Invasive Crayfish Collaborative
Great Lakes

Lesson 7

Crayfish as an Indicator Species

Subjects Science, Language Arts, Art

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

Time 45 minutes or more

Lesson Overview

Students will first read about a hypothetical mysterious phenomenon about crayfish disappearing from a river, then work in small groups to develop plans to investigate the issues. The plans should be based on the available information presented in the scenario and what they have learned throughout the unit about crayfish and freshwater ecosystems. We suggest having students first create a visual model, followed by a written explanation.
Lesson options are listed in the "Enrich/Extend" section, including ways to do water quality field investigations.

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

Goals

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

Objectives

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

Next Generation Science Standards

Performance Expectations

Building Toward

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

Crosscutting Concepts

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

Science & Engineering Practices

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

Core and Component Ideas in the Life Sciences

LS1: From Molecules to Organisms: Structures and processes

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

LS2: Ecosystems: Interactions, Energy, and Dynamics

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

Core and Component Ideas in Earth and Space Sciences

ESS2: Earth's Systems

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

Common Core State Standards

Speaking and Listening Standards for Grade 6

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

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

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

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

College and Career Readiness Anchor Standards for Writing

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

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

Center for Great Lakes Literacy Principles

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

Teacher Background

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

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

Materials

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

Preparation

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

Teaching Suggestions in the 5E Model

Engage

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

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

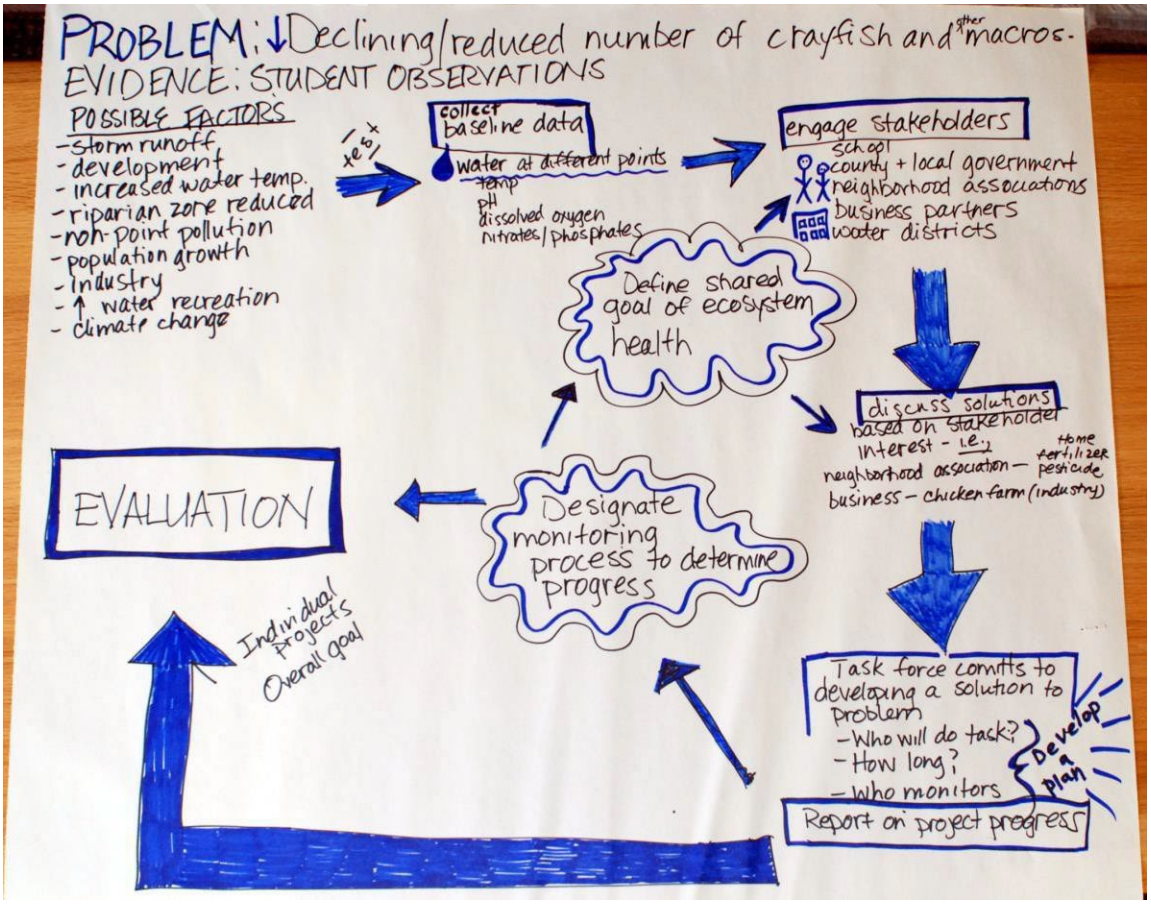
Explore

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

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

Explain

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



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

Enrich/Extend

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

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

- For younger and/or less experienced students, consider reading through the scenario as a class and answering questions before forming groups to work on the project.
- Investigate the biodiversity of macroinvertebrates in a nearby stream to evaluate water quality based on the prevalence of different species. You can also help improve water quality by doing a service project, such as planting native plants or removing trash. Good activities to support this field work are found in:
  - "Stream Side Science" lesson plans from Utah State Univ. Extension Service: extension.usu.edu/waterquality/educator-resources/lessonplans
  - SOLVE's *Environmental Service-Learning Curriculum:* engagingeverystudent.com/project/solve-environmental-service-learning-curriculum
- Explore the concept of a watershed in-depth with your students. See the "Introduction to Watersheds and Riparian Restoration" lesson in the SOLVE curriculum linked above and/or other online lessons, such as:
  - "Watersheds to Whales" in the "Exploring Ocean Mysteries" curriculum from NOAA: sanctuaries.noaa.gov/education/teachers/ocean-mysteries
  - "Discovering the Watershed" from Purdue Extension: extension.purdue.edu/extmedia/FNR/FNR-476-W%20Discovering%20the%20Watershed%2013.pdf
- Conduct water quality sampling activities with your students. Partners may be able to support your work, including your state university Extension Service, park district, or local watershed council.
- Ask students to read the article "Crayfish May Help Restore Dirty Streams, Study Finds" found at the end of the lesson and discuss the findings.
- If time allows, give students the option of creating dioramas to engineer engaging 3D models of their plans. They could construct areas of habitat restoration along the river, show ways to balance the needs of wildlife and humans, create bioswales, etc.

- Have students create public service announcement videos about ways to keep our water resources healthy for the benefit of both wildlife and humans.

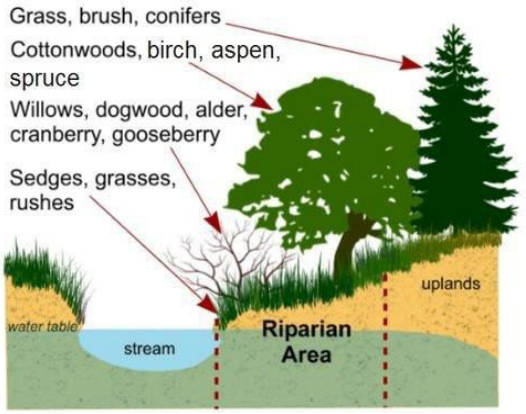
Evaluate

- Ask students to reflect on the lesson in writing and/or orally, including about what they learned and what you, as the teacher, might do to improve the lesson next time.
- Use completed student diagrams to evaluate student understanding of the concept of freshwater ecosystems.
- Review the short research projects about an organism from freshwater ecosystems and its interactions with other freshwater organisms.
- Use student participation in class discussion and activities, including the simulation of a freshwater web of life, to determine student understanding.

Expand Knowledge + Skills

Science/References

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



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

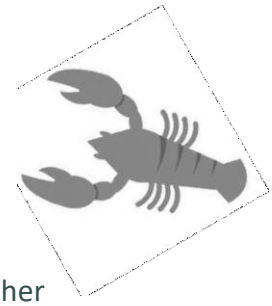
Lessons/Activities

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

Education Standards

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

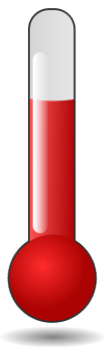
Mystery of the Disappearing Crayfish



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

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

  - **pH**: the measure of the number of hydrogen ions (which are acidic) in the water compared to the number of hydroxide ions (which are basic)
    - Neutral pH is 7, and crayfish prefer a range of 7.5–8.5. Most aquatic organisms prefer a range of 6.5 (slightly acidic) to 9 (a little basic).
    - Macroinvertebrates are generally quite sensitive to changes in pH.
  - **Sediment**: loose sand, clay, silt and other soil particles that settle on the bottom of a body of water
    - Sediments can build up to unhealthy levels when erosion increases on riverbanks and in the surrounding watershed.
    - Sediments can also be stirred up by rapidly flowing water and human activities.

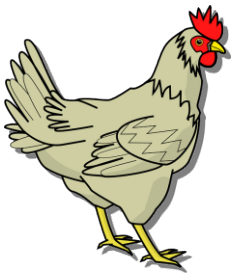


  - **Toxic substances**: pollution such as ammonia, metals, and oil-based products
  - **Temperature**: amount of heat energy contained in a substance (such as water or air); more oxygen can dissolve in cooler water and be available for animals to breathe
  - **Turbidity**: clarity (clearness) of the water; clearer water is generally healthier

  - **Bacteria** such as fecal coliform, *E. coli*, and enterococci

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

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



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

Your Challenge

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

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

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

Water Quality Improvement Plan Rubric

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

Teacher Comments:

Crayfish May Help Restore Dirty Streams, Study Finds

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

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

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

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

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

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

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

The study, "Effects of Invasive Crayfish on Fine Sediment Accumulation, Gravel Movement, and Macroinvertebrate Communities" (2016), was published in *Freshwater Science*.
It can be accessed at www.journals.uchicago.edu/doi/abs/10.1086/685860.
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