:* Document camera

Preparation

1. If you have any maps showing the Columbia River in your classroom, you can turn them over (or otherwise hide them).
2. Ensure the software and other materials listed above are ready for student use.
3. Review the additional information on The River Mile "Data Collection & Submission" page: therivermile.org/network-projects/data-collection-submission
4. *Optional:* You can get support from partners listed on The River Mile website: therivermile.org/participation/watershed-facilitators-stem-champions. Or you can email therivermile@gmail.com.

Teaching Suggestions in the 5E Model

Engage

1. Engage students by asking them to draw a map of the Columbia River 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 these details, writing the bullet points on the board or screen as you go:

- State and/or country boundaries
- Rivers and streams that flow into the Columbia
- Color shading for the entire Columbia River Basin (Columbia River watershed): 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 5 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 who thinks they created a pretty accurate mental map to share it 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-created map (or maps) of the Columbia, its tributary rivers and streams, and its complete basin available on The River Mile website: www.nps.gov/laro/learn/education/laro-river-mile.htm. Lead an interactive discussion about how the points on the map represent schools participating in research with The River Mile Network, the states and countries the river flows through, its major tributaries, the extent of the Columbia River and its basin (second largest river in the U.S. in terms of volume of water, largest entering the Pacific Ocean according to the EPA), 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.
4. Demonstrate for students how they submit their data through the Survey123 form if they have not yet done so. Explain that once all of the groups submit their data they will then be able to use ArcGIS Online to help compare their data with the data from other groups and schools.

Explain

5. Show students how to access the data using your ArcGIS Online account, and explain how they 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.
6. 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.
7. Circulate through the 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 2 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.
8. Allow the groups to share and close with a discussion about how the crayfish your class found compare with those found by other groups around the Columbia River Basin. 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 reference sources to create more realistic maps of the Columbia River Basin. Then they can add your city/town, research site(s), etc. Satellite photographs available on sites like Google Maps can also be used for reference.
- 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-5FClCaMyM
- Ask students to write in journals or notebooks about what they learned about the Columbia River Basin, ArcGIS, native and invasive crayfish, etc. throughout the lesson and unit.
- Have a more robust discussion about the concept of a watershed (basin). For instance, ask students to look up definitions of the terms, such as "an area of land that drains precipitation to a river, lake, ocean, etc."
- 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 the Vancouver (WA) Water Resources Education Center if your school is in that area.
- 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.
- Assess levels of oral participation and student understanding of the concept of a watershed, how ArcGIS can be used to visualize and interpret data about it, etc.

Expand Knowledge + Skills

- ArcGIS Skillbuilder Activities for Education: esri.app.box.com/v/agoskillbuilder
- 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
- More information about the Next Generation Science Standards, including a link to the *Framework for K-12 Science Education*: nextgenscience.org/framework-k%E2%80%9312-science-education

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

TheRiverMile.org