beetles
Science and Teaching for Field Instructors

Student Activity Guide

Food Web

Seeing live organisms can be a highlight of an outdoor science experience. *Food Web* builds on this excitement and deepens students' understanding of ecosystem interactions. In *Session 1: Building a Food Web*, students think back on an ecosystem they visited and build a food web from their observations, reasoning, and knowledge. Then, students use their food webs to make predictions and answer questions about the ecosystem. In *Session 2: Adding a Predator*, students read about the reintroduction of wolves into Yellowstone National Park and discuss the possible consequences of introducing/reintroducing a predator into the ecosystem they studied. Finally, students reflect on the usefulness and limitations of food webs as models for ecosystem management. This activity was designed for classroom teachers to use after students return from an outdoor science program. It can also be used after any outdoor experience in which students observed many organisms within an ecosystem.

Students will...

- **Construct a food web made of organisms observed during an outdoor science experience, using evidence of those organisms' interactions.**
- **Differentiate between firsthand observation, secondhand sources, and reasoning.**
- **Make predictions about the impacts of different changes, such as the introduction of a predator, based on the connections between organisms in the food web.**
- **Read about the impacts of reintroducing wolves to Yellowstone National Park.**
- **Discuss the usefulness and limitations of food webs.**

Grade Level:
Grades 5–8.

Timing:
Session 1: 60–75 minutes
Session 2: 60–70 minutes

Related Activities:
Field: *What Lives Here?*; *Eat, Build, Do, Waste*; *I Notice, I Wonder, It Reminds Me Of*; Classroom: *Evaluating Sources*; *Evaluating Evidence*

Materials:
See Materials and Preparation on pages 4–5 for details.

Tips:
To ensure a successful experience, review the teaching tips found on page 3 and throughout this guide.

NEXT GENERATION SCIENCE STANDARDS

FEATURED PRACTICE	FEATURED CROSSCUTTING CONCEPT	DISCIPLINARY CORE IDEAS
Developing & Using Models	Cause & Effect	Interdependent Relationships in Ecosystems and Ecosystem Dynamics

For additional information about NGSS, go to page 23 of this guide.

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Food Web

ACTIVITY OVERVIEW: SESSION 1

Session 1: Building a Food Web	Learning Cycle Stages	Estimated Time
Introducing the Activity	Invitation, Exploration	10 minutes
Creating Food Webs	Exploration, Concept Invention	30–40 minutes
Discussing Food Webs	Concept Invention, Application	20–25 minutes
TOTAL:		**60–75 minutes**

ACTIVITY OVERVIEW: SESSION 2

Session 2: Adding a Predator	Learning Cycle Stages	Estimated Time
Introducing or Reintroducing a Predator	Invitation, Exploration	10–15 minutes
Reading About Wolves in Yellowstone	Concept Invention	20 minutes
Discussing Whether or Not to Introduce/ Reintroduce a Predator	Application	20–25 minutes
Reflecting and Wrapping Up	Reflection	10 minutes
TOTAL:		**60–70 minutes**

TEACHING NOTES

TEACHING TIPS

Read the Instructor Support section. Beginning on page 18, you'll find more information about pedagogy, student misconceptions, science background, and standards.

Food webs with younger students. This activity can be challenging for younger grade 5 groups or for students who have had little experience with using models. If you're working with younger students or students less familiar with modeling, you'll likely need more time and will need to move more slowly through the introduction to the process of creating models and using them to make predictions and explanations.

Using the Things Eating Things Evidence Cards. The Things Eating Things Evidence Cards show animals eating other organisms, and the cards are critical to the success of this activity. Chances are that your students likely saw many organisms during their outdoor science experience, but they probably didn't get to observe many of them actually eating. The photos on the cards give students more evidence that they can use to fully construct their food webs. If the cards don't work for the ecosystem you've chosen, find other images that are representative of organisms eating organisms in the ecosystem that students explored and then print your own sets of cards.

Following student interest in discussion. This activity requires a fair amount of discussion. To make such discussion engaging for students, be sure to intersperse a lot of *Turn & Talks* and *Think, Pair, Shares*. This will increase students' participation and will better engage all students, even those who might not share in the large group. Additionally, follow students' interests and read the needs of the group. If students are excitedly talking and sharing ideas about a question, let them keep talking, ask follow-up questions, and bring in perspectives from other members of the group. If a discussion question or topic falls flat, don't force students to discuss it; instead, move on to a new topic or question.

TEACHING NOTES

MATERIALS AND PREPARATION

MATERIALS

For the class

- 1 copy of the Ecosystem Model (See page 27.)

For each group of 3–5 students

- 1 set of Things Eating Things Evidence Cards (See pages 28–31.)
- 1 sheet of chart paper
- markers

For each student

- 1 copy of the “Reintroducing Wolves to Yellowstone National Park” article
- student’s journal (if available)

PREPARATION

1. **Pick a specific ecosystem to frame the conversation.** If you don’t ask students to focus on organisms within a specific ecosystem (e.g., oak woodland, alpine forest, riparian woodland), they are likely to make inaccurate food webs that include organisms that would never interact with one another. Focus on the ecosystem your students explored during their outdoor science experience. If you’re not sure what ecosystem students explored, contact the outdoor science program your students attended (or ask your students). (**Note:** A forest ecosystem will match best with the Things Eating Things Evidence Cards included in this activity).
2. **Prepare copies of Things Eating Things Evidence Cards.** Print and make enough copies of the Evidence Cards (on pages 28–31) for each group of 3–5 students to have one set. Print the cards in color, single-sided, and cut apart cards. Each group will use these as secondhand sources of information to use when building their food webs. If the organisms on the cards don’t work for the ecosystem you’ve chosen, find other images that are representative of organisms eating other organisms in the ecosystem that students explored and then print your own sets of cards.
3. **Choose a predator.** The introduction of a predator in Session 2 makes for interesting discussions about ecosystem effects. It’s best to choose a predator with which students are familiar that once lived in the ecosystem students are discussing or a predator that could feasibly live there. Depending on your ecosystem, the predator you choose could be something large such as a wolf, mountain lion, grizzly, shark, whale, sea otter, badger, black bear, coyote, fox, bobcat, or wolverine. Other options could include smaller organisms such as predatory fish (e.g., mosquito fish, bass, or alligator gar), predatory birds (e.g., kingfishers, cormorants, or herons), predatory

MATERIALS AND PREPARATION (CONTINUED)

insects (e.g., dragonflies or water bugs), predatory amphibians (e.g., bullfrogs), predatory reptiles (e.g., snakes), or predatory marine invertebrates (e.g., sea stars or sea anemones).

4. **Find out if your students participated in the BEETLES activity *What Lives Here?*** That activity includes having each student make an ecosystem model. If your students did so, they can use their individual ecosystem models as a starting place for creating their food webs. Make it clear that unlike in their ecosystem models, which included different kinds of interactions, students' food webs will only include interactions in which one organism eats another.
5. **Print a photograph of the predator you plan to discuss.** This will help students who aren't familiar with the predator to have context for the discussion.
6. **Optional: Find field guides for the area where students had their outdoor science experience.** Students can use these to identify organisms they saw during their outdoor science experience, either to bulk up their list of organisms or to find information about what the organisms eat.
7. **Prepare copies of the "Reintroducing Wolves to Yellowstone National Park" article.** The article consists of 7 pages and is located at the end of this student activity guide. Print and make enough copies for each student to have their own copy on which to record.
8. **Gather 1 sheet of chart paper and several markers for each group of 3–5 students.**
9. **If students used journals at outdoor science school, make sure they have their journals on hand.**
10. **Set up a projector or other system to show the Ecosystem Model that is used by scientists (on page 27) so the whole class can see it together.**
11. **Make a slide to project of the following quotes and questions or record them on a whiteboard or handout:**
    - "No single organism will thrive in this planet without the interaction with other ones."—Carlos Magdalena
    - "All things are connected."—Ted Perry, as inspired by Chief Sealth (Seattle)
    - "Everything in an ecosystem is connected, but some things are more connected than others."—Neo Martinez, ecologist
    - Have your ideas about ecosystems changed during the course of this activity? How did your ideas change and what made them change?
12. **Review the Teaching Tips on page 3 and Instructor Support section on page 18.**

TEACHING NOTES

TEACHING NOTES

Asking about the ecosystem. If you're not sure which ecosystems your students were in during their outdoor science experience, contact the program or ask your students.

Including students who didn't attend an outdoor science program. For this initial exercise, pair students who weren't able to attend the outdoor science program with those who did, instructing them to ask questions about the organisms that were seen. Or for students who didn't attend, offer them a field guide or a species list for the ecosystem you'll focus on in the activity so they can contribute organisms to the guide or list. Make it clear that during the rest of the activity, they will be able to participate fully by sharing ideas, reasoning, and knowledge from other sources of information.

Species names. Students don't need to know the names of every species they saw. They can still build a food web with more general names (e.g., hawk instead of a name for a specific type of hawk, short purple flower plant). You can also offer students field guides so they can identify species.

Give students their journals to remind them of their experiences. If students used field journals during their experiences (particularly to make sketches or record observations), give them a chance to read and reflect on some of their observations as they brainstorm organisms.

Session 1: Building a Food Web

Introducing the Activity

1. **Soon after your students have an outdoor science experience, choose an ecosystem they explored and ask them to describe it.**
   - **a.** Ask: "What do you remember about the ____ecosystem where you had your outdoor science experience?" [Students might respond: dry, wet, hot, cold, hilly, flat, lots of trees, rocky, rich soil, logs, bushes, grasses, etc.]
   - **b.** Write abbreviated versions of students' descriptions on a whiteboard or sheet of chart paper.

2. **Ask pairs to brainstorm organisms they saw in the ecosystem.**
   - **a.** Think of organisms you learned names for and also describe organisms whose names you don't know.
   - **b.** With your partner, see how many organisms you can remember seeing.

3. **Create a class list of organisms that students saw in the [name of ecosystem] during an outdoor science experience.**
   - **a.** Get the whole group's attention and record students' ideas on a whiteboard or a sheet of chart paper.
   - **b.** If students only mention animals, remind them to include plants.
   - **c.** If needed, remind students of decomposers, too.
   - **d.** If students don't list many organisms, you might want to use a species list or a field guide for the ecosystem to add more to the list.

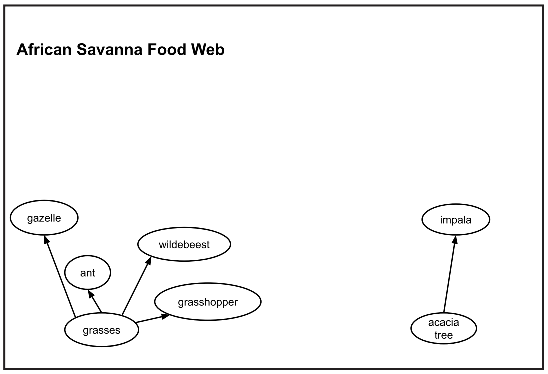
4. **Explain that pairs will discuss which organisms might eat which other organisms in the ecosystem:**
   - **a.** With your partner, think about which organisms might eat other specific organisms in the ecosystem.
   - **b.** Your ideas can be based on your own observations, which is firsthand information.
   - **c.** Your ideas can also be based on secondhand information—for example, from books, TV shows, or what you've heard from other people.

Creating Food Webs

1. **Explain that in small groups, students will use the list of organisms to make a food web—a diagram or model that shows which organisms eat other organisms within the ecosystem:**
   - **a.** You will build a food web that shows what eats what in this ecosystem.
   - **b.** It will be based on your observations, on secondhand information from other sources, and on reasoning.

2. **Draw an example food web on a whiteboard or chart paper as you explain how students will create their food webs. (See the example food web on the next page.)**

3. **Write "grasses" and "acacia tree" and explain:**
   - **a.** You'll make your food webs for the ecosystem you explored, using the organisms from the list we just came up with.
   - **b.** As an example, I'll begin making one that's from a totally different ecosystem: the African Savanna.
   - **c.** First you'll add plants from the ecosystem to your food web.
   - **d.** For my example, I'm writing "grasses" and "acacia trees." You will write specific plants from our list.
   - **e.** When you make your list, you can use specific names of plants that we brainstormed, or you can use categories such as grasses, trees, bushes, and so on.



4. **Write "ant," "grasshopper," "gazelle," "wildebeest," and "impala." Draw arrows from *grasses* to *ant*, *grasshopper*, *wildebeest*, and *gazelle*. Draw an arrow from *acacia tree* to *impala* and explain:**
   - **a.** You'll add the names of animals that eat plants to your food web. Then, you will use arrows to connect the plants to the animals that eat those plants.
   - **b.** I'm writing the names of plant-eating animals from the African Savanna on my example, but you'll write names of animals from our list that you think might eat plants that are on our list.
   - **c.** Always draw your arrows going from the organism being eaten toward the organism doing the eating.

5. **Explain how students will need to use evidence to draw arrows between organisms eating one another:**
   - **a.** When you add arrows between organisms to show them eating one another, you can't just make up these connections. They need to be based on evidence.
   - **b.** Your evidence could be your own observations, such as actually seeing a rabbit eat grass.
   - **c.** Your evidence could also be from another source of information, such as a book about what animals eat.
   - **d.** Your evidence could also be based on reasoning or, in other words, your own careful thinking about which organisms might eat one another.

TEACHING NOTES

Creating a food web. There are many ways to create a food web. The example shown (at left and at full size on page 39) is an approach that differentiates between various sources of evidence, which helps students gain deeper understanding about evidence. The African Savanna is used here as an example because it's different enough that students won't be able to just copy what you wrote, and because the organisms are ones about which most students have heard. If you prefer not to use the African Savanna example, you could just use general terms, such as *animal*, making sure that students understand that they will actually use individual types of organisms.

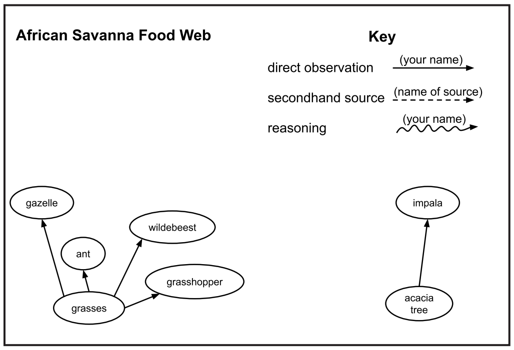
Why have the arrows point from prey toward predator? There *are* some food web diagrams in which the arrows point from the predator toward the prey. Many food webs point the arrows from prey toward predator, which we've chosen to do here because it shows the direction of the movement of matter and energy. (If your students have experience with the cycling of matter and the flow of energy, you can bring this to their attention.)

TEACHING NOTES

Connection to *Evaluating Evidence* and *Evaluating Sources*. If you've done either of the Pre-Outdoor Science activities, *Evaluating Evidence* or *Evaluating Sources*, remind students of these approaches for evaluating the strength of evidence.

Full size model drawing. See a full size version of the model drawing at right on page 39.

6. **Add a key to your model food web that lists solid lines for firsthand observations, dashed lines for secondhand observations, and squiggly lines for reasoning. Explain:**
   - **a.** Instead of using only solid-line arrows for the whole food web, you'll use three kinds of arrows to show what evidence you have for that connection.
   - **b.** We do this so we can evaluate how strong the evidence is. Direct observations of connections tend to be stronger evidence than reasoning.



7. **Show and explain how to use solid-line arrows for firsthand observations:**
   - **a.** You'll draw a solid-line arrow and write your name next to the line to show direct observations.
   - **b.** These are firsthand observations you made of an organism eating another organism in nature.
   - **c.** These could be observations from your outdoor science experience or another time in your life.

8. **Show and explain how to use dashed-line arrows for secondhand observations:**
   - **a.** You'll draw a dashed-line arrow and write the name of the source next to the line to show secondhand information.
   - **b.** This could be from a photograph of some organism eating another organism.
   - **c.** Or it could be from a book, a movie, or another person from whom you got information about which organisms eat what in the ecosystem.

9. **Show and explain how to use squiggly-line arrows for connections made through reasoning:**
   - **a.** Draw squiggly-line arrows and write your name next to the line to show connections based on reasoning.
   - **b.** This is for connections you think may be true, based on some evidence or knowledge that you have. For example:
     - *I saw a photograph of a caterpillar eating a leaf from a plant that is similar to this one—I think it's reasonable to say that the caterpillar would eat this plant, too.*
     - *I haven't seen raccoons eat slugs, but raccoons are omnivores, and based on their size, I think they could eat a slug.*
     - *I know hawks eat mice, so maybe they eat squirrels, too.*
   - **c.** Connections made through reasoning are the ones we have the least amount of certainty about, because they could be wrong.

10. **Briefly add to your model food web. Write "hyena," "lion," and "cheetah." Then add arrows, thinking aloud about which kinds of arrows to use (and clarifying to students that to model the activity, you are pretending to have already made some firsthand observations).**
    - **a.** Draw a solid-line arrow from *grasses* to *wildebeest*.
    - **b.** Draw dotted-line arrows from *wildebeest* to *lion* and from *wildebeest* to *cheetah*.
    - **c.** Draw squiggly-line arrows from *gazelle* and *impala* to *lion* and from *gazelle* and *impala* to *cheetah*.
    - **d.** Draw squiggly-line arrows from *gazelle*, *impala*, *lion*, *wildebeest*, and *cheetah* to *hyena*.
    - **e.** Narrate your thinking as you go. For example:
        - *Hmmm, one time I saw some wildebeest eating grass, so I'm going to use a solid arrow to show that.*
        - *I've seen photographs and videos of both lions and cheetahs hunting wildebeest, but that wasn't my direct observation, so I'm going to use a dotted line.*
        - *I don't have any direct observations or secondhand observations of lions, cheetahs, and hyenas eating gazelles and impalas, but I think if lions and cheetahs eat wildebeest, they could also eat gazelles and impalas because they're a similar size to wildebeest. This is my reasoning, so I'm going to use a squiggly line.*
        - *I know hyenas are scavengers, so I'm going to use my reasoning and a squiggly line to show that I think they are likely to eat gazelles, impalas, lions, wildebeest, and cheetahs at some point.*

11. **Hold up a set of Things Eating Things Evidence Cards and explain:**
    - **a.** Each group will get a set of these photographs of organisms to help you make your food webs.
    - **b.** Some photographs clearly show one organism eating another organism.
    - **c.** This is secondhand evidence about what eats what that you can use in your food webs.
    - **d.** Other photos might show evidence that could help you figure out a connection through reasoning.
    - **e.** For example, if you see a photo of caterpillars eating a leaf, and in the ecosystem you saw holes in leaves that looked similar to the holes in the photograph, you might use reasoning to say that those holes might have been made by caterpillars.
    - **f.** Or, if you see a photo of an animal eating a small rodent, but you can't quite tell what kind of rodent, you can use reasoning to say they eat mice or squirrels.

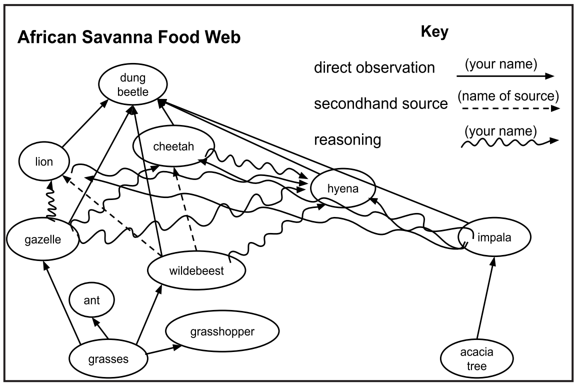
12. **Write "dung beetle" and draw arrows from *wildebeest, impala, gazelle, hyena, lion*, and *cheetah* to *dung beetle*. Explain:**
    - **a.** Dung beetles are decomposers that eat dung from other animals.
    - **b.** Make sure you include decomposers in your food web and show how they're connected to other organisms, too.

TEACHING NOTES

TEACHING NOTES

Full size model drawing. See a full size version of the model drawing at right on page 39.

Offer books as additional secondhand evidence. If you have access to other books or field guides with information on organisms' eating habits, offer them to students partway through the creation of their food webs so they can add more links to their food webs. Making the resources available too early could discourage students from recalling and using their own observations and reasoning.



13. **Explain that students' food webs will be complex, showing animals eating plants, animals eating animals, and animals eating plants *and* animals:**
    - **a.** Your arrows should show that some animals eat plants, some eat other animals, and some eat both animals *and* plants.
    - **b.** Some animals eat more than one thing; they will have more than one arrow connecting them to other organisms.
    - **c.** Some plants or animals are eaten by more than one animal; they will have more than one arrow connecting them to other organisms.
    - **d.** Many of the organisms will likely be connected to decomposers.

14. **Tell students they'll need to work together; discuss their ideas, evidence, and reasoning with others; and pay attention to what others in their group are writing.**
    - **a.** You'll need to intentionally work together to make your food webs.
    - **b.** If someone has already written something—for example, *deer*—on your group's food web, don't write *deer* again.
    - **c.** Instead, you could add an arrow to show a connection, or you could write your name next to an arrow that someone else drew if you also observed a deer eating or being eaten.
    - **d.** Communicate as you go, making sure everyone gets a chance to contribute ideas and create connections.

15. **Review directions, divide students into groups of 3–5, distribute markers, chart paper, and one set of Things Eating Things Evidence Cards to each group. Then tell students to begin making their food webs.**
    - **a.** Review directions in a way that will work best for your students.
    - **b.** For some groups, it works well to somewhat comically model doing the directions in wrong ways, challenging students to call out what you're doing wrong and to tell you what you should actually be doing.
    - **c.** Other groups do well with summarizing the directions verbally back to the teacher.
    - **d.** Some groups might need to ask clarifying questions or would benefit from having a bullet-point summary of the directions written on the whiteboard.

16. **As students work, you will circulate, engage groups in dialogue about their food webs, and support anyone who might be struggling.**
    - **a.** Tell students to write large enough so someone could read their food webs from across the room.

b. Remind students to include their sources of evidence when adding arrows.
c. Ask students questions about their ideas, evidence, and reasoning.
d. Remind students to include various types of organisms in their food webs.
e. If students are particularly focused on one type of organism or have neglected another type (e.g., decomposers), encourage them to consult the list of organisms for more ideas.
f. If any group is struggling to work together, offer support.

17. **After students have had time to make their food webs and before they become disengaged, give them a 2-minute warning and then post all food webs at the front of the room.**

Discussing Food Webs

1. **Explain that a food web is actually a model and that scientists use models to think about and understand complex systems:**
   a. When scientists want to better understand something that is too large or complex to observe all at once, they sometimes just study one smaller part of a bigger system.
   b. For example, scientists studying human health might look only at the digestive system or the respiratory system, focusing on one smaller system, studying it, and using their discoveries to better understand the human body as a whole.
   c. Scientists might just look at one ecosystem instead of a whole state or region, or they might look at an even smaller system, such as focusing on only the living organisms in an ecosystem.
   d. Then scientists use a model, such as a food web, to look at the parts of that smaller system to think about how the parts interact.
   e. Thinking about this smaller, simpler system makes it easier to make sense of relationships and interactions within the larger, more complex system.

2. **Explain how scientists can use models to make explanations and predictions about a system, and tell students that they will get to do this with their own food webs:**
   a. Scientists can use a system model to make explanations and better understand the system as a whole.
   b. They can also use models to predict how a change to one part of the system might affect other parts of the system and, therefore, the system as a whole.
   c. Let's analyze our food web models to better understand the [name of ecosystem].

3. **Ask students what they notice about the food webs, starting from a broad view and then focusing on certain aspects.**
   - *What do you notice about the food webs?*
   - *In what ways are our food webs similar to one another? Different?*
   - *Which organisms have more connections to other organisms?*
   - *Which organisms have fewer connections to other organisms?*

TEACHING NOTES

There are systems within systems within systems.... The biosphere is the huge system of all the parts of Earth in which living things are found. An ecosystem (e.g., an oak forest) is a much smaller system within that Earth system and includes both living and nonliving things. An organism (e.g., a turtle) is its own system of parts working together. The turtle's digestive system is another system within the turtle system, etc. Playing around verbally brainstorming systems within systems is one way that students can start to understand the concept.

Discussing matter and energy transfer in an ecosystem. If your students have experience with the concept of matter (or energy), you could tie that in by explaining that food is a package of matter and energy. A food web is a model that shows how matter and energy are transferred between organisms in an ecosystem. Each arrow in the food web represents matter (and energy) being transferred from one organism to another. Matter from the food provides materials for growth, while energy from the food provides energy that organisms need to do things. You might challenge students to trace the movement of matter (and maybe also energy) through their food webs.

Encouraging students to cite sources. As students point to arrows on the food web as evidence for their explanations, encourage them to name the source of the information (e.g., *We didn't actually see a hawk eating any mice, but someone thought that hawks probably would. Based on their reasoning that hawks likely eat mice in this ecosystem, maybe there would be more mice if all the hawks were to die off.*). Students don't need to name their information source every time, but doing so is a good opportunity for them to practice evaluating how reliable different sources of information are (and, in the process, to practice thinking about how strong the evidence really is).

4. **Lead a discussion in which students use their food webs as evidence for explanations about ecosystem dynamics.**
   - **a.** Keep the discussion moving, sticking with questions that lead to a lot of dialogue and moving on from questions that are less interesting to students.
   - **b.** Follow students' interests in the discussion, asking follow-up questions and probing their thinking. Move on before the class shows waning interest. For example:
     - *Based on our food webs, which organisms might compete for the same food?*
     - *How might other organisms in the food web be affected if this organism (choose one) decreased?*
     - *If this organism (choose a different one) increased or decreased, how might it affect the ecosystem as a whole?*
     - *How might other organisms in the food web be affected if this producer (choose a plant) were to die off?*
     - *How might other organisms in the food web be affected if this top consumer (choose one) were to die off?*
     - *How might the ecosystem as a whole be affected if this decomposer (choose one) were to die off?*
     - *What might happen to the organisms in this food web if there were more predators? Fewer predators?*

5. **Explain that some types of organisms are very significant:**
   - **a.** Some organisms are very significant because if they were gone, many other organisms would be affected.
   - **b.** Significant organisms are often connected to a lot of other types of organisms in the ecosystem.

6. **Ask students to identify significant organisms in the ecosystem.**
   - **a.** Are there any organisms in the food web that look like they are very significant in this ecosystem?
   - **b.** What is your evidence?

7. **After students have had some time for discussion and before they become disengaged, wrap up the discussion. Then, ask students to reflect on how their food webs helped them to learn.**
   - **a.** How did using a food web help you think about connections between organisms and how they interact with one another?

8. **Ask students to *Turn & Talk* about how scientists might use food webs.**
   - **a.** How might scientists use food webs?

9. **Ask students to share their ideas and then explain:**
   - **a.** Understanding how organisms interact with one another and how they depend on one another helps predict what could happen to organisms if something in an ecosystem changes.
   - **b.** This knowledge also helps scientists and government agencies make decisions about managing parks, forests, and places such as marine reserves, national monuments, or national parks in which organisms are protected.

TEACHING NOTES

Thinking about the complexity of impacts. It's a common misconception that only organisms in direct interaction with one another will be affected (i.e., more mountain lions = fewer deer). Encourage students to follow the chains of impacts through the food web by asking follow-up questions such as, "How might other organisms be affected in the food web if there were fewer deer?" If students oversimplify and say that everything would be affected, point out that organisms that are only one link away tend to be the most affected and that effects tend to decrease the more links away you go.

Producers, consumers, and decomposers. If your students are not familiar with the terms *producers*, *consumers*, and *decomposers*, define them. Producers are organisms that get matter from carbon dioxide and water and get energy from sunlight (e.g., plants or algae). Consumers are organisms that get matter and energy from eating other organisms. Decomposers are organisms that get matter and energy by eating dead organisms. Point out examples of each on a food web as you explain. If you want to avoid overloading your students with vocabulary, just use the terms *plants*, *animals*, and *decomposers*.

Break up whole-group discussion with a *Turn & Talk*. Including *Turn & Talk* opportunities—when everyone turns to a partner and talks for approximately 60 seconds—make group discussions more interesting and engaging for everyone. *Turn & Talks* allow every student to participate and practice expressing their ideas in the safety of speaking directly with one peer; afterward, students are more likely to volunteer to speak in the whole-group discussion and share more developed ideas.

Session 2: Adding a Predator

Introducing or Reintroducing a Predator

1. **Ask pairs to discuss predators and consider how they impact ecosystems.**
   - **a.** Ask pairs to discuss predators they have heard of and how those predators might impact ecosystems.
2. **Get the whole group's attention and then explain that the reintroduction, introduction, or elimination of a significant species in an ecosystem can cause big changes:**
   - **a.** Organisms are sometimes introduced into an ecosystem, often accidentally but sometimes on purpose.
   - **b.** Organisms can also be eliminated, die off, or leave an ecosystem.
   - **c.** Sometimes these changes can have significant effects on ecosystems.
3. **Refer to students' food webs and ask them to *Turn & Talk* about the possible effects that might occur if the predator you've chosen is introduced or reintroduced into an ecosystem.**
   - **a.** Ask: "How might it affect the food web if [your chosen predator] were reintroduced or introduced to the area?"
4. **Ask the whole group to share their ideas and use their food webs to predict possible impacts of a top predator introduction.**
   - **a.** Listen to students' ideas and facilitate discussion.
   - **b.** Encourage students to cite their evidence and respectfully agree or disagree with one another.
   - **c.** Bring students' discussion back to food webs, making sure that they use the connections on the food webs as evidence whenever they're predicting possible impacts.

Reading About Wolves in Yellowstone

1. **Tell students that they will read an article about a top predator that was killed off in Yellowstone National Park and reintroduced years later.**
   - **a.** Wolves used to be a part of the ecosystem of Yellowstone Park, but they had all been killed by the early 1900s.
   - **b.** Some people argued that if wolves were reintroduced, the ecosystem would become healthier and more stable. Others argued against reintroducing them.
   - **c.** Scientists made food webs and ecosystem models, like you did, to help understand how introducing wolves might affect the ecosystem.
   - **d.** Some things they predicted that might happen *did* happen, and many things happened that surprised the scientists.
2. **Explain active reading strategies that students should use while reading:**
   - **a.** Underline what you think are important points in the text.
   - **b.** In the margins, record questions you have.
   - **c.** In the margins, record connections you think of.

TEACHING NOTES

Facilitate; don't advocate. This discussion can become a microcosm of our society, and it's interesting to discuss because it's complex. It's not unusual to have one student who hunts contribute their ideas next to another student who doesn't think any furry things should ever be killed. This can lead to a very interesting exchange of ideas–or can become polarizing. Encourage respectful discussion and disagreement and keep the discussion evidence-based. One of the best ways to do this is to show respect yourself for all ideas and not show preference. If students bring up flat-out misconceptions, ask the group what they think and see what happens; other students might challenge the idea and change one another's thinking. The "Reintroducing Wolves to Yellowstone National Park" article can address misconceptions around these concepts; after the reading, assess whether you should add more evidence to the discussion to make sure students are working with accurate information.

Choosing a predator. See the "Preparation" section on pages 4–5 for information on how to choose which predator to discuss during this section.

If the reading proves too challenging. If the article seems beyond the ability of many of your students, consider reading it aloud to the group. If you choose this option, you could give each student a copy of the article and encourage them to read along with you. Or, you could read it aloud and hold up large copies of the photos as you tell the story.

TEACHING NOTES

Active reading. If students are familiar with the BEETLES activity *I Notice, I Wonder, It Reminds Me Of*, remind them of the three prompts. Encourage them to underline important points (observations or *I notice*) and to record both their questions (*I wonder...*) and their connection statements (*It reminds me of...*) in the margins. Or, if you use different guidelines for active reading with your students, you may prefer to use those. The important thing is that students engage deeply and carefully with the text as they read or as you read it aloud to them.

3. **Optional: Model active reading.**
   a. If your students are not familiar with active reading strategies, use a document camera or other visual aid to model underlining and recording questions and connections with the first paragraph of the article.

4. **Distribute copies of the "Reintroducing Wolves to Yellowstone National Park" article and circulate as students read.**
   a. Remind students to annotate their text while they read.
   b. If they are new to active reading, as they are beginning, you might want to occasionally announce strategies you see students using, such as the following:
      - *I've just seen someone connect two ideas with an arrow, writing what the ideas have in common.*
      - *I'm seeing a lot of questions written in the margins! That's a great strategy.*
   c. This helps give other students examples of the kinds of notes they might write.

5. **As students finish, instruct them to find another student who's finished reading and have them discuss the article together.**
   a. As students finish, instruct them to pair with someone else who's also finished reading.
   b. Students who are finished reading can raise their hands and pair themselves up with someone else who has also raised their hand.
   c. Or you might prefer to assign pairs as students finish.
   d. Tell pairs to discuss the article and their notes and see if they can answer each other's questions together.

Discussing Whether or Not to Introduce/Reintroduce a Predator

1. **When most students have finished, get the whole group's attention and lead a discussion about the article.**
   a. Ask the following questions:
      - *What surprised you about the reintroduction of wolves in Yellowstone and the effects on the ecosystem?*
      - *What questions did it bring up for you?*
      - *Does it make you think differently about how introducing/reintroducing [your chosen predator] might impact the ecosystem and food web we are studying?*
      - *Looking at the food webs we made, are there indirect effects you think could happen?*

2. **Share an Inuit proverb about how predators can keep prey populations strong.**
   a. Share this proverb: *The caribou feeds the wolf, but it is the wolf who keeps the caribou strong.*
   b. Ask your students what they think is meant by this.
   c. If necessary, explain that predators often kill off the older and weaker individuals so those that are stronger and faster are more likely to survive longer and can pass their DNA on to offspring that are strong and fast.

3. **Explain that, generally, the more biodiverse an ecosystem, the more stable it is:**
   a. Generally, more biodiverse and interconnected ecosystems are more stable when changes happen.
   b. Do you think introducing/reintroducing this predator might make the ecosystem more diverse or less diverse and stable? In what ways?

4. **Ask if the story changes students' ideas about how [the top predator discussed earlier] might impact their food web.**

5. **Facilitate a discussion about whether or not students think [your chosen top predator] should be introduced/reintroduced into this ecosystem.**
   a. Ask: "Using evidence from this reading, your food webs, and other sources, explain whether or not you think this predator should be introduced/reintroduced into this ecosystem."
   b. Ask follow-up questions and encourage respectful disagreement.
   c. Encourage students to think beyond only the ecosystem effects, taking into account policy factors such as money required to breed and reintroduce predators.
   d. Before the discussion runs out of steam, you might want to conclude by giving students a chance to vote on the choice they would make with the information they have.
   e. Alternatively, you might conclude by summing up the points that have been made without requiring students to take one position or the other.
   f. Encourage students to keep open minds about the issue and to pay attention to information in the news about the introduction of species into various ecosystems.

6. **Explain that scientists are conducting investigations to try to be more certain of whether or not these changes were caused by the wolves being reintroduced:**
   a. The Yellowstone ecosystem changed significantly after wolves were reintroduced. While it seems highly likely that the changes were influenced by the wolves' presence, some observers are less certain of this than others.
   b. Part of the work scientists are doing is trying to figure out how big a role the wolves are playing in causing these changes.
   c. Scientists can't assume that the wolves caused *all* the changes, because there are other factors that also could have played a role.
   d. Scientists have to investigate whether the patterns of increase and decrease in the populations of different organisms are, in fact, tied to the wolves.

7. **Explain that examining cause and effect is a useful thinking tool for scientists:**
   a. We've been considering some possible effects of introducing an organism into an ecosystem.
   b. Scientists also think about causes and effects to help them understand how things work or to make predictions about what could happen in the future.

TEACHING NOTES

To vote or not to vote? One of the biggest challenges of issues-related curricula is helping students to be *and remain* open-minded. There is often a tendency to take on a side and then to only see the issue from that perspective. If students are pressed to vote early on in an activity like this, they are more likely to pick a side and stick with it, thus not being open to weighing different perspectives or thinking about the complexity of issues. There is tremendous value in seeing issues from contrasting perspectives, and there's also value in students' sometimes taking a stance. If you do have students vote, couch the vote with strong messages about the dangers of being closed-minded, the importance of being open to changing your mind, and the reality that voting decisions aren't always simple to make. See the BEETLES activity *Argumentation Routine* for a way to guide students to see an issue from varying perspectives.

Correlation does not imply causation. If you think your students are up for it, you might want to dig a little deeper into this extremely useful idea. Figuring out cause-and-effect relationships is an important aspect of science and of learning about the world in general. If you tip over a cup of water, and the water spills out, it's a pretty clear cause-and-effect relationship. The correlation is that the cup being tipped over caused the water to spill. If you slam a door, and at that very moment someone trips over something in the house next door, that's a correlation, although it's extremely unlikely that causation is involved. Some things are trickier to figure out. It's important not to assume causation whenever there is correlation. Lots of things changed in Yellowstone that correlated with the time when wolves were reintroduced, and it's reasonable to assume that some changes may have been caused by the wolves, both directly and indirectly. The less direct the changes, however, the more difficult it is to know for sure.

TEACHING NOTES

Connections to Social and Emotional Learning. The significance of diversity in ecosystems can be a useful metaphor for the importance of diversity of perspectives, cultures, and backgrounds among groups or even nations of people. Point out this connection and ask students how having diversity in a group of people can help them to be more resilient.

The limitations of models. Thinking about the limits of models is an important part of developing students' competency with this practice.

c. Making models of ecosystems by identifying the parts of the ecosystem and how they interact with and impact one another and then using the models to help answer what the effects might be when something changes in the ecosystem is one way scientists do this.
d. Thinking about cause-and-effect relationships and coming up with explanations about why things happen is a major part of science.
e. Cause-and-effect thinking is also interesting to do and can be useful when we look at other systems and other disciplines such as history or social science.

8. **Reiterate that, generally, the more biodiverse an ecosystem, the more stable it is.**
   a. Generally, more biodiverse and more interconnected ecosystems are more stable when changes happen.
   b. The more diverse and interconnected ecosystems are, the less impactful changes that eliminate or decrease populations of organisms tend to be on the rest of the food web.

Reflecting and Wrapping Up

1. **Remind students that food webs are models, which by definition are always incomplete. Explain:**
   a. Nature is tremendously complex—too complex for us humans to ever fully understand.
   b. A food web is a model that shows a small part of an extremely complex ecosystem.
   c. Simplifying the ecosystem into a model can make it easier to study, but doing so also means that some things are left out of the model.
2. **Ask about some of the limitations of food webs as models.**
   a. "What are some parts of the ecosystem, or things that affect it, that are not included in the food web?" [Nonliving parts such as water, soil, weather.]
   b. "How might nonliving parts of ecosystems affect organisms in the food web?"
3. **Explain that these limitations of food web models are important to keep in mind when thinking about how changes might affect the ecosystem.**
4. **Explain that your students have been taking on a complex task and discussing things in ways similar to those of scientists:**
   a. Our discussions about food webs are like discussions that scientists might have when deciding how to manage wildlife and make decisions about reducing human impacts on the environment.
5. **Show an example of a more complex ecosystem model made and used by scientists.**
   a. Explain: Scientists use food webs that are even more complicated, and they may use advanced computer models that help them predict how changes might affect the ecosystem.
   b. Show an example of an ecosystem model used by scientists (Ecosystem Model on page 27).

6. **Post the following quotes and the question and tell students to *Turn & Talk* (or write) to reflect on some of them:**
   a. "All things are connected."—Ted Perry, as inspired by Chief Sealth (Seattle)
   b. "Everything in an ecosystem is connected, but some things are more connected than others."—Neo Martinez, ecologist
   c. "No single organism will thrive in this planet without the interaction with other ones."—Carlos Magdalena
   d. *Have your ideas about ecosystems changed during the course of this activity? How did your ideas change and what made them change?*

TEACHING NOTES

TEACHING NOTES

Instructor Support

Teaching Knowledge

Modeling Ecosystems. Ecosystems are ridiculously complex, and it's pretty near impossible for scientists to completely understand how they work. Ecologists make models that explain and focus on different parts of an ecosystem in order to help us better understand the whole. One type of model is a food web, which shows what eats what (trophic relationships) and focuses on how matter and energy are transferred as organisms eat one another. There are many other kinds of models of ecosystems, each meant to simplify and explain a part of the whole. For example, some models focus on the movement of particular nutrients in the ecosystem (e.g., nitrogen), while other models focus on specific populations within the ecosystem. When scientists develop models, they can't include *everything*, so they make decisions about what to include and what not to include (in other words, they delineate the boundaries of the system). These decisions affect the usefulness and complexity of the model. So scientists consider the limitations of the model when they use the model to draw conclusions and make predictions about an ecosystem. As scientists investigate the ecosystem and gather evidence about the relationships between its parts, they also refine their models to make them more accurate and more useful.

Building understanding of modeling over time. It takes time for students to build understanding of and comfort with different Science and Engineering Practices. Modeling can be especially difficult to understand, and it's okay if students don't totally understand everything about modeling in this one activity. Pointing out what a model is and having students think about how to use models is one step in this process; they will need to have multiple learning experiences to fully develop competency with this Science and Engineering Practice.

Food Web is designed to engage students authentically in the practice of developing and using models. Students' encounters with organisms during their outdoor science experience provide opportunities for them to create food webs grounded in firsthand experience with the ecosystem and also in using some firsthand evidence, along with secondhand evidence and reasoning. Discussing their food webs and the Yellowstone article highlights both the usefulness and the limitations of models. Questions about why it is difficult to predict cause-and-effect relationships in ecosystems, and which parts of an ecosystem are not included in food webs, help to illuminate these limitations.

Connecting to the Outdoor Science Experience. Outdoor science school programs tend to be extremely memorable and can even be life changing for students. The more opportunities students have to connect what they are learning in the classroom to what they experience in outdoor science programs, the more meaningful their outdoor experience will be and the more lasting the impacts are likely to be, academically as well as socially. This activity is one way to connect classroom and outdoor learning by using evidence gathered in the outdoors. Think of other ways you can connect what students are learning at school to what they experienced in outdoor science school, helping to build on their social and emotional development while offering them more opportunities to learn outside or to engage with science content from the program.

Discussing the possible introduction of predators and reading the Yellowstone article also gives students an opportunity to start thinking about how models are used in practice to, for example, inform scientific recommendations to policymakers and land management groups. Using a food web in this way can lead students to have *aha!* moments about real-world applications of science and how scientific information is used.

Science Language. Science is about coming up with the best explanation for all the available evidence. It's also about being open-minded to other explanations that could be even better or more accurate. In science, nothing is ever considered proven. That's why scientists tend to use the language of uncertainty when discussing ideas and explanations. When students use their food webs to discuss ecosystem dynamics, try to use sentence starters such as *Maybe…*, *I wonder if…*, *That evidence makes me think…*, *The evidence seems to show…*, or *I'm not sure, but I think…* and encourage students to phrase their statements, using similar language.

TEACHING NOTES

Ideas for Additional Activities

- **Discussing the effects of human impact.** If interest is still there, you can use the food webs your students made for further discussion about how human behavior can impact food webs directly or indirectly. Tell students that human behaviors sometimes affect specific organisms in a food web. For example, when humans cut down trees, that has a direct impact on part of the food web (the trees). Human behaviors can also impact food webs indirectly. For example, when humans affect nonliving parts of an ecosystem, like when they pollute water sources, that can affect organisms in the food web. Explain that human behaviors are impacting the environment everywhere. Ask students to *Turn & Talk* about the following questions: *How might human behaviors cause changes to this ecosystem? How might those changes affect the food web?* Then, get the attention of the whole group and ask students to share their ideas and use their food webs to predict the impacts of human behaviors. Start off with one human impact and encourage students to cite their evidence and to agree or disagree with one another respectfully. Ask follow-up questions to help students trace chains of impact. Before discussion about that human impact dies down, move the discussion along to the impacts of a different human behavior.
- **Discuss a policy issue related to human impacts on the environment.** Challenge students to discuss a hypothetical policy issue around a human impact on the environment. For example: *Should we build a road/power lines through the ecosystem?* or *Should we develop part of the land for housing/industry/agriculture?* Choose a human behavior or action about which your students seem particularly interested and provide some framing around the reasons for the human behavior or action to provide fodder for rich discussion of the social, political, economic, and environmental implications of the action. Encourage students to include evidence from their food webs and other sources and to be open to multiple explanations and opinions based on the evidence. Ask for differences of opinion, but don't advocate for a specific opinion. See the BEETLES activity *Fire Management Discussion* for ideas about how to structure conversations about human impacts on the environment.
- **Discussing matter and energy transfer in an ecosystem.** If your students have experience with matter (and maybe with energy, too), you could tie that in by explaining that food is a "package" of matter and energy that is digestible by an organism. Plants package matter from air and water with energy from sunlight, which makes food available for other organisms. A food web is a model that shows how matter and energy are transferred between organisms in an ecosystem. Each arrow in the food web represents matter (and energy) being transferred from one organism to another; matter from the food provides materials for growth, while energy from the food provides energy that organisms need to do things. You might challenge students to trace the movement of matter (and maybe also energy) through their food webs. Ask them to start at a carnivore and see how far back they can trace where the matter came

TEACHING NOTES

from. Then, have students do this with other carnivores. Ask where the matter started when students traced it back. Students should find that it started in plants, which is an opportunity to discuss where plant matter comes from (photosynthesis) and also to highlight how sunlight provides the energy that flows through the food web. You could introduce the terms *producer* and *consumer* and have students label the producers (plants) and consumers (animals) in their food webs. You could also challenge students to think about where matter leaves the food web (e.g., as waste) and how it cycles (e.g., as decomposers). See the BEETLES activity *Matter & Energy Diagram* for an example of how to frame this kind of discussion.

Content Knowledge

Food Webs. Food webs are models that show which organisms eat or are eaten by others in an ecosystem. The arrows in a food web represent the transfer of matter and energy that happens when one organism eats another. Typically, an arrow points in the direction in which the matter and energy is moving (toward the consumer).

- **About Producers.** Producers are mainly photosynthetic organisms that transform light energy into the chemical energy in glucose through the process of photosynthesis. Using light energy from the sun, plants and plantlike organisms such as algae make glucose (a simple sugar) by combining water and carbon dioxide from the air. No other type of matter is needed. Organisms that produce their own food are called autotrophs. Some producers live in environments without light and use chemical energy to produce their food through a process called chemosynthesis. Chemosynthetic bacteria use varying pathways to cause inorganic compounds to react with carbon dioxide and oxygen to make the sugars they need to live.
- **About Consumers.** Consumers can't make their own food, so they get it by eating other organisms. Humans and other animals can't make their own food, but must get it by consuming plants or other animals that have consumed plants. Fungi and other decomposers are also considered to be consumers because they can't produce their own food. Organisms that can't produce their own food and need to get it from the environment are called heterotrophs.
- **About Decomposers.** Decomposers transform dead organisms into simpler substances to get the energy they need to live and grow. Some by-products of this process are released into the soil (or water) and the atmosphere and can be used by plants and other organisms. Since they release nutrients, carbon dioxide, and other organic matter back into the environment, decomposers are necessary to complete the cycle of matter.

Trophic Pyramid. A food web is made up of connected food chains. The place where an organism is found in a food chain is called its trophic level. The trophic level indicates how many steps the organism is from the start of the food chain. Trophic level 1 consists of producers; organisms that eat producers are at trophic level 2, and so on. Producers, consumers, and decomposers in an ecosystem can be organized into a trophic pyramid that

TEACHING NOTES

represents feeding relationships between these groups of organisms. The pyramid also shows the distribution and amount of biomass (organic matter that can be eaten as food) among different trophic levels. Most pyramids begin with producers on the bottom and go through the various trophic levels, from herbivores (primary consumers) to carnivores (secondary consumers) and end with carnivores that eat carnivores (tertiary consumers) at the top. Interestingly, most trophic pyramid diagrams leave decomposers off the diagram completely or connect decomposers to all three consumer levels by writing them across the side of the pyramid.

At each trophic level, some energy is lost as heat energy, while other energy is used to maintain additional life processes. For this reason, consumers don't get all the energy that is consumed or stored by organisms they eat. Since they can't get all the energy from the trophic level below them, organisms higher up in the chain need more biomass from the producer and consumer levels beneath them. This is the reason why specific food chains are not usually longer than four or five organisms. It's also the reason that when you look at most ecosystems, you see much more plant matter than animal matter. A food chain or a food web does not represent everything an organism eats. The sun, for example, does not belong in food chains or food webs because it is not food.

Indirect Effects. A food web helps us see direct effects, but it also can model and help us understand indirect effects. For example, consider a situation in which coyotes eat rabbits, and rabbits eat wildflowers. The coyote may not have a direct effect on the wildflowers, but if there's a change in the coyote population—if the coyote population decreases because of hunting—the rabbit population could increase, gobbling up more wildflowers, which would have a negative effect on the population of wildflowers. In this case, the coyote has an indirect effect on wildflowers because a change in one level (carnivore) affects lower levels (producer). The opposite can happen, too. A change in a lower level of the food chain can affect a higher level—if the population of wildflowers were to increase or decrease, it could affect rabbits directly and coyotes indirectly. Of course, the organisms in a food web are highly interconnected with the ecosystem, so indirect effects may be made stronger or weaker by the interactions between organisms at any level of the food web with other organisms in the ecosystem.

Keystone Species. In some situations, one species may have big effects on many other species within an ecosystem. In an extreme case, changes to one species may cause dramatic changes in the entire ecosystem. This type of species is called a keystone species. Sea stars are one well-known example of a keystone species. Sea stars prey on mussels; without sea stars, an intertidal ecosystem can be overrun by mussels, which outcompete other organisms. Another example of a keystone species is the honey bee. Honey bees are important pollinators; without them, plants make fewer seeds, which could ultimately lead to catastrophic effects on plant populations and on the many species that rely on plants for food, shelter, and the like. Top predators are often considered keystone species because of the cascading effects caused by changes in their populations—as exemplified by the article about wolves in Yellowstone National Park.

TEACHING NOTES

Relationships Between Living and Nonliving Things. In addition to living things interacting with one another in an ecosystem, ecosystem dynamics are made more complicated by interactions between living and nonliving parts of an ecosystem. In many ways, the nonliving parts of an ecosystem determine the organisms that live there. The availability of water, nutrients in the soil, and the quality of the air all affect which organisms can or cannot survive somewhere. Changes to these and other nonliving parts of an ecosystem can affect living parts, which can cause more changes to living parts, which in turn can cause more changes to nonliving parts, which in a ripple effect change living parts; and on it goes!

Human Impacts on Ecosystems. Humans are major drivers of change in ecosystems. Some of the changes we humans have caused are direct and easily observable. For example, the destruction of forests to build cities and roads or to clear land for agriculture have obvious destructive effects on ecosystems. Extraction of resources—water, food, wood, coal, and so on—also have observable effects on ecosystems. Yet humans impact ecosystems in many other ways that are harder to observe directly. The uncountable effects of human-induced climate change on ecosystems is one glaring example. Research to better understand ecosystems and ecosystem dynamics helps people become aware of these impacts and can help people figure out how to better manage natural resources.

Common Relevant Misconceptions

Misconception. Predators are harmful to prey.

More accurate information. An individual predator eating an individual prey certainly is harmful to that individual prey, but some populations of prey can benefit from predation. This Inuit proverb helps explain it: *The caribou feeds the wolf, but it is the wolf who keeps the caribou strong*. Predators often kill off the older and weaker individuals (human hunters often do the opposite), so those that are stronger and faster are more likely to pass on their DNA to offspring that are strong and fast. Over time, this can strengthen the caribou population as a whole. Some students may say, *But if you reintroduce wolves to the ecosystem, they will kill all the deer*, showing a lack of understanding of the complexity of predator/prey relationships. It's partly because of this common misconception that the Yellowstone story was included in the session.

Misconception. In a food web, a change in the size of one population will only affect the populations of its predators and prey.

More accurate information. The organisms in a food web are intricately connected. When one population changes, it can affect the populations of species that are directly related to it through predator/prey relationships. However, it can also affect populations of organisms that are indirectly related and are more than one food-chain link away. The extent to which a change in one population affects other populations or the food web as a whole varies, depending on its role in the ecosystem, how many links away from the change the population of organisms is, and the overall health of the ecosystem.

Misconception. If one species in a food web dies off, everything else in the ecosystem will be affected, and the ecosystem will collapse.

More accurate information. When a species dies off, those directly connected to it in a food web tend to be most affected. Other organisms may also be indirectly affected, but the effects are less, depending on how many links away they are from that species. The loss of certain species (see Keystone Species section) impacts an ecosystem more than other species. The more diverse an ecosystem, the more resilient it is. When a species is lost, the ecosystem will adjust to the loss but will be less diverse and less resilient to other impacts. Certain catastrophic effects, such as changing climate, increased acidification of the ocean, asteroid impacts, overfishing, or deforestation, can all contribute to causing ecosystem collapse in which the carrying capacity (the amount of organisms it can support) for species of the ecosystem is reduced. When the effect is really bad, it can lead to mass extinction. The severity of an impact on an ecosystem by an event or loss of species depends on how bad the effect is and how diverse and resilient the ecosystem is.

Connections to Next Generation Science Standards (NGSS)

BEETLES student activities are designed to incorporate the three-dimensional learning that is called for in the Next Generation Science Standards (NGSS). Three-dimensional learning weaves together Science and Engineering Practices (what scientists do), Crosscutting Concepts (thinking tools scientists use), and Disciplinary Core Ideas (what scientists know). Students should be exploring and investigating rich phenomena and figuring out how the natural world works. The abilities involved in using Science and Engineering Practices and Crosscutting Concepts—looking at nature and figuring things out, using certain lenses to guide thinking, and understanding ecosystems more deeply—are mindsets and tools students can take with them and apply anywhere to deepen their understanding of nature, and they're interesting and fun to do!

In *Food Web*, students engage in the Science and Engineering Practice of *Developing and Using Models* and have the opportunity to relate what they learn to the Crosscutting Concepts of *Cause and Effect* and *Systems and System Models*. Students will build understanding of Disciplinary Core Ideas related to *Interdependent Relationships in Ecosystems* as well as *Ecosystem Dynamics, Functioning, and Resilience*.

Featured Science and Engineering Practice

Engaging students in Developing and Using Models. According to the National Research Council's *A Framework for K–12 Science Education*, scientists use conceptual models to investigate parts of a system that are too complex or too difficult to observe so as to better visualize and understand phenomena. Scientists decide what to include or not include in their models, which affects what they can see or can't see through the model. Students should develop models that represent their current understanding of

TEACHING NOTES

About the Next Generation Science Standards (NGSS). The development of the NGSS followed closely on the movement to adopt nationwide English language arts and mathematics Common Core standards. In the case of the science standards, the National Research Council (NRC) first wrote *A Framework for K–12 Science Education* that beautifully describes an updated and comprehensive vision for proficiency in science across our nation. The *Framework*—validated by science researchers, educators and cognitive scientists—was then the basis for the development of the NGSS. As our understanding of how children learn has grown dramatically since the last science standards were published, the NGSS has pushed the science education community further toward engaging students in the practices used by scientists and engineers and using the "big ideas" of science to actively learn about the natural world. Research shows that teaching science as a process of inquiry and explanation helps students to form a deeper understanding of science concepts and better recognize how science applies to everyday life. In order to emphasize these important aspects of science, the NGSS are organized into three dimensions of learning: Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas (DCI's). The DCI's are divided into four disciplines: Life Science (LS); Physical Science (PS); Earth and Space Science (ESS); and Engineering, Technology, and Applied Science (ETS).

Read more about the Next Generation Science Standards at http://www.nextgenscience.org/ and http://ngss.nsta.org/

TEACHING NOTES

NGSS quote about systems. "The natural and designed world is complex; it is too large and complicated to investigate and comprehend all at once. Scientists and students learn to define small portions for the convenience of investigation. The units of investigations can be referred to as 'systems.' A system is an organized group of related objects or components that form a whole. Systems can consist, for example, of organisms, machines, fundamental particles, galaxies, ideas, and numbers. Systems have boundaries, components, resources, flow, and feedback."—National Science Education Standards

a system or process under study so they can develop explanations and communicate ideas to other students.

- In *Food Web*, students make food web models to build their understanding of the complex web of interactions through which organisms obtain food.
- Students use different types of arrows to show the sources of evidence (firsthand, secondhand, and reasoning) that support the connections in their food webs, supporting them in understanding how scientists' models are based on various kinds of evidence.
- Students use these models to make explanations about the ecosystem. Students also use these models to make possible explanations about the ecosystem's characteristics, such as significant species within the ecosystem.
- Students also use their models to predict how a change to one part of the food web might affect other parts, helping them to learn how models are a powerful tool for making predictions.
- Students discuss limitations of the model, learning how models always include inaccuracies.
- Reading and discussing the article about wolves in Yellowstone helps students understand that it's important to consider the limitations of models, since they show only one part of a system and are based solely on the evidence at hand, which is not always comprehensive.

Featured Crosscutting Concept

Learning science through the lens of Cause and Effect. When scientists make explanations for how or why something happens, they are thinking about the connection between cause and effect. What we can observe of the natural world are actually the effects of many possible causes. Understanding relationships between cause and effect leads to a deeper understanding and appreciation of our world, which is helpful in making predictions and explanations about what might happen under similar conditions in the future.

- In *Food Web*, students use their food webs to think about the potential effects on different parts of the ecosystem caused by changes to other parts.
- In particular, students discuss how the introduction of a top predator could affect other organisms in the food web.
- Students read about the cascading effects of the reintroduction of wolves into Yellowstone National Park.
- The article also highlights how teasing out causation in complex systems can be extremely difficult.

If students don't get the chance to think about how the idea of cause and effect connects to their process of creating, interpreting, and using food webs, they miss the opportunity to recognize this as an important way of looking at the natural world. They also might not realize that this idea also applies in other scenarios. Make sure to emphasize this with students and give them more opportunities to apply the idea of cause and effect in various contexts.

Featured Disciplinary Core Ideas

Building a foundation for understanding Disciplinary Core Ideas. The NGSS make it clear that students need multiple learning experiences to build their understanding of Disciplinary Core Ideas. *Food Web* gives students a chance to develop an understanding of some Disciplinary Core Ideas related to *Interdependent Relationships in Ecosystems* (LS2.A) as well as to *Ecosystem Dynamics, Functioning, and Resilience* (LS2.C).

- Students' food webs serve as models of many of the interdependent relationships in the ecosystem they explored. (LS2.A)
- As students discuss the effects of changes to one part of the food web on the rest of the food web, and as they read about the reintroduction of wolves into Yellowstone, they develop an understanding of the complex (and sometimes indirect) ways that organisms depend on one another. (LS2.A)
- Students also learn how the elimination or introduction of a species can lead to shifts in other species populations, thus altering the balance of the ecosystem. (LS2.C)

Performance Expectations to Work Toward

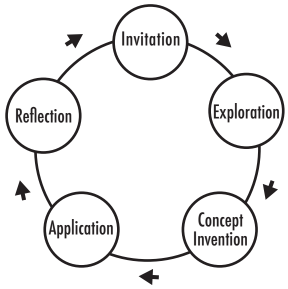
The NGSS represent complex knowledge and multifaceted thinking abilities for students. No single activity can adequately prepare someone for an NGSS Performance Expectation. Performance Expectations are examples of things students should be able to do, after engaging in multiple learning experiences or long-term instructional units, to demonstrate their understanding of important Disciplinary Core Ideas and Science and Engineering Practices, as well as their ability to apply Crosscutting Concepts. Performance Expectations are not a curriculum to be taught to students. Below are some of the performance expectations that this activity can help students work toward.

- **5-LS2-1.** Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.
- **MS-LS2-2.** Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
- **MS-LS2-3.** Develop a model to describe the cycling of matter and the flow of energy among living and nonliving parts of an ecosystem.
- **MS-LS2-4.** Construct an argument, supported by empirical evidence, that changes to physical or biological components of an ecosystem affect populations.

TEACHING NOTES

Translating the codes for the NGSS Performance Expectations. Each standard in the NGSS is organized as a collection of Performance Expectations (PE's) for a particular science topic. Each PE has a specific code, which is provided here so they can be easily referenced in the NGSS documents. The first number or initial refers to the grade level: K = kindergarten, 1 = first grade, 2 = second grade, MS = middle school, and HS = high school. The next letters in the code refer to the science discipline for the standard: LS, PS, ESS, ETS. The number following the discipline denotes the specific core idea within the discipline that is addressed by the PE, and the last digit identifies the number of the PE itself. So, 3-LS4-3 means the Performance Expectation is part of a third-grade standard (3) for life science (LS), addressing the fourth core idea (4), Biological Evolution: Unity and Diversity, within the life science standards, which deals with Adaptation. It's also the third Performance Expectation (3) that makes up the complete LS4 standard at this grade level.

TEACHING NOTES



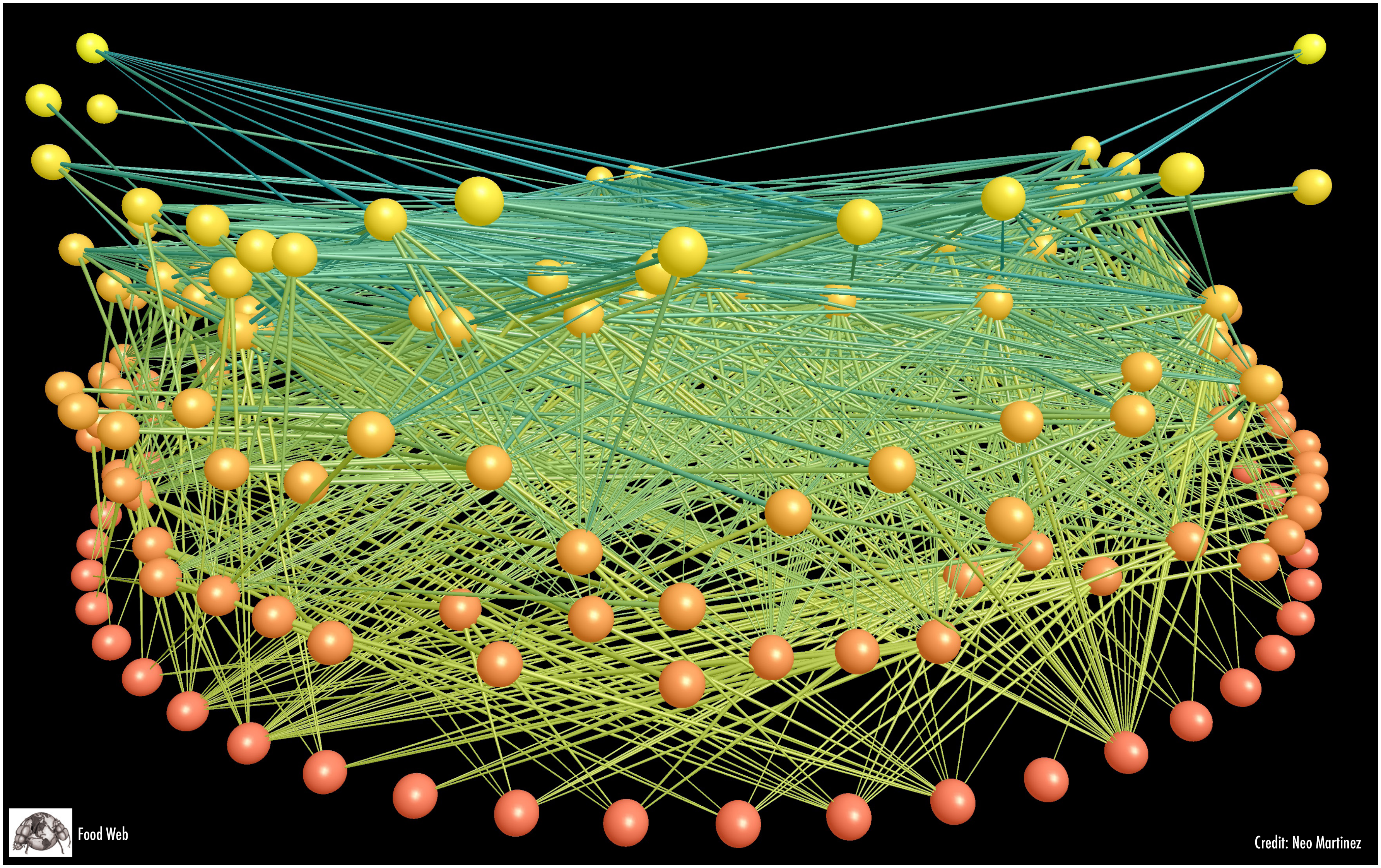
Within a longer sequence of activities, *Food Web* functions as an Exploration or a Concept Invention activity.

Activity Connections

This activity is designed to follow students' experiences in outdoor science, particularly at an outdoor science school. Other BEETLES activities that focus on interdependent relationships in an ecosystem, engage students in creating models, and further students' understanding of matter cycling in an ecosystem are *What Lives Here?*; *Decomposition Mission*; and *Food, Build, Do, Waste*. If your students are familiar with the routine *I Notice, I Wonder, It Reminds Me Of*, they can use the prompts when doing active reading with the "Reintroducing Wolves to Yellowstone National Park" article. The classroom activities *Evaluating Sources* and *Evaluating Evidence* focus on evaluating the quality of sources and the strength of evidence and could support students in reflecting on the accuracy of their food webs.

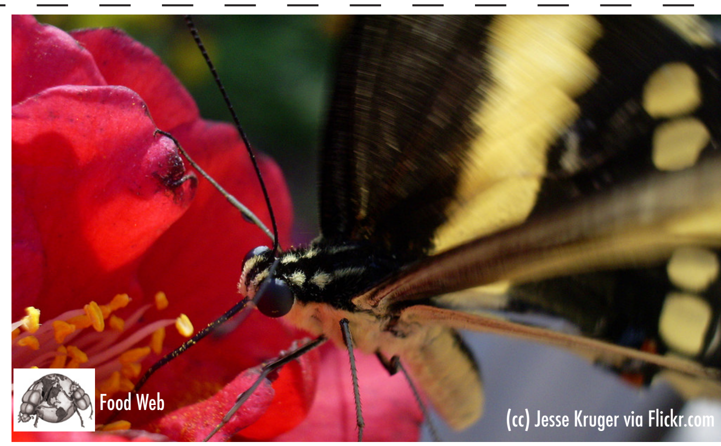
Learning Cycle: *Food Web* completes a full learning cycle as a discrete activity. Combined with a sequence of activities from outdoor science, this activity serves as both Concept Invention and Application of ideas that students explored outdoors. Within a sequence of many activities focused on developing students' understanding of ecosystem dynamics, this activity could serve as an Exploration or a Concept Invention.

ECOSYSTEM MODEL



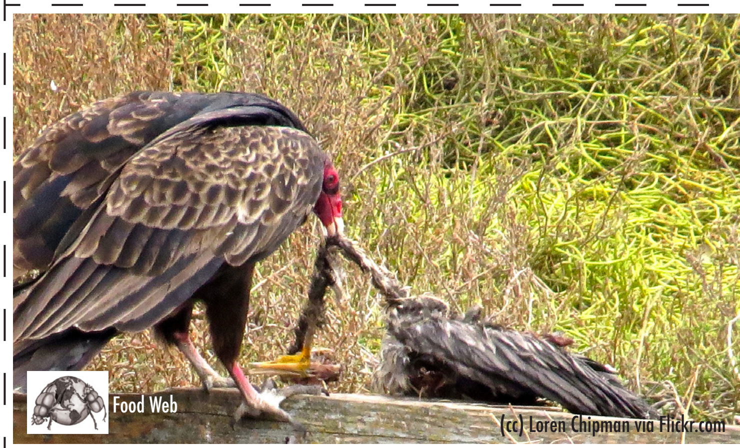
THINGS EATING THINGS EVIDENCE CARDS

THINGS EATING THINGS EVIDENCE CARDS



THINGS EATING THINGS EVIDENCE CARDS

THINGS EATING THINGS EVIDENCE CARDS



Name: ______________________________ Date: ______________

Reintroducing Wolves to Yellowstone National Park

For many thousands of years, wolves lived in many parts of North America, including the area that is now Yellowstone National Park. However, when settlers from Europe arrived, they started killing off the wolves. Although healthy wolves have rarely been known to attack humans, many people thought of them as big, bad, scary animals to be feared. Ranchers didn't like that sometimes, wolves would hunt and eat their cows and sheep.

Yellowstone National Park sign at the north entrance.

The last wolf pack in Yellowstone was killed in the 1920s or 1930s. Over the years, without wolves, the ecosystem at Yellowstone changed. The populations of some organisms increased, while some populations decreased. The population of elk, which wolves used to hunt and eat, increased. However, it was not clear what all the changes were that had happened and which of these might have been caused by the wolves' being gone. What was clear was that the ecosystem became less healthy than it once was.

Over the years, scientists argued that wolves should be reintroduced to Yellowstone. Scientists argued that predators such as wolves are important parts of ecosystems and that the ecosystem would be healthier if wolves were reintroduced. Others fought hard against the reintroduction. Ranchers, in particular, were worried about wolves killing their sheep and cattle. Eventually, it was decided that wolves should be reintroduced. In 1995 and 1996, some wolves were caught in Canada and then released in Yellowstone.

Take a few moments to predict what changes might have happened to the ecosystem when the wolves were introduced.

Name: ________________ Date: ________________

Truck carrying wolves driving through the Roosevelt Arch with schoolchildren watching.

(Left to right): Mike Phillips, Jim Evanoff, Molly Beattie (Director of USFWS), Mike Finley (YNP Superintendent), and Bruce Babbitt (Secretary of the Interior) carrying the first crate with wolf in it to the Crystal Bench pen.

Wolf in Rose Creek pen (1969).

Name: ______________________ Date: ______________

Here are some of the changes that happened:

- Many people predicted that the return of the wolves would cause the elk population to decrease, because wolves hunt elk. The elk population did decrease, although some scientists disagree about how big a role wolves played in this happening and argue that impacts of climate change and hunting also caused fewer elk to survive. The decrease in the number of elk is not the whole story, though. Wolves also had a major effect on how elk behaved. Without wolves, elk had lived in large herds that didn't move around very much in the winter. When wolves were reintroduced, the elk lived in smaller herds that moved around more.

Bull elk at canyon.

Name: ______________________________ Date: ______________

- That's not all that happened! When the wolves were gone, very few young aspen trees survived because elk would eat and step on the trees. There were old aspen trees, but not new young trees. Willow trees and cottonwood trees also were impacted by the elk. When the wolves were reintroduced, the elk couldn't hang around and eat these young trees as much, and as a result, many more young aspen, willow, and cottonwood trees survived

Aspens with fall color.

- That's still not all that happened! With more young trees surviving, beavers came back. Then, beaver dams and shade from trees made more habitat for fish and other water organisms.

Beaver, Lamar River

Name: ______________________________ Date: ________________

- Even more changes happened! With more willow trees, songbirds returned to live in the trees.

Mountain Chickadee

- That's *still* not the end of the changes! Healthy willow, aspen, and cottonwood trees started to grow in areas that were heavily eroded. As more young trees grew in these areas, less erosion occurred. Less erosion made the rivers healthier, which in turn supported all the organisms that depend on rivers.

Mudslide caused by heavy rain in Gibbon Canyon.

Name: ______________________ Date: ______________

- There were still more changes! Wolves and coyotes have a complex relationship—they compete over some of the same food sources, but wolves also hunt coyotes. With the return of the wolves, coyote populations decreased. There is some evidence that this allowed populations of smaller mammals that coyote hunt—such as red foxes, mice, and rabbits—to increase, creating more food for other predators, such as hawks.


Credit: John Good, National Park Service

Coyote

- Just one last thing that we know happened! Elk carcasses. When the wolves would kill an elk and eat it, they would leave behind parts of the carcass. Lots of animals love to eat leftover elk carcasses. Beetles, ravens, wolverines, coyotes, eagles, magpies, bears, and lynx all fed on the elk carcasses. Without the wolves, these animals had to wait for elk to die in other ways so they could feed on their carcasses, which happened often during the cold winters but not so often during the rest of the year. With wolves hunting elk, there were more elk carcasses to feed on, so there was less competition between other carnivores and scavengers.


Credit: Bryan Harry, National Park Service

Grizzly bear on elk carcass near Terrace Spring.

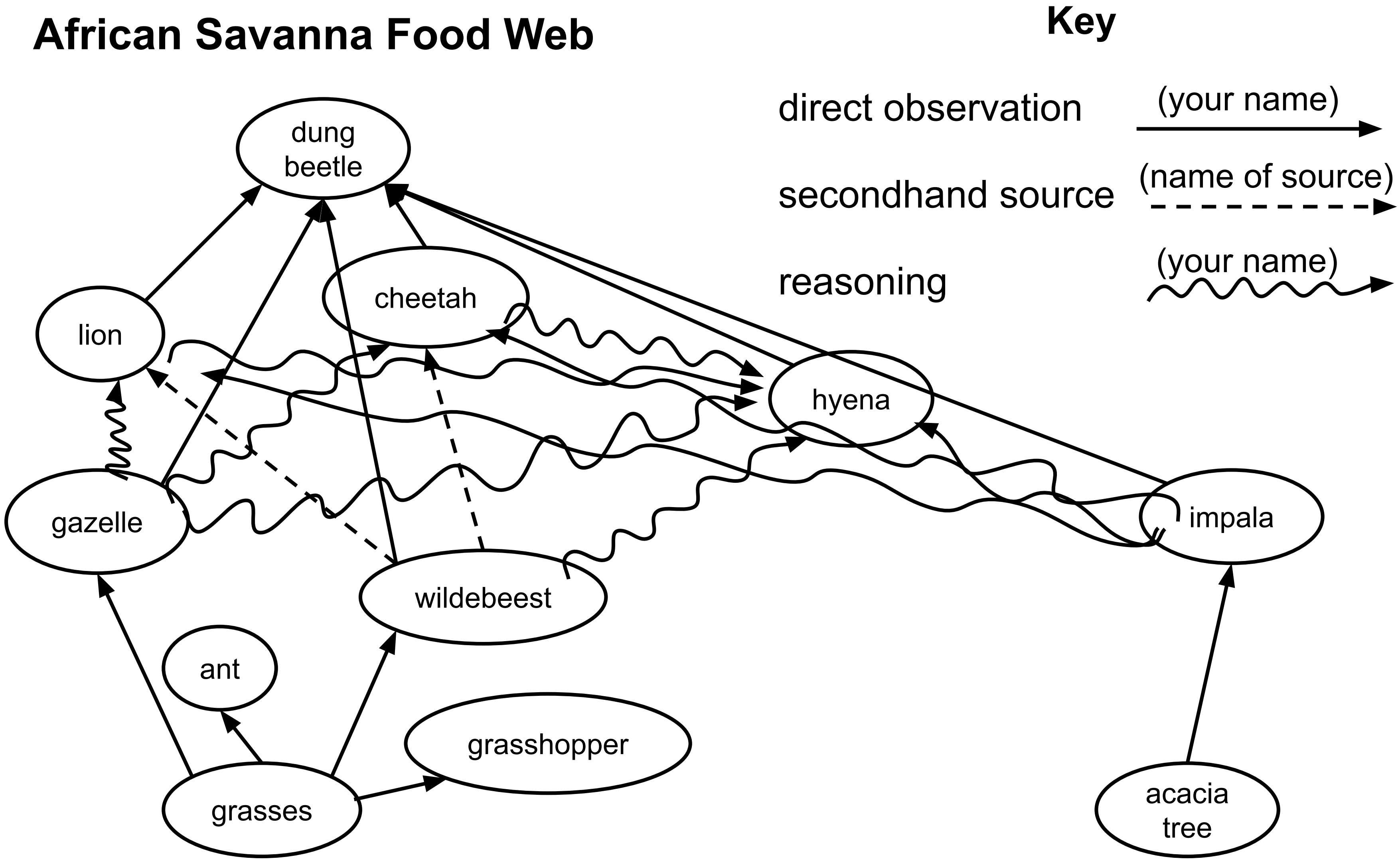
Name: ______________________ Date: ______________

Now, think about all the changes that happened just by reintroducing wolves to the Yellowstone ecosystem! Human impacts have caused many, many species to die off in ecosystems around the world and, in some cases, to become completely extinct. Scientists often study what happens when a species is removed from an ecosystem. However, it's rare that scientists get to study the opposite—as when a key species, such as the wolf, is reintroduced to an ecosystem.

Scientists thought that reintroducing wolves would make the Yellowstone National Park ecosystem healthier. They made food webs of the ecosystem to try to predict how wolves might affect it. Yet even after all the work of scientists, many of the effects surprised them. Scientists are still eagerly researching the effects of wolves being reintroduced to Yellowstone so they can make better predictions about other ecosystems and about the many ways in which predators affect those ecosystems. The better that scientists and wildlife management officials understand these interactions, the better they can manage ecosystems and help keep them healthy.

MODEL FOOD WEB DRAWING

African Savanna Food Web



ABOUT BEETLES™

BEETLES™ (Better Environmental Education Teaching, Learning, and Expertise Sharing) provides environmental education programs nationally with research-based approaches and tools to continually improve their programs.

www.beetlesproject.org

Lawrence Hall of Science is the public science center of the University of California, Berkeley.

www.lawrencehallofscience.org

Craig Strang, *Principal Investigator*
Kevin Beals, *Program Director*
Jedda Foreman, *Project Director/Manager*
Emilie Lygren, *Curriculum and Professional Learning Specialist*
Ramya Sankar, *Operations Manager*
Additional Contributers: **Emily Arnold, Lynn Barakos, José González, Catherine Halversen**, *and* **Emily Weiss**.
Research Team: **Mathew Cannady, Melissa Collins, Rena Dorph, Aparajita Pande,** and **Valeria Romero.** Emeritus: **Bernadette Chi, Juna Snow**
Project Consultants: **John (Jack) Muir Laws, Penny Sirota,** and **Mark Thomas**
Advisory Board: **Nicole Ardoin, Kevin Crowley, José González, Maggie Johnston, Celeste Royer, Bora Simmons,** and **Art Sussman.** Emeritus: **Kathy DiRanna, Kathryn Hayes, April Landale, John (Jack) Muir Laws, Jack Shea, Penny Sirota, Drew Talley,** and **Mark Thomas.**
Editor: **Trudihope Schlomowitz**
Designer: **Barbara Clinton**

The following programs contributed to the development of these materials by field testing and providing invaluable feedback. For a complete list of contributors and additional partners, please see beetlesproject.org/about/partners/

California: YMCA Camp Campbell, Rancho El Chorro Outdoor School, Blue Sky Meadow of Los Angeles County Outdoor Science School, YMCA Point Bonita, Walker Creek Ranch, Santa Cruz County Outdoor Science School, Foothill Horizons Outdoor School, Exploring New Horizons Outdoor Schools, Sierra Nevada Journeys, San Joaquin Outdoor Education, YMCA Camp Arroyo, Shady Creek Outdoor School, San Mateo Outdoor Education, Walden West Outdoor School, Westminster Woods.

Other locations: Balarat Outdoor Education, CO; Barrier Island Environmental Education Center, SC; Chincoteague Bay Field Station, VA; Eagle Bluff Environmental Learning Center, MN; Great Smoky Mountains Institute at Tremont, TN; Wellfleet Bay Wildlife Sanctuary Mass Audubon, MA; Mountain Trail Outdoor School, NC; NatureBridge (CA, WA, VA); Nature's Classroom (CT, MA, ME, NH, NY, RI); North Cascades Institute Mountain School, WA; NorthBay, MD; Outdoor Education Center at Camp Olympia, TX; The Ecology School, ME; UWSP Treehaven, WI; Wolf Ridge Environmental Learning Center, MN; YMCA Camp Mason Outdoor Center, NJ; and YMCA Erdman, HI.

Photos: Pages 1 and 2 by Kevin Beals. *Icons*: Backpack by Rémy Médard; Growth by Arthur Shlain; Cut by Nathan Thomson; Outside by Petr Holusa; Park by Antar Walker; &Time by Wayne Middleton all from The Noun Project.

Funding from 2012-2019 for BEETLES publications such as this one has been generously provided by the S.D. Bechtel, Jr. Foundation, The Dean Witter Foundation, Pisces Foundation, the Mary A. Crocker Trust, and the National Science Foundation under Grant No. 1612512. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

To contact BEETLES™, email beetles@berkeley.edu